TRENDS IN MIXER DAMAGE

Chance M. Glenn and Robert V. Garver

Harry Diamond Laboratories, Adelphi, MD 20783

ABSTRACT

The dynamic damage properties of 74 pairs of 1N23 X-band mixer diodes have been measured using a train of 30 short pulses at a 1-pps repetition rate. A first 30-uJ pulse caused a 3-dB degradation of conversion loss. The damage of successive 16-uJ pulses asymptotically approached 3-dB.

INTRODUCTION

Most mixer damage measured to date is for a continuous train of pulses. A method for measuring mixer damage for single pulses and observing the progressive damage for successive pulses was reported previously [1]. This method has been refined and measurements have been made on a large number of 1N23 mixer diode pairs for a range of pulse widths and peak power levels. The pulsewidths used were from 25 ns to 1 us and the pulse risetimes were less than 2 ns.

TEST PROCEDURE

The refined measurement circuit is shown in figure 1. The device under test (DUT) is a balanced mixer (diode pair) mounted in X-band waveguide. The local oscillator (LO) is fed directly into the mixer while the rf test signal is introduced into the 10-dB arm of a directional coupler. The signal incident on mixer is at -40 dBm to insure that the mixer is not overdriven. The intermediate frequency (IF) output of the mixer is fed to a spectrum analyzer. A low-pass filter is placed between the IF output and the spectrum analyzer for keeping transients from the high power pulses out of the spectrum analyzer. The frequency of the signal remains fixed while the frequency of the LO is swept so that a 20-MHz sweep is achieved across the display of the spectrum analyzer. The damaging pulses are at 9.25-GHz with controlled pulse widths and peak power levels.

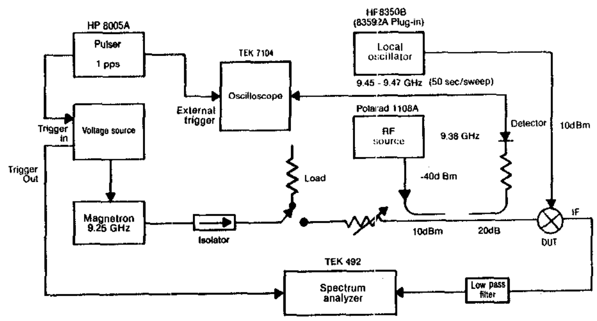

Figure 1. Block diagram of mixer diode damage setup.

The spectrum analyzer and high power pulser are synchronized so that one damaging pulse occurs each second and so does one sweep. The sweep of the LO is adjusted so that the line for the IF output walks slowly across the screen of the spectrum analyzer, one line with each sweep of the spectrum analyzer. When the spectrum analyzer is put in the memory mode, then each line is added to the display giving a picket fence at the conversion loss of the mixer. When the conversion loss of the mixer is degraded from pulse to pulse, the display of the spectrum analyzer gives a histogram of the conversion loss. The use of the spectrum analyzer is particularly advantageous in that it displays a wide range of conversion loss linearly.

An improvement was made in the testing procedure. A pulser set at a 1-pps repetition rate was used to externally trigger the high-voltage pulser, the spectrum analyzer and the oscilloscope.

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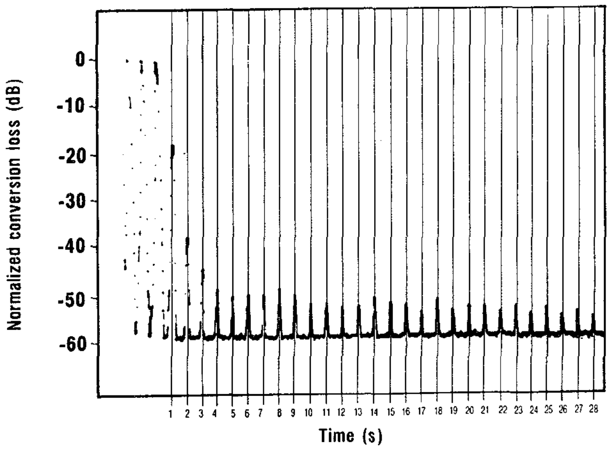

Figure 2. Spectrum analyzer display of mixer response to 1 us, 1 kW, 9.25 GHz pulses.

