AN S-BAND SWEEP GENERATOR AND TEST SET

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ABSTRACT

A low-power all-electronic S-band sweep generator and test unit has been built which provides a single sweep from 2600 to 3600 Mc or a 150-Mc sweep whose center frequency may be continuously varied and set at any frequency within a 1200-Mc region from 2600 to 3800 Mc. Under square-wave modulation conditions a detector consisting of a broadband bolometer mount, tuned amplifier, and oscilloscope is used to provide a visual indication of the frequency response of S-band components. The sweep is obtained by mixing the output of two K-band klystrons. This technique eliminates moving parts and provides a nearly flat output response.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

NRL Problem R12-02
RDB Project NR 512-020

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INTRODUCTION

The design of this unit arose from the need of obtaining measurements of the frequency response of traveling wave tubes and S-band components without the tedious process of point-by-point measurements. It was decided that a 1000-Mc sweep centered at 3100 Mc would be the most advantageous. It was also desirable that the output be as flat as possible over this 1000-Mc range and that the entire unit be compact, portable, and without moving parts. The method adopted satisfies these requirements to a large extent.

At the present time most of the unit is in the "breadboard" stage and is operating as a test bench setup; however, it will be combined into a single cabinet in the near future.

FREQUENCY SWEEP GENERATOR

The S-band frequency sweep is obtained by mixing the output of two K-band klystrons in a K-band mixer. One klystron is set at a fixed frequency and the other is thermally tuned by means of a pulse applied to its thermal grid causing it to sweep over a 1000-Mc range. Proper mixing of these two signals results in an S-band signal sweeping over a 1000-Mc range.

A thermally tuned type 2K50 reflex klystron provides a signal which sweeps from 23,500 to 24,500 Mc. A Raytheon type QK306 velocity variation klystron employing a self-contained cavity provides the fixed frequency signal. This tube is mechanically tunable from 18,000 to 22,000 Mc. When the QK306 klystron is set at 20,900 Mc, it provides an S-band center frequency of 3100 Mc for a 1000-Mc band as the 2K50 klystron sweeps from 23,500 to 24,500 Mc. The QK306 fixed-frequency klystron is square-wave modulated to facilitate detection by means of a tuned amplifier.

Since variations in the output amplitude of the mixer are primarily dependent upon variations in the weaker signal entering the mixer, the fixed-frequency signal was made the weakest so that variations in the output of the 2K50 klystron as it swept over its range would have a small effect on the amplitude of the S-band output. In this application the 2K50 klystron acts as a local oscillator and the QK306 klystron acts as an r-f signal. The output of the 2K50 klystron is fed directly into the mixer and is intentionally maintained at its maximum power to secure a nearly constant conversion efficiency although relatively large variations may occur in the local oscillator power as it sweeps (1). This procedure also permits a greater output from the mixer because the fixed-frequency signal can be set at a high level while still maintaining a satisfactory ratio of local oscillator power to signal power. Unfortunately, this ratio also results in a higher noise figure, but this is outweighed by the advantages of maintaining a constant and greater mixer output power over the band.

The power from the 2K50 klystron in conjunction with the smaller power from the QK306 causes a crystal current of approximately 4 ma. However, no crystal failures have occurred to date as a result of the relatively large crystal current flowing. A block diagram of the system is shown in Figure 1.

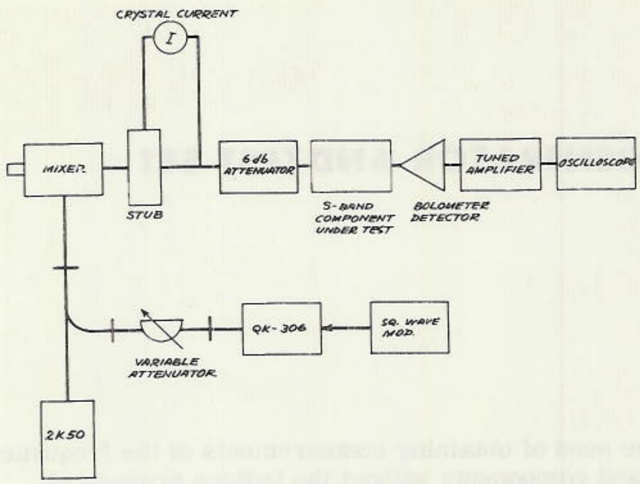

Figure 1 - Block diagram of S-band sweep generator and test set

WAVEGUIDE CIRCUITRY

A variable attenuator in the output circuit of the QK306 klystron serves to control the output of the mixer. This is a commercial flap-type attenuator using a resistance card disc as the absorbing element.

