October 1, 1962

TO: Holders of TN-62-43

FROM: J. Jasberg

SUBJECT: Supplement to TN-62-43, "Experimental Results of Tests on Two Microwave Detectors: The 'Bolomistor' and the Pencil Dicde"

The following comments on TN-62-43 by the manufacturer of the "Bolomistor" may be of interest:

"It might be of interest to note that the reversal phenomenon which you have observed was characteristic of the material used in the early days of the 'Bolomistor'devices. This was due to using a lead-telluride which did permit some association of the sodium dopent with oxygen with time, resulting in anomalous effects. Our supplier has advised that the problem has been solved, and accordingly we have not noticed this reversal here for some time."

TN-62-43
August 1962

EXPERIMENTAL RESULTS OF TESTS ON TWO MICROWAVE DETECTORS: THE "BOLOMISTOR" AND THE PENCIL DIODE

K. B. Mallory, J. Jasberg, and M. M. Brady

INTRODUCTION

Two unusual types of microwave detector, the Bolomistor[1] manufactured by MSI Electronics in Richmond Hill, N. Y., and the 6173 pencil diode manufactured by Lewis and Kaufman, have been experimentally examined to determine the feasibility of their use as broad dynamic range detectors. The Bolomistor physically looks like a 1N21 type crystal and comprises an internal structure resembling that of a point contact diode. The device is not a rectifier, but it operates on the Seeback effect and is thus square-law over much of its operating range. The pencil diode investigated is a space-charge limited diode operated at a low enough signal level that its characteristic is predominately square law. The pencil diode was tested in a mount supplied by the manufacturer, while the Bolomistor was tested in a standard crystal mount. All rf tests were made at approximately 2856 Mc. A rough comparison of the characteristics of the units against a 1N21 type crystal is shown in Fig. 1. Note that the crystal is still the least noisy of the three devices, but that the two devices tested have a broader square law region in their characteristics.

THE BOLOMISTOR

The Bolomistor is a semiconductor device relying on the Seeback effect to produce an output signal proportional to input power. It is available in either 40 db or 50 db ranges with minimum sensitivities ranging from - 60 dbm to 0 dbm. Prices range from $20.00 for the least sensitive of the 40 db range types to $85.00 for the most sensitive of the 50 db range types. Physically the unit is packaged in a 1N21 type mount and requires the same electrical connections as does a crystal. The manufacturer claims that the units are usable from 800 Mc to 12.4 Gc tests were made in this laboratory at or around 2856 Mc. A total of ten Bolomistors were examined: three B-120 (minimum sensitivity of - 20 dbm, 40 db range), three B-100 (minimum sensitivity of 0 dbm, 40 db range), and four B-130 (minimum sensitivity of - 30 dbm, 40 db range). A standard crystal mount with coaxial two-stub tuners was used for all tests.

