which produced maximum sensitivity, detection in this tube was not satisfactory.

A new tube designated type VAD-161-4 was developed which had a collector redesigned for depressed operation. With this tube no instability was observed at any value of collector voltage, beam current or beam velocity.

Fig. 2 is a three-dimensional model of collector current for the VAD-161-4. The collector current below the oscillation starting current increases with both beam current and collector voltage, indicating that no virtual cathode exists.

At the start of oscillations (a beam current of about 3.5 ma), there is an abrupt change in collector current. At a low collector voltage the collector current rises at the oscillation starting point, but at a higher collector voltage the beam current drops steeply when oscillations begin. This steep drop may be used to detect small changes in beam velocity distribution.

Fig. 3 is a plot of detected output signal level for a constant input vs collector voltage. Beam current was optimized for maximum output.

An important characteristic of the autodyne detector is the rate at which the output signal is reduced as the beam current is increased beyond starting current. In Fig. 4, normalized output from the two types of detector is plotted against normalized beam current. One hundred on the abscissa represents starting current. The crystal detector is much less sensitive to variations in beam current. Note that in contrast to the crystal detector the collector detection efficiency falls off almost as rapidly above starting current as it does below.

The mechanism of detection by a negatively biased collector is such that it is the beat frequency between the oscillation and the signal which is actually detected. When either of these becomes large relative to the other, the change in collector current due to the beat becomes small and detection efficiency drops off.

When the beam current is increased above starting current, the amplitude of the oscillation increases extremely rapidly, so that detection efficiency decreases rapidly for beam currents above starting current.

Because of this effect, a velocity sorting detector has not proved superior to a crystal detector in the electronically tunable receiver application, although sensitivity equivalent to a good crystal detector can be easily obtained.

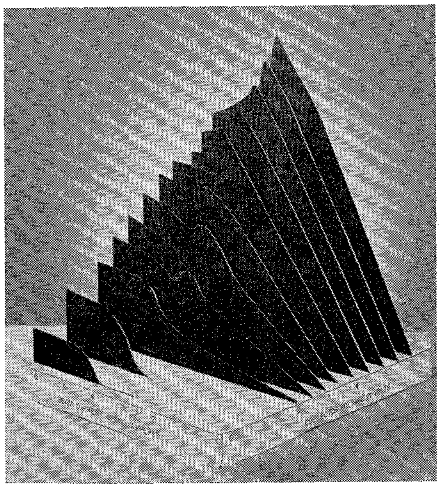

Fig. 2—Three-dimensional graph of measured collector current for type VAD-161-4 tube.

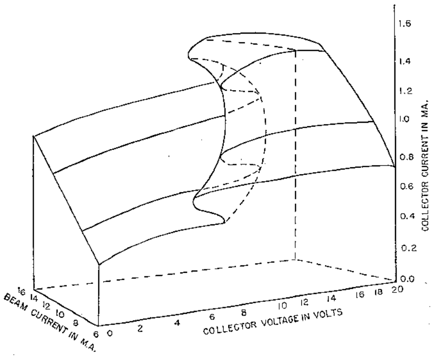

Fig. 1—Three-dimensional graph of measured collector current for type VAD-161-2 tube.

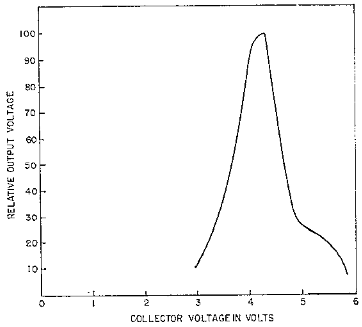

Fig. 3—Detected output level vs collector voltage.

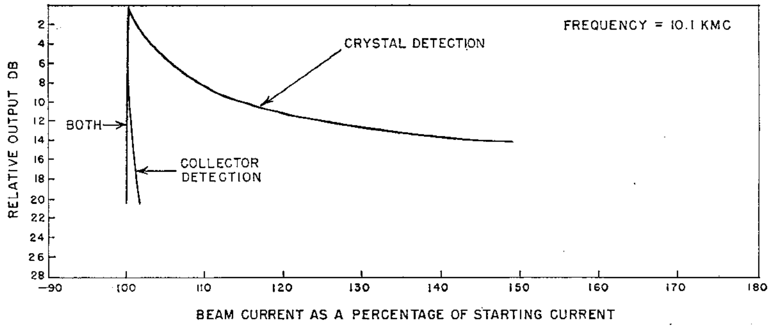

Fig. 4—Normalized output for two types of detector vs beam current.