The mixer, a crossbar type, uses a 1N26 crystal. The Sylvania crystal is preferable to the Western Electric crystal for this application since it results in a more constant output over the frequency range covered. The crystals may be readily interchanged, and although a means is provided for varying the insertion of the crystal for tuning purposes, this adjustment is not critical and different crystals have given almost identical responses. A diagram of the mixer is shown in Figure 2.

The directional coupler, built to couple the 20,900-Mc signal to the mixer, is a simple double-slot coupler with quarter-wave-slot spacing (2). It was designed to have a coupling coefficient of 9 db.

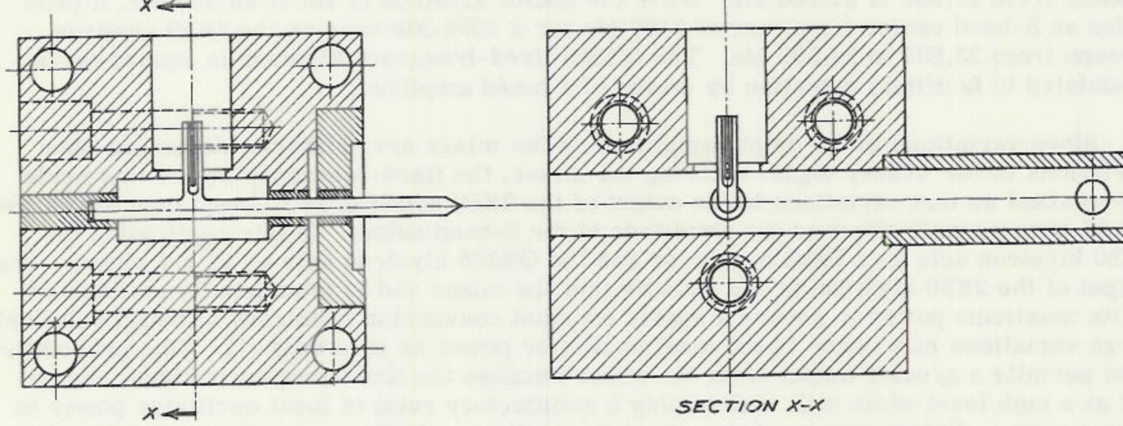

Figure 2 - K-band mixer

COAXIAL CIRCUITRY

A type-N connector on the mixer output couples to a broadband coaxial stub support which provides a return for the crystal current and may be used in monitoring the current (3). A series capacitance, introduced into the coaxial line at the stub output, was made by insulating with clear shellac varnish the portion of the center conductor that was inserted in the stub section. The distance that the center conductor fits into the stub was made a quarter wave at the center i-f frequency so that it presents an effective short circuit to the center conductor at the input. The capacity of this section is about 20 $\mu\mu f$ as indicated on a capacity bridge. This section has a negligible effect on the i-f signal but it prevents the crystal current meter from being short circuited if the system should be operating into an i-f termination which is a dc short circuit.

A 6-db metallized-glass attenuator is placed between the stub and the output terminal so that the output impedance of the mixer remains fairly constant and reflections reaching the mixer from the load are negligible in normal operation.