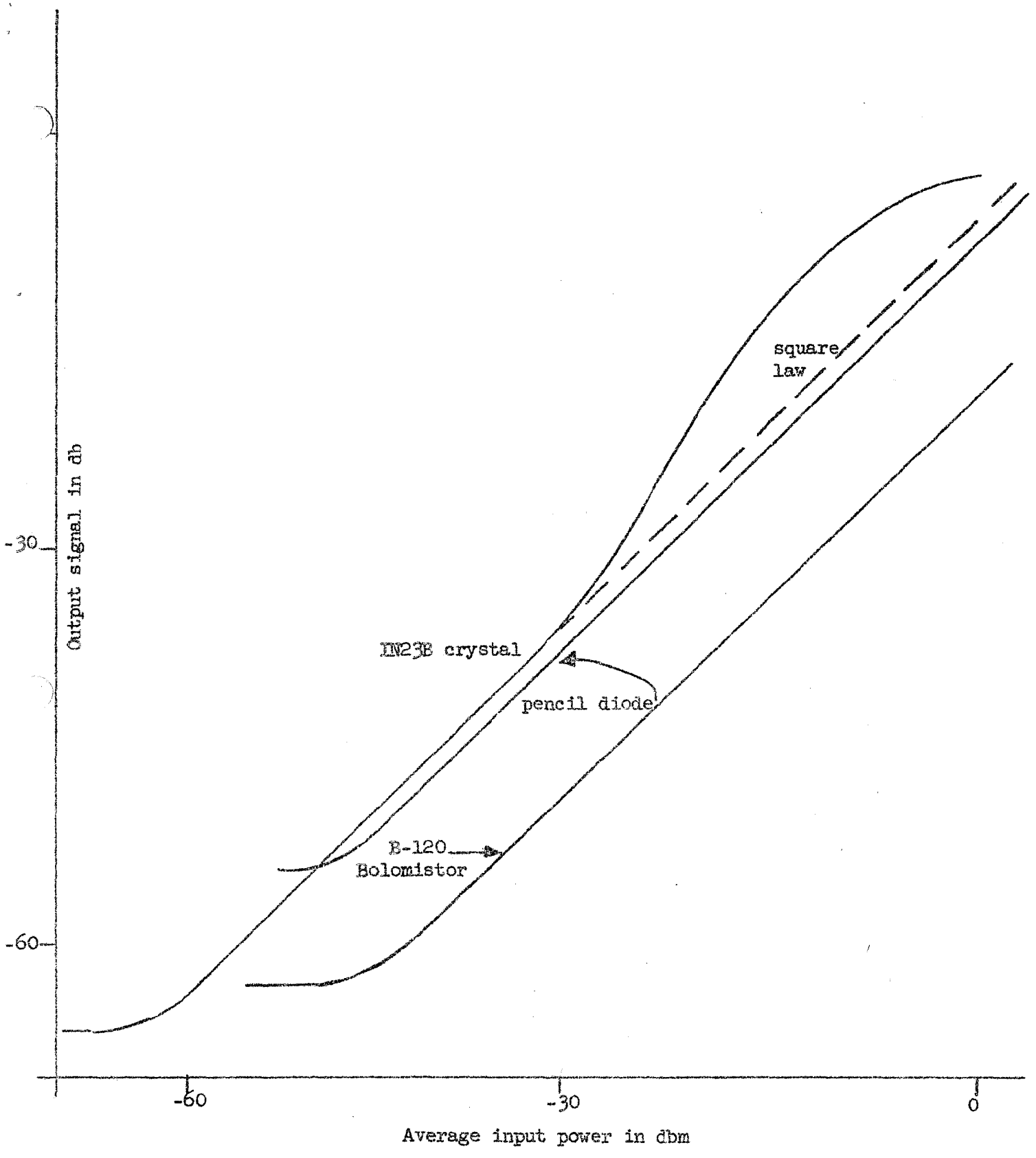

FIG. 1--Comparison of pencil diode and Bolomistor with crystal diode.

Input Impedance

The input impedance of the units tested was found to be quite low: from VSWR measurements it is evident that the rf input impedance in an untuned coaxial mount is in the neighborhood of five ohms. With two-stub tuners it is possible to match the Bolomistor in an untuned mount to the impedance of coaxial line to an input VSWR of about 1.015. The match achieved is not dependent on power level; i.e., the input VSWR is independent of power level over the operating range of the Bolomistor. Within any one type the Bolomistor appears to be more uniform from unit to unit than crystal diodes. When a mount was tuned to an input VSWR of 1.05 with one unit installed, substitution of other units of the same type resulted in input VSWR's of no greater than 1.30. However, if units of another type (i.e., B-100 units installed in a mount tuned for a B-120 unit) are substituted, the input VSWR may be as great as 15. One can then conclude that it is not necessary to retune a mount if only a reasonable match is desired, as units of the same type are changed. If, however, units of another type are substituted, the mount must be retuned.

Output Impedance

The 1000-cycle output impedance of the B-120 units was found to be from 2 to 5 ohms.