The backward wave oscillator tubes used in these experiments were developed by Varian of Canada, Ltd., under the auspices of the Defence Research Board, Canada, (Electronic Components Research and Development Committee).

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A Broad-Band Crystal Mount 10.5 kmc to 20 kmc*

Laboratory measurements at microwave frequencies very often require the use of a sensitive detector with broad-band characteristics.

A crystal mount has been developed with a nearly uniform response from 10.5 kmc to 20.0 kmc using coaxial crystals type 1N26 or 1N78A. The best over-all sensitivity is obtained with 1N78A crystals, although the 1N26 crystals are more sensitive from 17 to 20 kmc.

Basically, the mount consists of a section of type RG-91/U waveguide containing a tapered ridge guide-to-coaxial-line junction [1]. The first design matched the waveguide to a 65-ohm coaxial line, but as the crystal impedance was not 65 ohms the dimensions had to be modified considerably to obtain the maximum sensitivity across the frequency band. Dimensional details of the crystal mount are shown in Fig. 1. A low impedance between the crystal body and the mount is obtained by means of an insulated sleeve which forms a capacity of 50 $\mu\mu f$. With a bias current of 75 μamp the video impedance is about 700 ohms, which results in a rise time of less than 0.1 μsec.

The narrow dimension of the waveguide was reduced from the standard 0.311 inch to 0.281 inch to eliminate a sharp dip in sensitivity at 19.2 kmc. In the final version of this mount, the tapered ridge and the insert which reduces the narrow dimension of the guide were machined from one piece of metal, and then placed in the standard waveguide. This method of construction places the junction of the insert and the waveguide at the walls of the guide instead of at the base of the ridge. The results of electrical tests indicated that the performance of the mount does not depend on a good electrical contact at this junction. With this method of fabrication, the assembly of the mount will be greatly simplified.

During all measurements, crystals were biased with 75 μamp of forward current to improve both the detection efficiency and the RF impedance of the complete mount. The video amplifier following the crystal detector had an input impedance of 50 ohms and a bandwidth of 0.5 mc. A pulse-modulated signal was used, with a pulse width of 1 to 2 μsec. The measurements were limited to a few crystals of each type, as the effort

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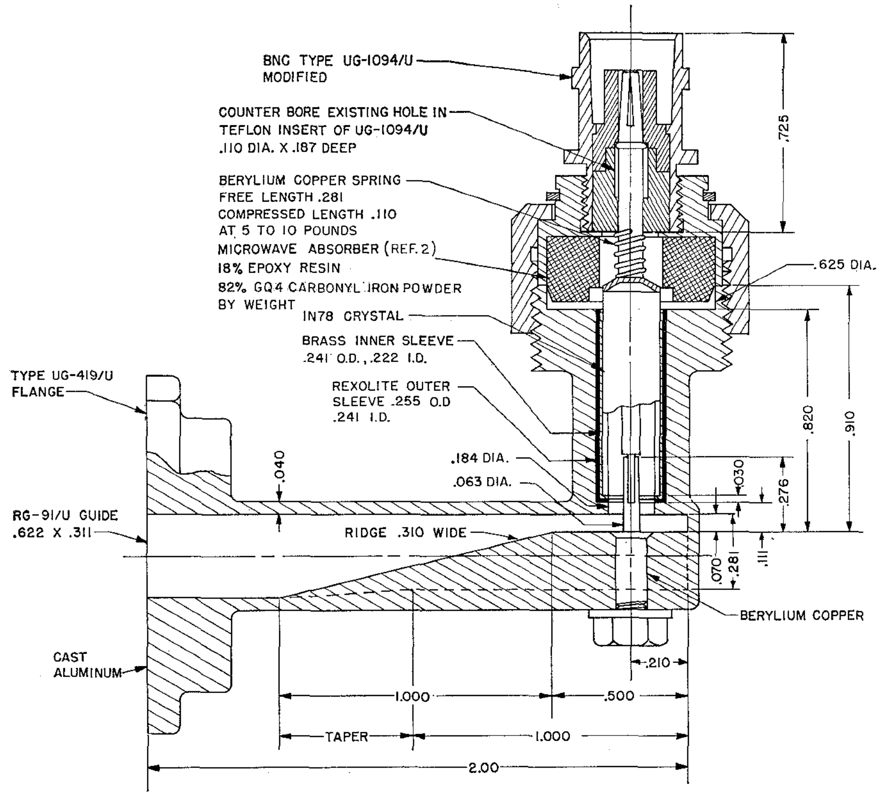

Fig. 1—KU band crystal mount (all dimensions in inches).