Silicon crystals at microwave frequencies are much more frequency sensitive than bolometers and are also less uniform in their characteristics (2). For these reasons it was decided to use a bolometer as the detector of the S-band sweep although its sensitivity is much less. To avoid the use of dc amplifiers and the drift problems of bridges, the output of the QK-306 is square-wave modulated by a symmetrical multivibrator. The demodulation component of the bolometer bias current is then amplified with a conventional tuned amplifier. The only type of bolometer immediately available was the Sperry type 821 which is a low power bolometer usually operated at a resistance of 200 to 250 ohms. To match the bolometer to the 50-ohm line a broadband transformer, consisting of 4 quarter-wave sections, was designed as a part of the bolometer mount (3,4). The complete mount is shown in Figure 3. The inductive post between the transformer section and bolometer is necessary for matching and also provides a return for the bolometer dc bias current. This bolometer mount has a VSWR of 2 or better over a 1000-Mc band centered at 3100 Mc, when the bolometer is operated at a resistance of 200 to 250 ohms. The bias current is adjustable to provide an optimum match for the 1000-Mc band. The mount is of sturdy construction and is designed so that the bolometer may be easily and quickly replaced if necessary.

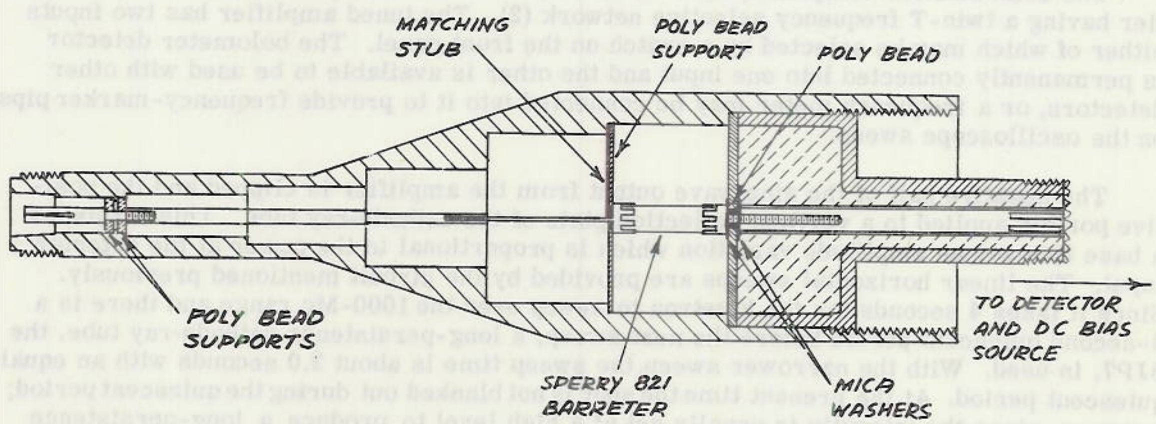

Figure 3 - Broadband bolometer mount

THERMAL TUNING AND SWEEP CIRCUITS

It is desirable that the frequency-vs-time relationship of the klystron sweep be as linear as possible so that the frequency response as shown on an oscilloscope will have a linear frequency base. Tests made on a 2K50 klystron indicated that the variation of frequency with time was not linear when a square pulse of voltage was applied to the thermal grid causing it to sweep (Figure 4). The change of frequency with time when the klystron is sweeping from a lower to a higher frequency does not correspond to the change when sweeping back from the higher to the lower frequency. This fact is apparently due to unequal rates of heating and cooling of the frequency-determining element in the 2K50 klystron. In this test set, only the sweep from the lower to upper frequency is used. Over an observed range of 1000 Mc, Curve A (Figure 5) was obtained at the i-f frequency when the 2K50 thermal tuning grid was pulsed with a -13-volt square pulse of 5-second duration. By slowing down the rise time of the pulse by integration it was possible to obtain a nearly linear variation of frequency with time covering 1000 Mc in 4 seconds (Figure 5, Curve B).

To maintain the output of the 2K50 klystron at the optimum power level during the 1000-Mc sweep, the klystron reflector voltage is also swept so that the output power is at a maximum during the entire sweep. The same circuit that furnishes the pulse for the thermal tuning furnishes this reflector sweep and also provides a linear sweep for the oscilloscope. The circuit used to provide the necessary wave forms is a free running, double screen-coupled phantastron (Figure 6).

