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A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
TELEPHONE EASTBROOK 7571 • TWX 219 241—2968

RADIO FREQUENCY LABORATORY
3700 EAST PONTIAC STREET
FORT WAYNE, INDIANA

15 July 1963

Mr. Vince Rose
Building #56
Naval Research Laboratory
Washington 25, D.C.

Dear Mr. Rose:

Enclosed are several copies of a report describing a portion of the tunnel diode study we are conducting. I would appreciate it if you would give a copy of the report to Mr. Mayo and other NRL personnel that are directly concerned with this type of problem. This work and the results are considered ITT proprietary and should be revealed only to the NRL personnel who have a direct reason to be aware of the effort.

I feel the technique is proven but not refined to the point that it could be sold without a small amount of development effort to determine the environmental performance characteristics. At the present, it appears that a tangential sensitivity of -65 dbm to -70 dbm should be feasible for a 400 mcs RF bandwidth in C Band. A better tangential sensitivity may be achieved by decreasing the RF bandwidth. This is the specific approach that is of interest to your type of receiving system. This work is being done on company funding and is emphasized only when more pressing problems are not present; hence, the pace is quite slow. I will keep you informed of any progress in the development program.

We would, of course, be interested in developing a specific frequency model of this unit for your requirements.

Contact me if you have any questions concerning the report or other problems that are of mutual interest and concern.

Yours truly,

Paul L. Mast

Paul L. Mast

PLM:jo

Enclosures

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COMMUNICATIONS SYSTEMS DEPARTMENT
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# TUNNEL DIODE UTILIZATION STUDY

## Video Sensitivity Improvement

STATUS REPORT

June 15, 1963

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TUNNEL DIODE UTILIZATION STUDY
Video Sensitivity Improvement

BACKGROUND

The advent of the microwave tunnel diode has made possible many new concepts of active and pseudo-passive microwave circuit concepts and applications. Many imaginative schemes and new techniques have been conceived for the utilization of these relatively new devices.

The extremely small size and low power requirements make tunnel diodes particularly attractive for satellite systems operating in virtually any portion of the radio frequency spectrum. The importance and the potential utilization of tunnel diodes for various HF through microwave applications is recognized by the Radio Frequency Laboratory.

A preliminary program has been inititated to determine the performance characteristics of tunnel diodes for various applications and rf frequencies. The applications to be considered in the total scope of the preliminary study are:

(1) Video detection sensitivity improvement by integration of a tunnel diode into a bandpass filter.

(2) Utilization of tunnel diodes directly in antenna arrays to accomplish a psuedo-passive reflecting array or a specific pattern performance array.

(3) Development of a low-noise pre-amplifier for either in-line use or integration into an antenna structure.

It is the ultimate goal of this study to generate new and/or unique concepts of tunnel diode utilization. The techniques resulting from this study shall be carried sufficiently far to either verify the technique or give sufficient reason to eliminate it from further consideration. It is anticipated that this program will result in new techniques that are proprietory to ITT Kellogg Communications Systems and enhance the competitive position of the company. Design finalization is to be considered only when there is sufficient reason to believe the end item will represent a competitive, reliable product that may be marketed.

Much effort has been expended to determine the characteristics of tunnel diodes and the techniques of their utilization for video detection. An extremely successful technique has evolved from this study. This report gives the basic design concept and performance data of the video detection sensitivity improvement portion of the tunnel diode utilization study.

TECHNICAL DISCUSSION

The technique being presently explored for achieving improved video sensitivity is an integrated filter-amplifier-detector. These functions are both electrically and mechanically integrated. (Figures 1 and 2). The technique is such that they cannot be considered as separate items.

Briefly, the filter is designed for a termination at one end only; thus, if all the other resonators of the filter were disconnected, the output resonators would have a loaded Q of infinity. The tunnel diode amplifier gain is obtained through two mechanisms. First, part of the gain is obtained from a reactive power step-up in a filter designed for a resistive termination at one end only. This reactive power step-up corresponds to an impedance or Q step-up equal to the number of parallel tuned circuits in the filter or an admittance step-up if series tuned circuits are used. The amount of resistive impedance or admittance step-up is equal to the number of resonators for the maximally flat filter or a lesser value for the Chebishev type response filter.

