III-4. LOW-LEVEL LIMITING UTILIZING IMPACT IONIZATION IN BULK GERMANIUM AT 4.2°K*

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Low-level garnet limiters operating in the coincidence region have previously been reported at 4.2°K (Reference 1). These devices, however, operate only within an octave frequency range, which is a function of the $4\pi M_s$. For YIG at 4.2°K, for example, this frequency range is 2.3 to 4.6 gc. This paper describes the application of impact ionization in bulk semiconductors to obtain low-level limiting, for which no such frequency limit exists in the microwave range.

The limiting mechanism uses the large change in conductivity (several orders of magnitude) experienced in a semiconductor for small variations in electric field in the vicinity of a critical field. This critical field is typically between 4 and 10 volts/cm in n-germanium. Below the breakdown field, the charge carriers are essentially "frozen out" at these low temperatures, and the semiconductor behaves as a dielectric (ϵ = 16 for germanium). As the electric field is increased, a free-carrier multiplication process is caused by impact ionization of impurities by field accelerated carriers. A typical v-i characteristic is shown in Figure 1. Previous experiments (Reference 2) have shown that the current rise time just above the threshold level is of the order of 10^{-8} seconds and decreases as the applied voltage increases. Under pulsed condition (100-mw peak, rise time less than 0.1 μsec), the germanium limiter had a spike leakage of 5×10^{-3} erg. The spike passed by a ferrite coincidence limiter is typically 0.5 erg under similar conditions.

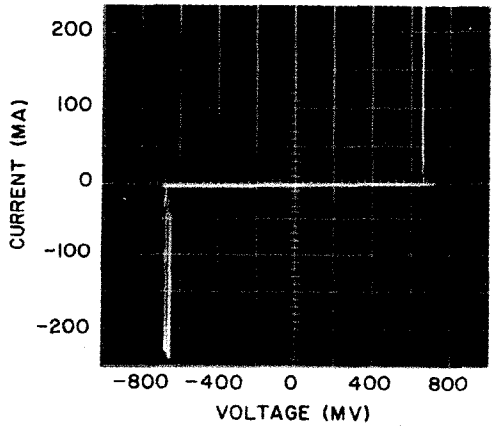

Figure 1. Typical Voltage - Current Characteristic of 0.030-Inch Thick, 1.5-Ohm-cm N-Type Ge Slab at 4.2°K

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To obtain low limiting levels, a balanced DC biasing arrangement is used in which the germanium is biased just below the breakdown field. This paper includes a discussion of negative-resistance phenomena due to the presence of acceptors as well as apparent negative-resistance effects due to thermal oscillations. These considerations are important in relation to limiting level since they determine how close to breakdown the bias can be set without causing instability. A discussion of the dependence of the breakdown field and recovery time, on doping is also included. Finally, a general analysis is made of the relationship between limiting level, insertion loss, and bandwidth, based on a simple transmission resonator model.

The devices described include a Stripline structure (Figures 2 and 3) and a ridged-waveguide structure (Figure 4) both of which operate at C-band. A preliminary limiting curve obtained from the latter structure appears in Figure 5. The 3-db bandwidth was 200 mc centered at 3875 mc. Unfortunately, the dynamic range could not be measured due to the power limitation of the available source. On the basis of room-temperature measurements, however, a dynamic range considerably in excess of 30 db is predicted. Work on a resonator having a higher Q is now taking place in order to achieve a projected limiting level of -20 dbm.

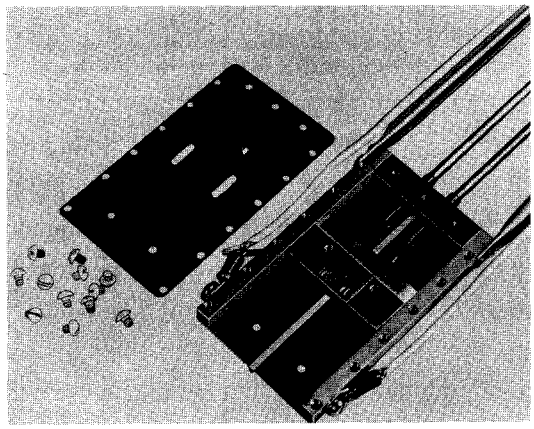

Figure 2. Stripline Resonator with Top Cover Removed

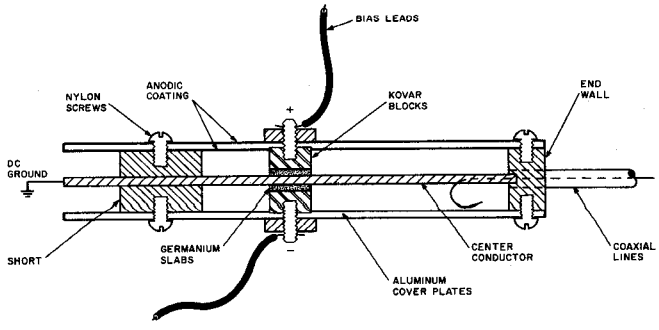

Figure 3. Cross Section of Stripline Resonator Showing Bias Voltage Polarities

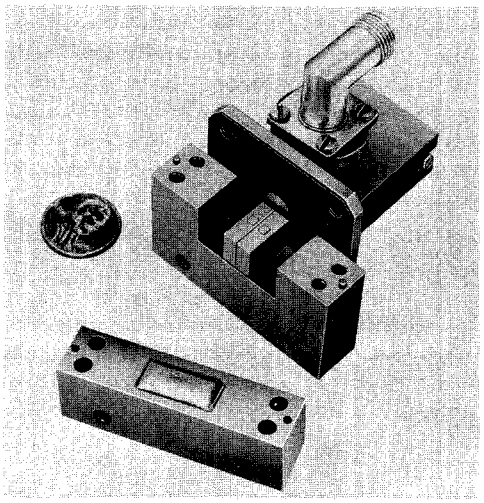

Figure 4. Ridge-Waveguide Structure Showing Waveguide to Coaxial Transition and Coupling Iris

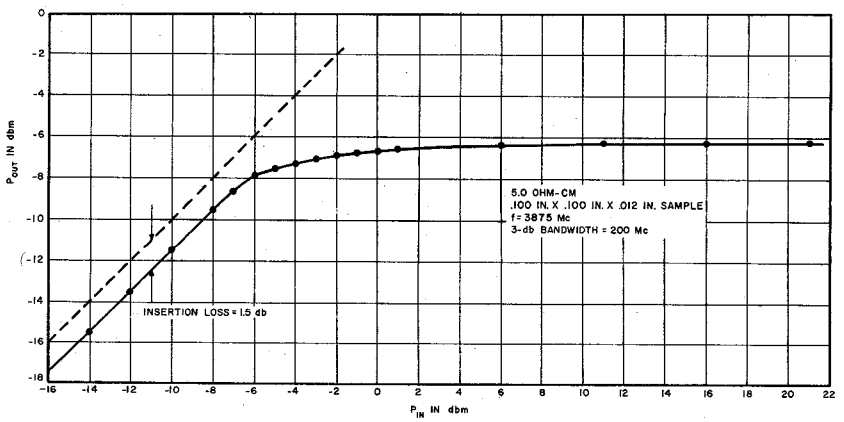

Figure 5. Typical Limiting Curve Obtained from Ridge-Waveguide Resonator

ACKNOWLEDGMENTS

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