Two sweep ranges are provided, one of which sweeps over a full 1000-Mc range centered at 3100 Mc and another which provides a narrower sweep whose center frequency is continuously variable and can be set at any frequency within a 1200-Mc band by means of a single control. The range has been increased on these narrower sweeps so that it is possible to cover a region from 2600 to 3800 Mc. The frequency sweep width varies from about 175 Mc at the lower end of the range to 100 Mc at the upper end around 3700 Mc. The narrower sweep is particularly useful for observing narrow-band components and portions of broadband components.

AMPLIFIER AND OSCILLOSCOPE PRESENTATION

The demodulation component of the bolometer current is amplified with a tuned amplifier having a twin-T frequency selective network (2). The tuned amplifier has two inputs either of which may be selected by a switch on the front panel. The bolometer detector is permanently connected into one input and the other is available to be used with other detectors, or a frequency meter may be connected into it to provide frequency-marker pips on the oscilloscope sweep.

The negative half of the sine wave output from the amplifier is clipped and the positive portion applied to a vertical deflection plate of the cathode-ray tube. This furnishes a base line and an amplitude variation which is proportional to the power at the detector input. The linear horizontal sweeps are provided by the circuit mentioned previously. Since it takes 4 seconds for the klystron to sweep over the 1000-Mc range and there is a 4-second quiescent period before the next sweep, a long-persistence cathode-ray tube, the 5JP7, is used. With the narrower sweep, the sweep time is about 2.0 seconds with an equal quiescent period. At the present time the spot is not blanked out during the quiescent period; however, since the intensity is usually set at a high level to produce a long-persistence trace, this spot should be blanked out to avoid damage to the tube phosphor. A circuit can readily be built to provide the necessary blanking using one of the square pulses available at the screen or suppressor grids of the phantastron tubes. (This circuit will be included in the final unit.) A maximum vertical deflection of 1.5 inches on the cathode-ray tube may be obtained before the amplifier circuits begin to limit the output.

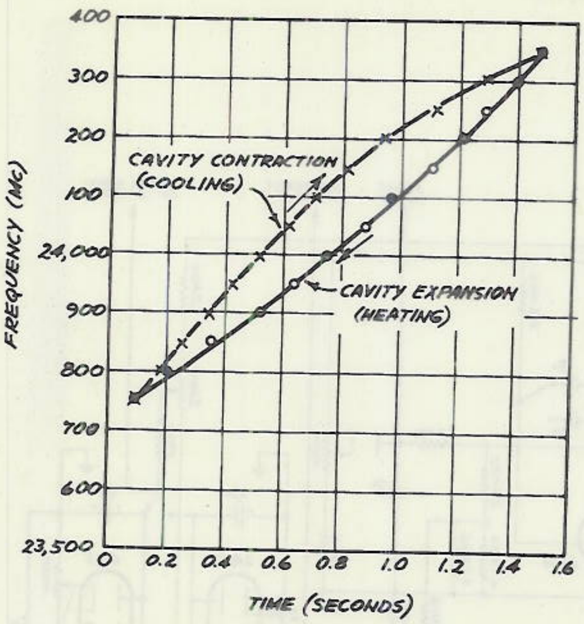

Figure 4 - Thermal tuning characteristics of a 2K50 klystron NP-975. Thermal grid voltage changed instantaneously from 0 to -16.5 volts and back to 0 after 1.7 sec; V_R equals -52 volts; sweep length equals 1.7 sec (3.84 in.)