The second part of the amplifier gain is obtained by using the negative admittance characteristics of the tunnel diode to connect a resistive load to the filter but yet maintain an output loaded Q of infinity. The gain of the tunnel diode amplifier is given by:

$$A = \frac{4G_L G_g}{(G_L + G_g - G)^2}$$

where

$A$ = Insertion Gain
$G_L$ = Transformed Load Conductance
$G_g$ = Transformed Source Conductance
$G$ = Transformed Negative Conductance

The tunnel diode is adjusted such that $G_L = G$. Therefore,

$$A = \frac{4G_L}{G_g}$$

Substituting values for $G_L$ and $G_g$ such that $Q_1$ is the generator loading of the input resonator and $Q_n$ is the loaded Q of the output resonator with the other resonators shorted and the tunnel diode not energized, the gain equation becomes:

$$A = \frac{4NQ_1}{Q_n}$$

$$G_g = \frac{B}{Q_g} = \frac{B}{NQ_1} \text{ and } G_L = \frac{B}{Q_n}$$

where:

N = number of resonators; the input conductance is divided by N when transformed to the output

B = resonator shunt susceptance

In the unit designed as a microwave test piece, ($f_o$ = 3.67 gc based on SCL77), N=5, $Q_1$ = 3.85 and $Q_5$=10, the value attainable from a MA-408B detector crystal when operated at maximum sensitivity with 20 to 40 μamp bias. Using the above values, the theoretical insertion power gain is 7.7 (8.9 db) referenced to a load impedance matched to a generator.

The measured tangential sensitivity of this system was -67.5 dbm (Figure 3). All data in this report recorded with a SCC70C video amplifier that has a video bandwidth of approximately one megacycle. The measured tangential sensitivity of a similar impedance matched RF system without a tunnel diode was -59 dbm (Figure 4). The measured gain of the tunnel diode amplifier is therefore approximately 8.5 db.

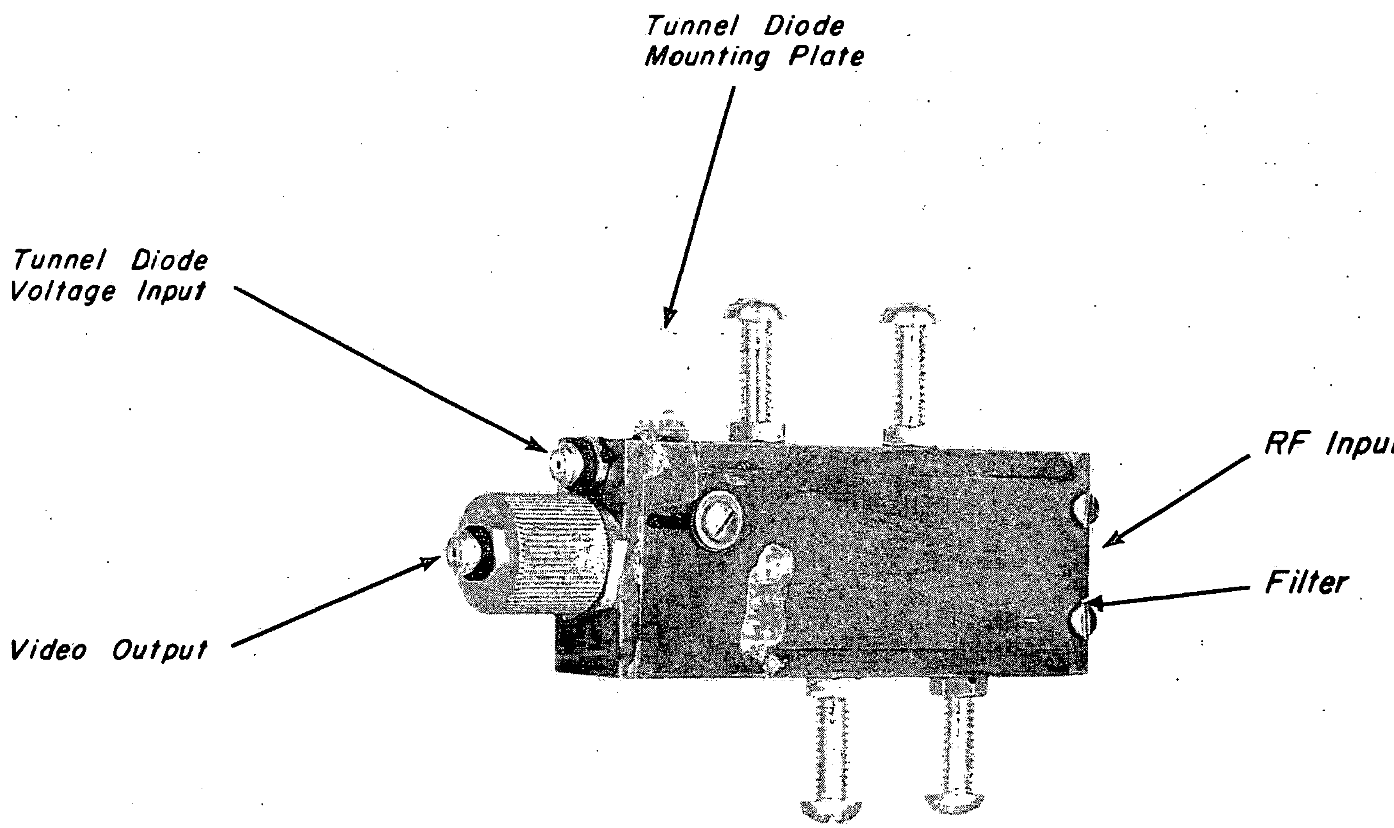
Sufficient data has been recorded on this unit to show that the technique is a theoretically and experimentally correct concept. Tests have been made to show that the gain and bandwidth of the unit may be varied (Figure 5). In general, increased gain may be achieved at the expense of rf bandwidth