Characteristics

The characteristics of three B-120 Bolomistor units are shown in Fig. 2. The dips in the characteristics of units #1 and #3 at low power levels are most likely due to some sort of phase reversal phenomenon at low signal levels. Note that the minimum sensitivity for square-law operation for unit #3 is around -34 dbm and that the total square-law range is almost 50 db. This has led us to believe that the manufacturer merely makes a number of units and then selects by testing those that are most sensitive and have the broadest range. The dip occurring at about 12 dbm in the characteristic of unit #2 is a phenomenon that was in no way mentioned by the manufacturer. Further investigations using dc instead of 1000 cps modulation and indication showed that the voltage output of the unit reversed polarity at this point. This would amount to a 180 degree phase reversal in an ac signal; the characteristic of Fig. 2 appears to continue upward above the dip.

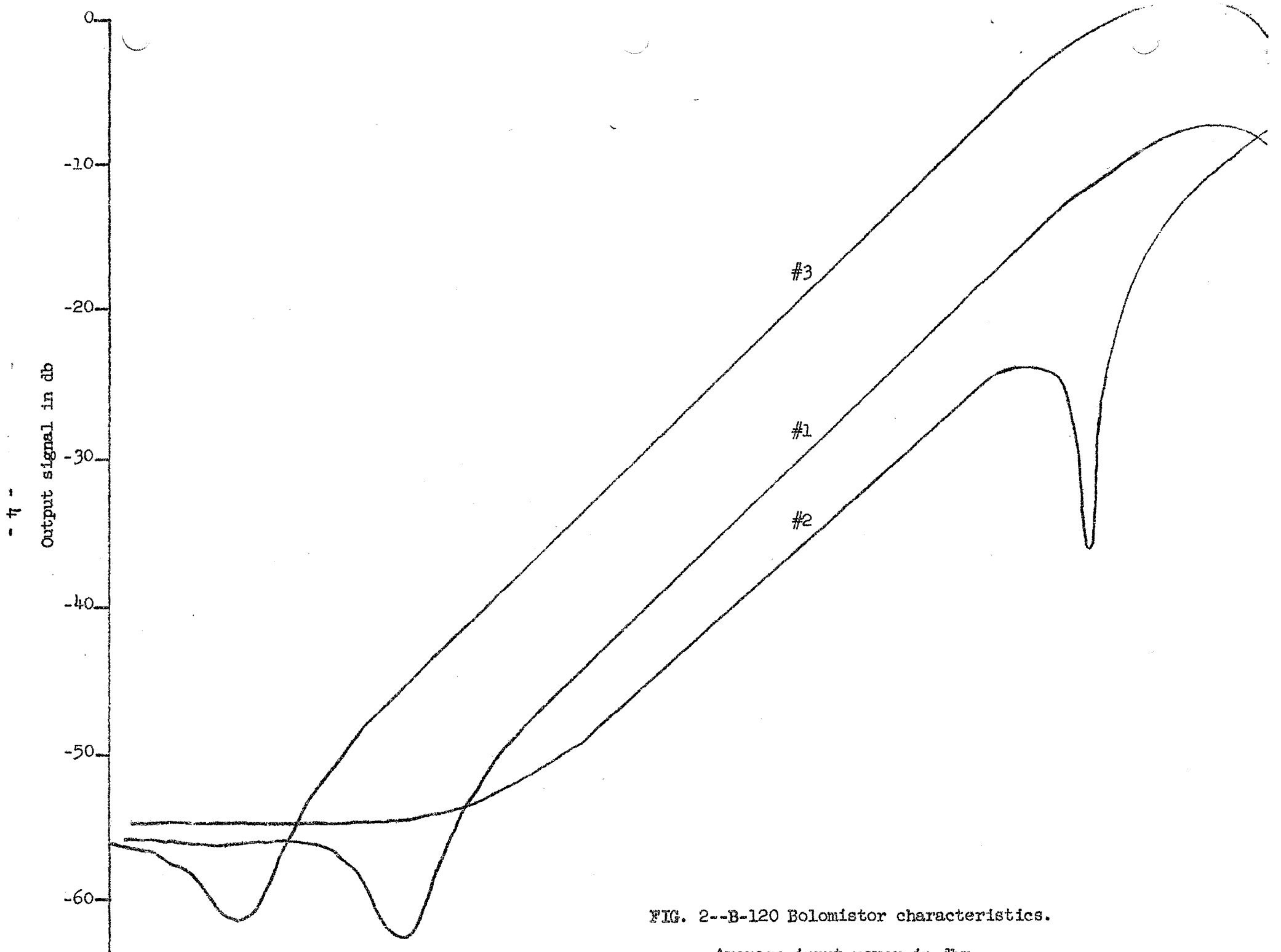

FIG. 2--B-120 Bolomistor characteristics.