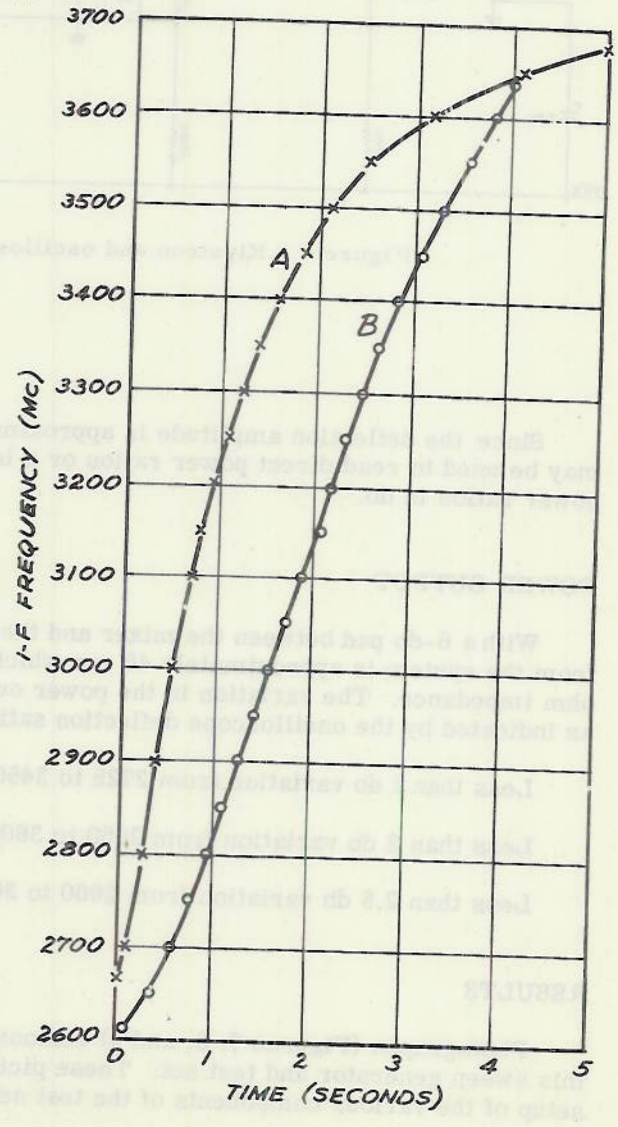

Figure 5 - Thermal tuning characteristics of a 2K50 klystron after mixing with a frequency of 20,900 Mc. Curve A: Thermal tuning grid pulsed with -13-volt square wave of 5-second duration. Curve B: Thermal tuning grid pulsed with -14.5-volt integrated square wave of 4-second duration

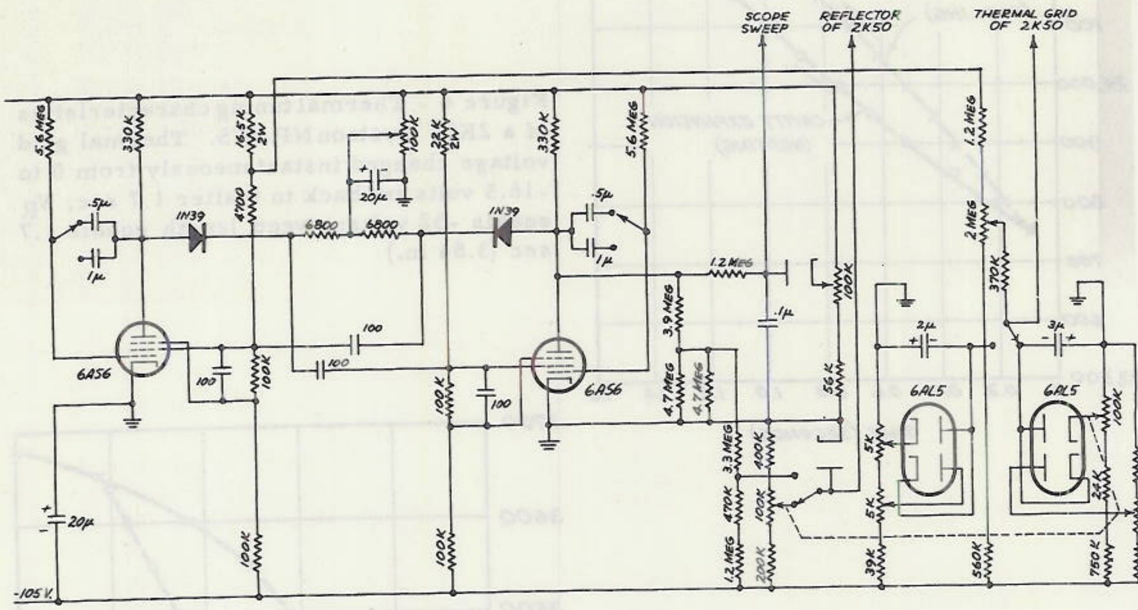

Figure 6 - Klystron and oscilloscope sweep circuit diagram

Since the deflection amplitude is approximately proportional to power, a linear scale may be used to read direct power ratios or a logarithmic scale may be used to indicate power ratios in db.