PLANNED EFFORT

The mechanical positioning device for the tunnel diode needs improvement to more accurately control the location of the tunnel diode. The present mechanism was only intended to show technique feasibility. One of the more pressing applications for the technique is in the 4.7 gc to 5.1 gc region. A 1 to 2 db loss in crystal rectification efficiency compared to S Band should be anticipated. The S Band model effort should be complemented by additional effort on a 4.7 to 5.1 gcs model. These two designs will yield detailed information on the gain -bandwidth product that may be expected and refine the other design criteria. Stability and sensitivity variations under environment conditions of temperature, shock, and vibration will be studied.

RECOMMENDATIONS

The results on this program to date are such that this program should be continued with increased emphasis as funds become available. This technique is not presently used by any known competitor and should remain company confidential.




FIVE RESONATOR TUNNEL DIODE AMPLIFIER, 3675 mc
with FILTER & VIDEO DETECTOR
Figure 1



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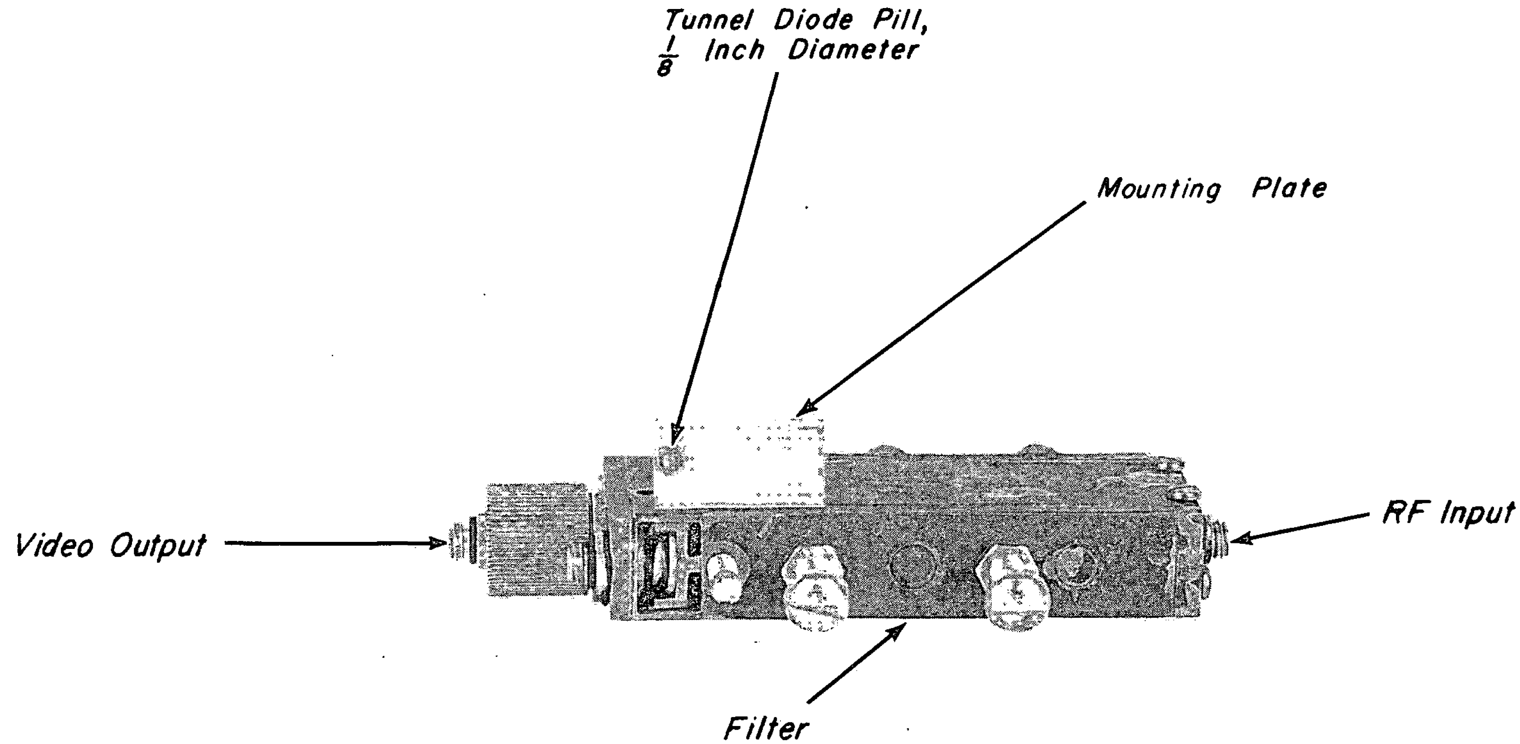