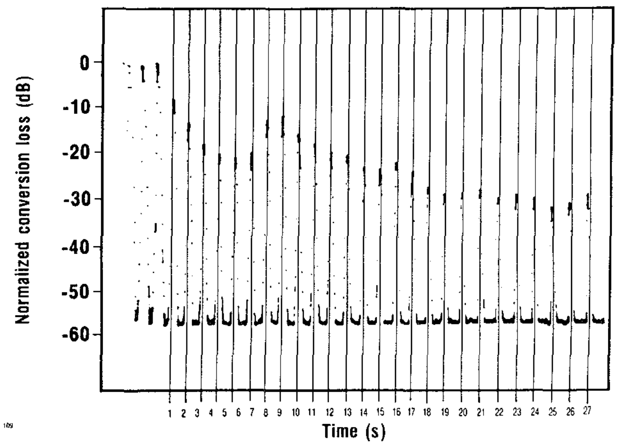

Figure 3. Spectrum analyzer display of mixer response to 1 us, 100 W, 9.25 GHz pulses.

RESULTS

The purpose of the experiment was to measure the damage threshold of mixers when subjected to one or few rf pulses, the case wherein the pulses are so far apart that there is no heat carried over from pulse to pulse.

Figure 2 shows the spectrum analyzer display as the result of subjecting the mixer to successive 1-us, 1-kW, 9.25-GHz pulses at a repetition rate of 1 pps. Several pulses were recorded before the damaging pulses started in order to establish a reference conversion loss before damage (0 dB). The figure shows the progressive degradation during the application of 28 pulses. There is a rapid decline in conversion loss. The first pulse caused 18 dB of degradation; the degradation from successive pulses leveled off at greater than 50 dB.

An example of a more gradual degradation is shown in figure 3. Successive 1-us, 100-W, 9.25-GHz pulses at a repetition rate of 1 pps were applied. The first pulse degraded the conversion loss 9.5 dB. The damage leveled off around 28 dB; however, there were fluctuations between degradation and partial recovery, interpreted as partial annealing. This annealing phenomenon appeared in many of the responses and is discussed further in reference [1].

The resulting pictures from the spectrum analyzer (like figures 2 and 3) were used to analyze the data. Plots of damage differentials versus the number of pulses were created to identify trends in the damage profiles. Figure 4 is an example of such a plot. This plot corresponds to the damage profile in figure 2. As shown, there are large increments of damage for the first few pulses. Data points below zero correspond to annealing, while positive ones correspond to damage. Note that the annealing and damage stop after many pulses. There are primarily two points of interest in each set of data: the magnitude of damage from the first pulse and plateau for damage from many pulses.

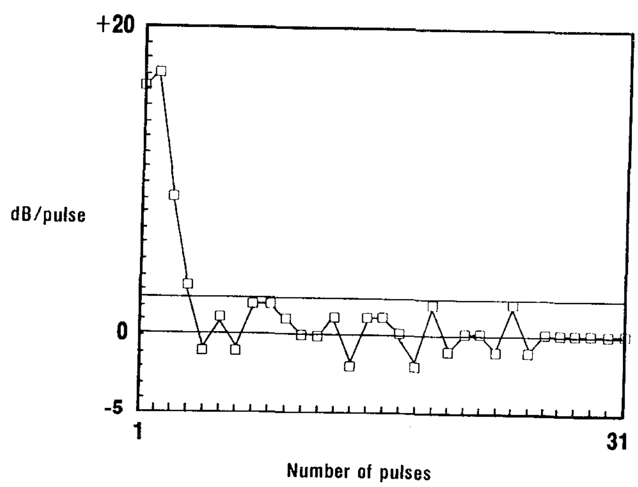

Figure 4. Damage differential versus the number of pulses for 1 us, 1 kW, 9.25 GHz pulse response.

