V-3. The Versatile Tunnel-Diode Video Detector

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The tunnel-diode video detector to be discussed is shown in Fig. 1; it consists of a diode mount and a ferrite isolator. The isolator is necessary because the tunnel diode is biased into its negative resistance region. The diode mount was designed for operation at the C-band frequency range of 5.4 to 5.9 Gc. This mount is tunable in order to accomodate diode replacement, and its rf bandwidth is adjustable between the limits of roughly 30 Mc to 700 Mc for selected diodes.

The performance characteristics of a tunnel-diode video detector are quite different from those of the standard 408B crystal type. Figure 2 shows a comparison of typical detection voltage characteristics. Note that there is no single characteristic for the tunnel-diode detector but, rather, a wide-spread family of curves which depend upon diode bias and loading. The 408B crystal will also exhibit a family of curves for these variables, of course, but with far less spread. The detection voltage level at which the effects of self-bias become significant, i.e., where the curves depart from square-law behavior, is lower for the tunnel diode than the 408B, and it exhibits considerably greater limiting action as the rf power level increases. In working with these two types of detectors, the most striking difference is the remarkable flexibility of control over the detection voltage sensitivity of

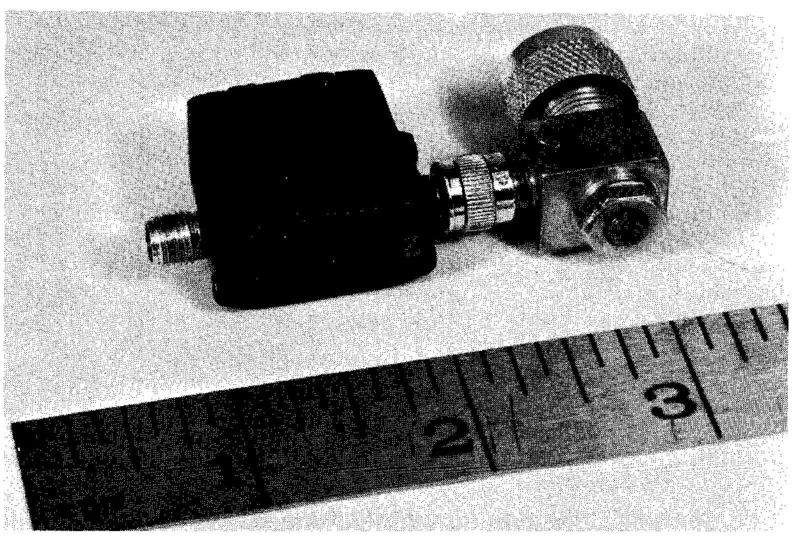

Fig. 1 C-band tunnel-diode video detector, AGAC Model 4.

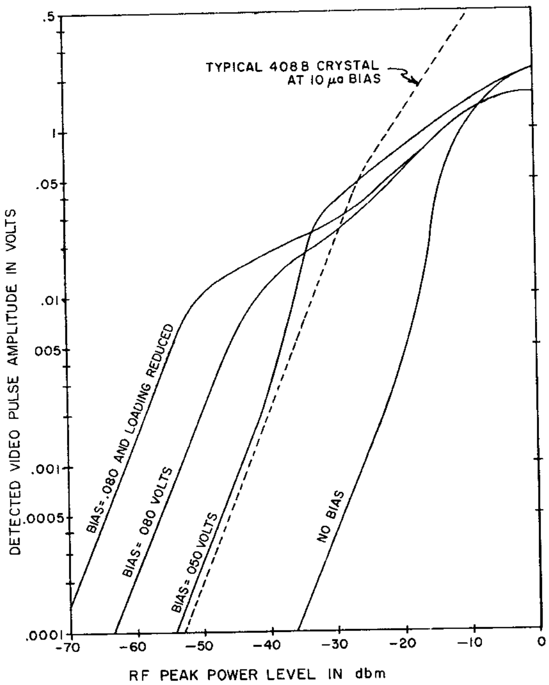

Fig. 2 Detection voltage characteristics of tunnel-diode detector.

the tunnel diode, which control may be exercised by variation of the bias voltage across the diode, variation of the rf impedance loading on the diode, or variation of the video output resistance loading. The underlying factor behind this flexibility is the biasing of the diode in its negative resistance region, and the most important variable to use in tieing down the detector sensitivity is its bandwidth.