TUNNEL DIODE AMPLIFIER
SHOWING TUNNEL DIODE MOUNTING PLATE

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Figure 2

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Fig 3

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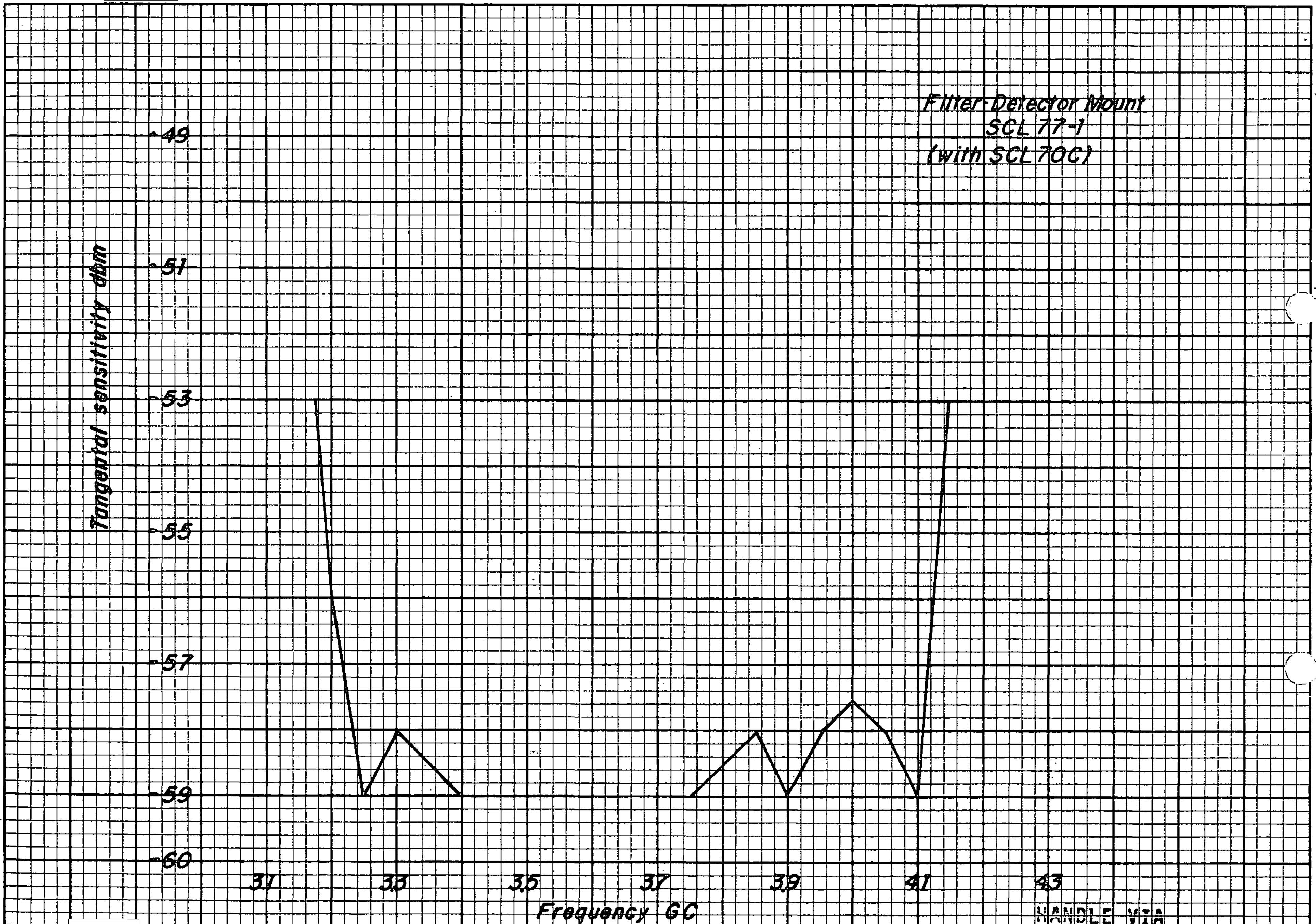