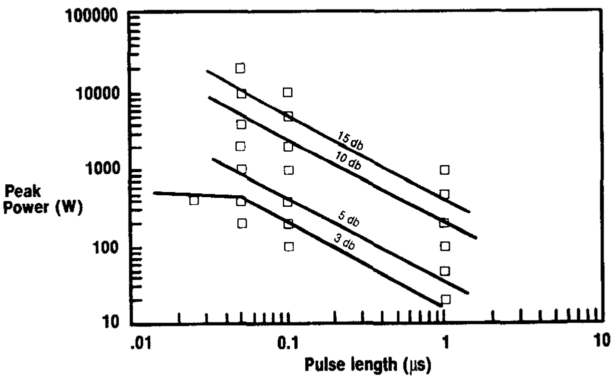

Figure 5. First pulse damage profile. Power versus pulse length.

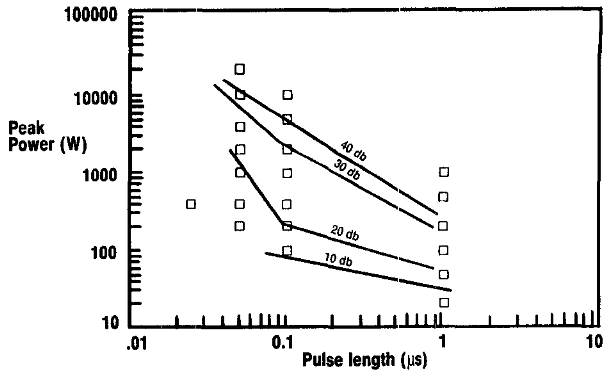

Figure 6. Final damage profile. Power versus pulse length.

A summary of the first pulse damage profiles is shown in figure 5. A plot of peak power versus first pulse damage was made for each pulse length and the points for 3 dB, 5 dB, etc interpolated from them. These curves were then combined to give the parametric set of curves shown in figure 5, giving a total picture of first pulse damage.

All of the damage points measured are shown. A 45-deg slope in the pulse width damage profile corresponds to constant energy damage, which was observable with all of the sets of data. The constant energy property for short length pulses is due to uniform heating of the junction to a damage temperature when the pulse is too short for heat to flow away from the junction (adiabatic). Note that the 3-dB line became horizontal at 400 W for very short pulses. Not enough data has been collected yet to make any significant conclusions about this trend. The energies for first pulse damage are given in table 1.

TABLE 1
SUMMARY OF MIXER DEGRADATION

CONVERSION LOSS DEGRADATION (dB)	ENERGY FOR FIRST PULSE DAMAGE (uJ)	ENERGY FOR FINAL DAMAGE AT 1 uS (uJ)
3	16	16
5	31	
10	210	36
15	420	
20		80
30		200
40		350

Figure 6 is a summary of the final damage profiles. As in figure 5, all of the damage pulses observed are shown. The general trend in the final damage data also suggests energy dependence of failure except at 10 dB degradation and the longer pulse range for 20 dB degradation. The slope of $T^{-1/2}$ suggests a linear heat flow path and intermediate time constants. This is termed the Wunsch-Bell characteristic. Very long pulses give constant power and very short pulses give constant energy. Intermediate length pulses give $P \sim T^{-1/2}$. There is 1-s between each mixer damage pulse and the entire experiment takes 30 s. There does not appear to be good cause for $T^{-1/2}$ performance other than a gradual transition from constant power to constant energy.

CONCLUSION

Conversion loss degradation of mixer diodes caused by single or multiple microwave pulses can be measured by the methods outlined in this paper. Two trends in the degradation of the mixers were observed. There was an initial damage slope which was either steep or gradual depending on the energy of the damage pulse. The second trend was the leveling off of the degradation.

Only one occurrence of constant power damage for very short pulses was observed in this experiment. More experiments should be conducted in the 20 ns regime to determine whether this lower energy realm is of any substance.

REFERENCE

1. R. Garver, C. Fazi, and H. Bruns, "Dynamic Diode Mixer Damage Measurements," 1985 IEEE MTTS International Microwave Symposium Digest (May 1985), pp 535-536.