A plausible argument for this phenomenon would be that there is a secondary longer time constant effect in the semiconductor (lead telluride) that operates over a different temperature range than the primary effect and produces an opposite polarity signal. If this were so, then one could observe a degradation of the shape of a square-wave signal at power levels approaching the point where the phase reversal occurs. Investigations with pulses a few microseconds long have shown that this secondary effect is fairly fast, having a time constant of about 5 microseconds. If the time constant of the reversal were long, its effect on a short pulse would be evident in droop. The curves in Fig. 3 show, however, that the effect is fast enough to seriously affect 2-microsecond pulses. The effect that produces the droop or reversal appears to have a threshold; below about 10 watts peak is not observable with 5 microsecond pulses.

The maximum output signal obtainable was less than 300 millivolts. The low output impedance of the Bolomistor suggests that it would be easy to step up the output signal with a pulse transformer. With the B-120 Bolomistors a 1:10 pulse transformer worked very well and delivered signals over 1 volt into 1000 ohms at an oscilloscope.

Tests of Bolomistor characteristics in other laboratories[3] substantiate our findings on the square-law characteristics. Although others have observed the dip phenomenon, we have heard of no other investigations of the output reversal.

Pulse Response

Other than the degraded pulse response in the region of the phase reversal point observed in some units, the pulse response of the Bolomistor is negligibly different from that of a microwave point-contact crystal. At oscilloscope sweep speeds of 0.5 microseconds/centimeter the Bolomistor response time appears to be just observably longer than that of a 1N21 or 1N23 type crystal.

Miscellaneous

The Bolomistor apparently burns out in a manner quite different from a crystal. When its maximum power level is exceeded, its output slowly drops off and takes several seconds to decrease appreciably. After this has occurred, the characteristic of the unit is changed considerably in that it is no longer as sensitive and follows a different law than before "burn out." Unit #3 of Fig. 2 eventually was

FIG. 3--Bolomistor pulse response.

(a) 12 watts peak, 1 mw average power input
(b) 48 watts peak, 4 mw average power input
(c) 96 watts peak, 8 mw average power input

damaged at an average power level of 24 dbm and was disassembled and examined under a microscope. Physically the construction of the unit is almost identical to that of the 1N21 family of point-contact diodes. Several pits of different depth and width were observed on the semiconductor block; one could conclude that the manufacturer made several tries at assembling the unit.

At this writing there is no life test data available on the Bolometer, although we have no cause to believe that the life of these units will be any different from that of a 1N21 family diode.

THE PENCIL DIODE[4]

The type 6173 pencil diode, manufactured by RCA and Lewis and Kaufman, is a space-charge limited diode approximately two inches long and 3/8 inch in diameter. The units tested were mounted in Lewis and Kaufman type DS-5R mounts, which are simple coaxial mounts employing quarter-wave sleeve matching with a dc return. The design of the mount itself is poor in that the diode is mounted in a spring-contact well with the heater connections at the bottom of the well. The heater connections on the diodes are merely support wires brought out through the glass envelope. Installing the diode in its mount is then quite difficult, for the heater wires are difficult to align properly so that they do not bend when the diode is inserted in its well. Once inserted in its well the diode and its heater and video connection block are screwed onto the rf section of the mount, which means that the fore part of the diode is rotated in a spring contact ring. The DS-5R mount with a 6173 diode and heater transformer cost $131 when Lewis and Kaufman's northern division was still in operation. Cascade Research, the southern division of Lewis and Kaufman, advertises that they now make the mounts and diodes[5]. A number of the mounts now owned by the Klystron Group were made by Cascade. At this writing Physical Electronics of Palo Alto appears to be interested in building a mount for the RCA 6173 diode.