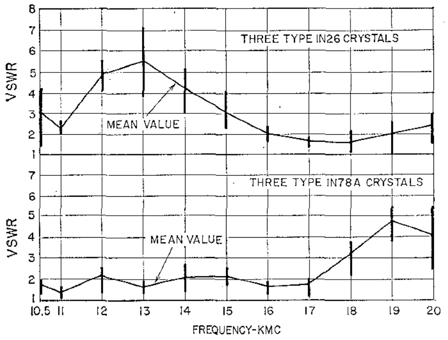

Fig. 2—VSWR at −36 dbm.

available did not permit a more extensive investigation.

The VSWR's of the mount, with two types of crystals, are shown in Fig. 2. The type 1N78A is a better match below 17 kmc, whereas the 1N26 crystal is better between 17 and 20 kmc. The mean tangential sensitivity vs frequency is plotted in Fig. 3, with two types of crystals. The short vertical lines indicate the spread in sensitivity of the group of crystals at each frequency. The arithmetic average sensitivity of the 1N78A crystals was −46.5 dbm, and that of the 1N26 crystals was −44.5 dbm.

In certain applications, such as in ratiometers, it is desirable that the sensitivity curves be parallel. The departure from this condition, known as "tracking error," was estimated from the data and is shown in Table I.

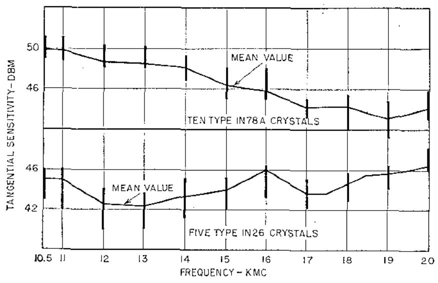

Fig. 3—Tangential sensitivity; video bandwidth 0.5 mc.

TABLE I

TRACKING OF SENSITIVITY OF CRYSTALS AND MOUNTS

Crystal		Number of Mounts	Tracking Error	
Number	Type		10.5–15 kmc	15–20 kmc
Ten	1N78A	One	2 db	2.7 db
Five	1N26	One	1.5 db	1.1 db
One	1N78A	Eight	1.5 db	2.5 db

The choice of crystal type depends upon which frequencies are the most important in the particular application. The 1N78A crystals, designed for 16 kmc, have a higher sensitivity and a lower VSWR from 10.5 to 17.0 kmc, whereas the 1N26 crystals designed for 24 kmc are better from 17 to 20 kmc.

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Proposed Parametric Amplifier Utilizing Ferroelectric Substance*

Ferroelectric substance has been utilized as nonlinear substance in parametric amplifiers.[1–4] However, all of these have been done at low-frequency regions. A surface-wave parametric amplifier employing ferroelectric substance in the microwave region has been proposed.[5]

The character of ferroelectric substance is not so clear at microwave frequencies as at lower frequencies. The nonlinearity caused by the domain wall motion cannot be utilized in the microwave region, because of the slow response of the wall motion.[6] However, the nonlinearity of (BaSr)TiO$_3$ has been measured in the microwave region (3000 mc).[7] This nonlinearity may be caused by the potential of the ionic atom (Ti atom or O atom). Therefore, we may consider the frequency limitation to depend upon the response of the motion of ionic atom. Infrared spectrum studies[8] show that the resonant wavelength of the Ti atom is in the order of 50 μ. From these results it seems feasible that some ferroelectric substance can be utilized in parametric amplifiers at microwave frequencies.

There are several problems to be considered in using ferroelectric substance for a parametric amplifier. First, three different frequencies (signal, idling, and pumping) should be supplied into the substance with minimum reflection. Second, the amplifier is desired to be operated with a low pumping power, especially at high frequencies.

Now, when microwave is applied to an isotropic, homogeneous material whose length is equal to an integer multiple of the half wavelength in the material, the wave reflected at the first surface is cancelled by the wave reflected at the other surface, and there is no reflected wave, provided that the material is lossless. When a TEM wave is used, *e.g.*, when the ferroelectric substance is set between two parallel plates or between the conductors of a strip line or coaxial line, the wave length in the material is expressed as follows:

$$\lambda = \frac{\lambda_{\text{air}}}{\sqrt{\epsilon}} \propto \frac{1}{\omega} \cdot \tag{1}$$

Therefore, when

$$\omega_{\text{pumping}} = \omega_{\text{signal}} + \omega_{\text{idling}}, \tag{2}$$

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