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Fig. 4

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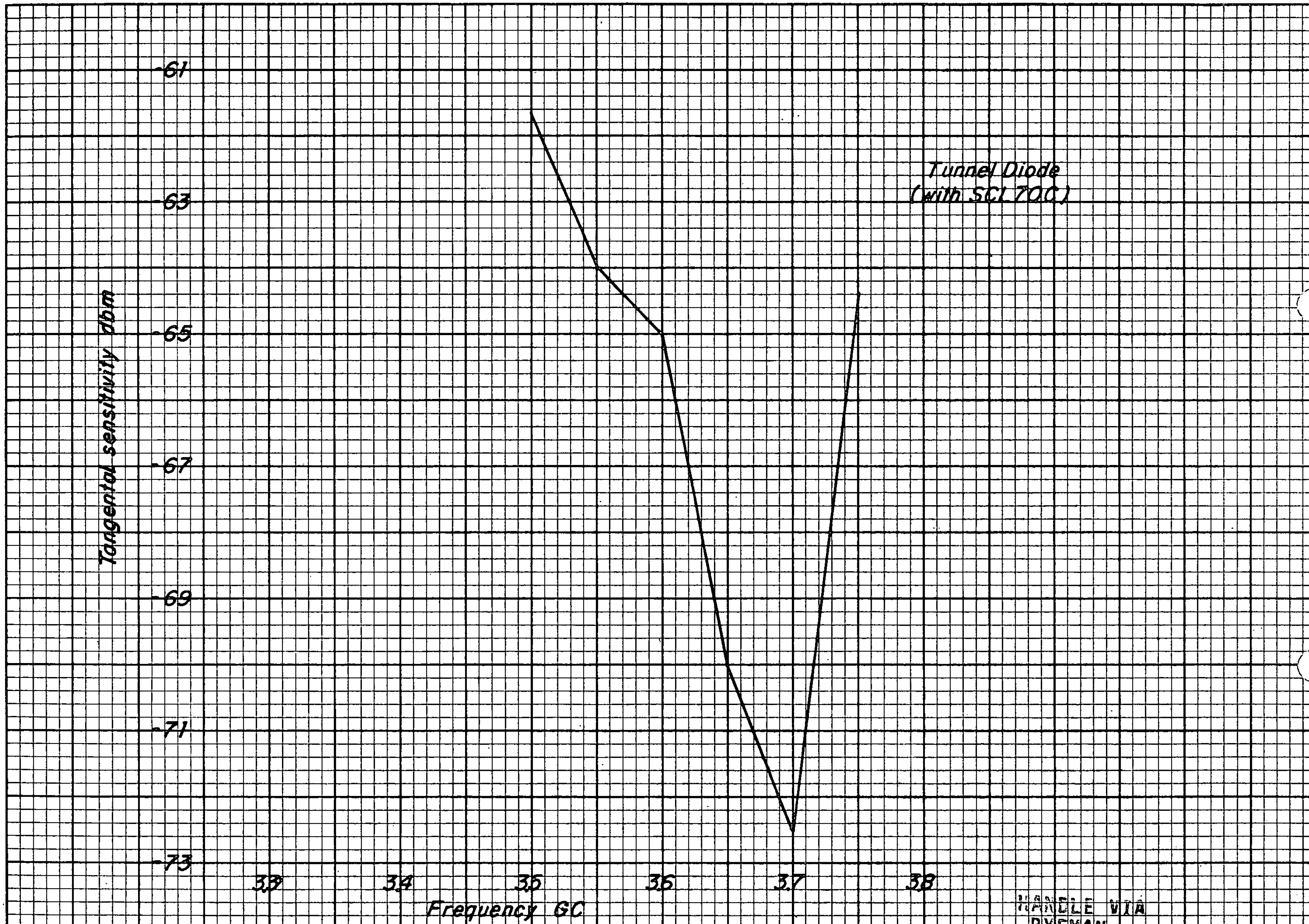


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Fig.5

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