Bandwidth dependence of the detector is illustrated in Fig. 3, which shows a typical plot of rf bandwidth of the detector mount vs rf power required to achieve one millivolt output. The data shows that there is some difference in the characteristic depending upon whether the bias voltage or the rf impedance loading is varied. The general behavior may be directly related to the gain-bandwidth product of the tunnel-diode mount when considered as an rf amplifier. This gain-bandwidth product may be derived from the equivalent series circuit and is given by the expression:

$$\text{gain} \times \text{bandwidth} = \frac{\left|(R_s - R_d') - R(f)\right|}{2\pi L_t}$$

where R_s = diode series resistance; $-R_d'$ = equivalent series negative resistance of the diode; $R(f)$ = equivalent series rf resistance loading by the 50 ohm input; and L_t = total equivalent series inductance.

Since it is simultaneously a tunnel-diode rf amplifier, this detector is subject to the same stability criteria[1] as any other tunnel diode amplifier, and it will oscillate if the criteria is violated. For this reason, it requires the use

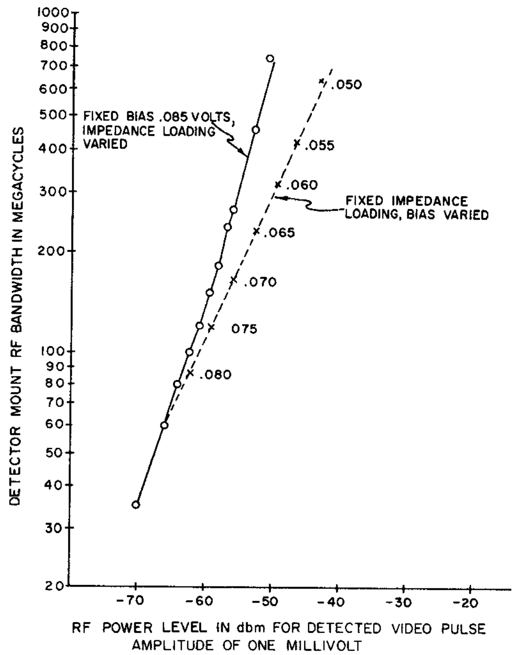

Fig. 3 RF bandwidth vs millivolt detection characteristics.

of a ferrite isolator to insure stability against external impedance variations in the 50 ohm rf input line.

The bandwidth dependence carries over into the all-important tangential sensitivity of the detector, which is shown in Fig. 4. The data in Fig. 4 represents several diodes, operating under various bias and loading adjustments, with a video noise bandwidth of 10 Mc and a video amplifier noise figure of approximately 4 db. It is very obvious that, in specifying tangential sensitivity for a tunnel-diode video detector, one must state the rf bandwidth as well as the video noise bandwidth, because the ease of bandwidth control is such that one can obtain practically any sensitivity desired.

Another interesting property of the detector is its ability to give either positive or negative polarity output video pulses. The polarity is determined by the direction of rectification in the diode, and this relates back to the inflection point in the diode characteristic, shown in Fig. 5 as point *D*. Note that Fig. 5 has been plotted as a back-diode characteristic in order to compare it with a typical 408B crystal characteristic. On the right-hand side of the inflection point (such as points A, B, or C), the diode nonlinearity has a concave curvature which results in a net positive rectified current. On the left-hand side of the inflection point (such as points *E* or *F*), the diode nonlinearity has a convex curvature which results in a net negative rectified current. Obviously, if biased exactly at the inflection point, rectification ceases and the video output drops to zero. These rectification effects result in a discriminator type of video output vs bias voltage characteristic, which is shown in Fig. 6 for a typical detector. This property could be used for sensing or control purposes by relating bias voltage to the desired control variable.

In the video frequency range, the diode and its biasing circuit, plus any additional output video circuitry, form a tunnel-diode video amplifier stage which must be designed on the basis of the usual stability criteria and the video bandwidth characteristics desired. The gain of this video amplifier can be varied either by means of bias adjustment or video resistance adjustment. The latter control is purely video, and is characterized by the fact that it permits variation of the voltage output and equivalent RC time constant of the detector without changing the rf tangential sensitivity. The video noise[2] is mainly shot noise and 1/f noise generated in the diode and, because of the video amplification, it is not necessary to employ a low-noise stage following the detector.