Input Impedance

The input VSWR at 2860 Mc of six 6173 diodes in DS-5R mounts received from Lewis and Kaufman ranged from 1.18 to 1.45. The input VSWR at 2860 Mc of eighteen diodes in mounts received from Cascade ranged from 1.1 to 2.5, with eleven units having an input VSWR less than 1.5. The only Lewis and Kaufman data sheet available stipulates a single-frequency input VSWR of 1.5 or less. Twelve 6173 diodes

were measured in a single mount with resulting input VSWR's of 1.1 to 4.5. As in the case of the Bolomistor this indicates that there may be uniformity between selected units but not on a cross section of all units. There appears to be quite a bit of rf leakage through the diode to the video output, for the input VSWR is sometimes critically dependent on the length of coaxial cable connected between the mount and the indicating instrument used.

Output Impedance

The 1000-cycle output impedance of the 6173 diodes in DS-5R mounts was found to be between 400 and 900 ohms. The open-circuited, zero-signal dc output of the units is about 0.7 volts. This is due to contact potential and thermal emission.

Characteristics

A typical characteristic for a 6173 diode in a DS-5R mount is shown in Fig. 4. Note that the dynamic range presented is about 90 db in extent, while the device is square-law up to 1 milliwatt average power input. The characteristics of the units tested were surprisingly uniform: eleven out of 18 units tested had characteristics that fell within less than 2 db of each other at power levels below 1 milliwatt. Note that it is possible to obtain a 1-volt output signal for an input power of 15 dbm. If these units are to be used as cw monitors, some method must be devised to remove the residual signal that is present under zero-signal conditions.

Miscellaneous

The high input VSWR's encountered with different diodes in a single mount suggests that some sort of external matching might be necessary. No life test data is available, although the manufacturer hints that 2000 hours is not an unreasonable figure.

SUMMARY

Both the 40 db type Bolomistors and the pencil diodes were found to have a 40 to 50 db square-law region as compared to slightly over 30 db for a crystal. The available dynamic range of the 40 db type Bolomistors is little greater than their square-law range, while the available dynamic range of the pencil diode is apparently in excess of 90 db. The Bolomistors have a noise level approximately 10 db above a 1N23B crystal; the pencil diodes have a noise level 2 to 3 db higher than that of the Bolomistor. Very little data is available from the manufacturers of these detectors, so it has not been possible to correlate with specified performances.