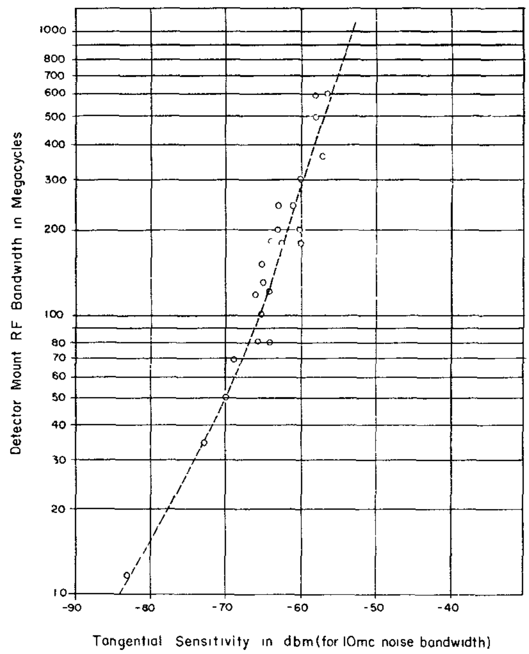

Fig. 4 Tangential sensitivity vs rf bandwidth for tunnel-diode video detector.

From the data measured on this detector, it appears that the device behaves as if it were three components in tandem: an rf amplifier, a video detector, and a video amplifier. If this assumption is correct, then one should be able to increase the performance of the device by using tunnel diodes with greater gain-bandwidth products. When adjusted for a high video gain and used in conjunction with a sensitive oscilloscope, it permits direct oscilloscope observation in sweep-frequency bench testing at rf power levels of the order of −80 dbm.

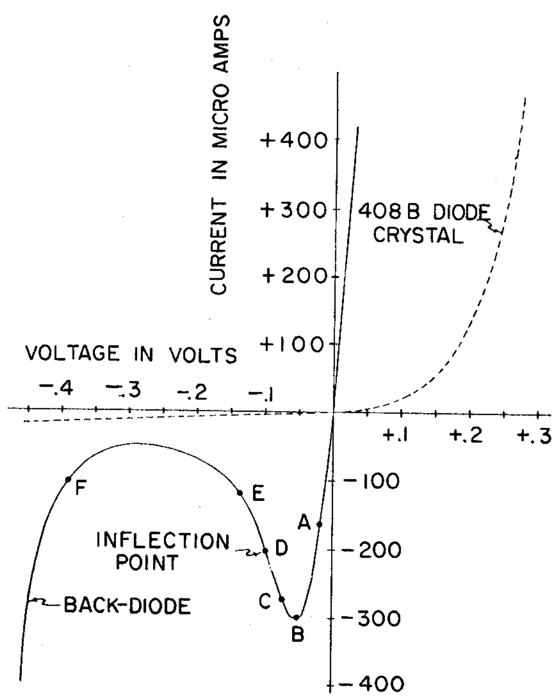

Fig. 5 Static voltage-current characteristics of back-diode and 408B crystal.

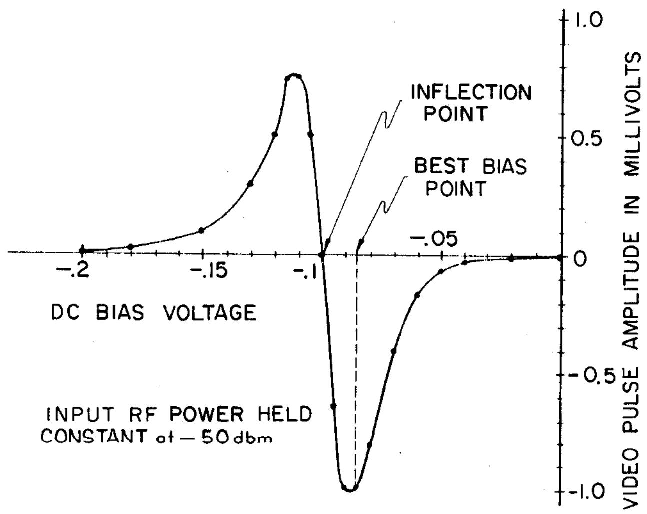

Fig. 6 Typical plot of video pulse amplitude and polarity vs dc bias voltage.

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2. E. G. Nielson, "Noise in Tunnel Diode Circuits," *N.E.C. Convention Record* (Chicago: National Electronics Conference, Inc., 1960).