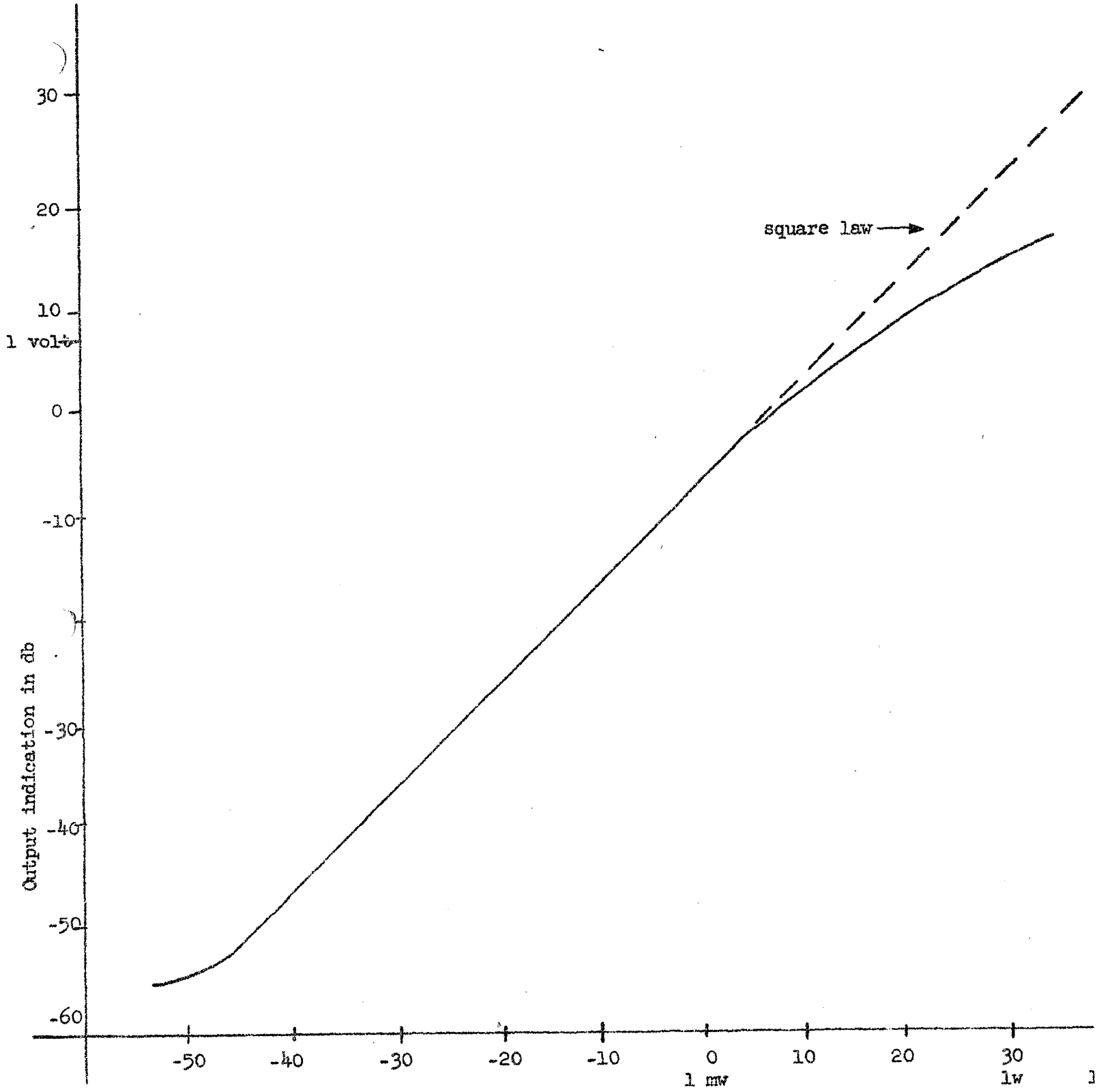

FIG. 4--Characteristic of 6173 diode in DS-5R mount.

NOTES

1. The Bolomistor is a trademark for a microwave detector manufactured by:

   MSI Electronics Inc.
   116-06 Myrtle Avenue
   Richmond Hill 18, New York

   represented locally by:

   Peninsula Associates
   1345 Hancock Street
   Redwood City, California

2. The experiments reported here are recorded in the following data books:

   M.L. Data Notebook #351 issued to K. B. Mallory: pp. 64-66.

   M.L. Data Notebook #471 issued to J. Jasberg: pp. 17-22.

   M.L. Data Notebook #570 issued to M.M. Brady: pp. 96, 97, 102-120, 122-126.

   SLAC Data Notebook #55 issued to M.M. Brady: pp. 18-21.

3. Correspondence between A. P. King, Aerospace Group, Hughes Aircraft and J. Jasberg of SLAC February 21, 1962.

4. The type 6173 pencil diodes tested were manufactured by Lewis and Kaufman; RCA manufactures a 6173 diode (described in an RCA data sheet dated 9/58). The manufacture of Lewis and Kaufman 6173 diodes and DS-5R mounts has now been taken over by Cascade:

   Cascade Research Division
   Lewis and Kaufman Electronics Corp.
   5245 San Fernando Road
   West Los Angeles 39, California

   represented locally by:

   Elliott Recht Associates
   175 South San Antonio Road
   Los Altos, California

5. See, for example, page 25 of the July 1962 Microwave Journal.