POWER OUTPUT

With a 6-db pad between the mixer and the output the maximum S-band power output from the system is approximately 40 mw which results in a voltage of 45 mv across a 50-ohm impedance. The variation in the power output of the system over the 1000-Mc range as indicated by the oscilloscope deflection satisfies the following specifications:

Less than 1 db variation from 2725 to 3450 Mc,

Less than 2 db variation from 2660 to 3600 Mc,

Less than 2.5 db variation from 2600 to 3600 Mc.

RESULTS

Photographs (Figures 7, 8, and 9) demonstrate the performance and capabilities of this sweep generator and test set. These pictures were taken with a laboratory bench setup of the various components of the test set designed and described above.

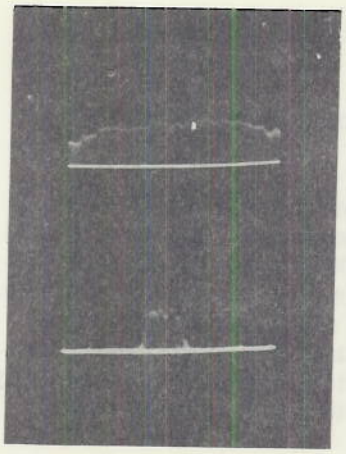

Figure 7 - Transmission characteristics of a wide band-pass filter

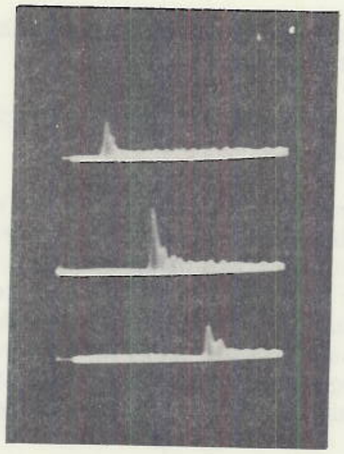

Figure 8 - Transmission characteristics of a tuned crystal detector

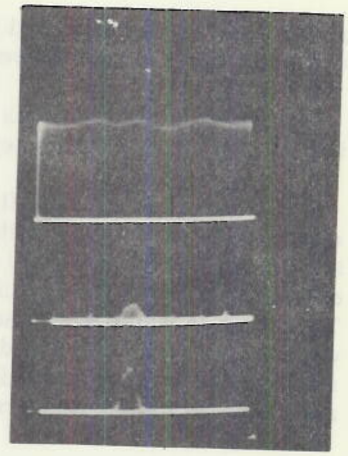

Figure 9 - Transmission characteristics of a narrow band-pass filter

Figure 7, Trace A, is a view of the 1000-Mc sweep. The variations in power output described above are shown here. In Figure 7, Trace B, a waveguide filter (with its transition end connections) has been inserted in the test setup. This filter has a measured band pass of 220 Mc with a center frequency of 3125 Mc. Trace B also shows frequency markers every 100 Mc from 2600 to 3600 Mc, accomplished by inserting a transmission-type frequency meter in the test setup.

In Figure 8 a coaxial tuned crystal detector inserted in the test setup is tuned to 2800 Mc in Trace A, about 3050 Mc in Trace B, and about 3300 Mc in Trace C. These three pictures were made with the 1000-Mc sweep.

Trace A, Figure 9, shows the response from the narrowband sweep centered at about 3125 Mc; at this point the sweep is about 175 Mc wide. Trace B, Figure 9, shows the response of a 23-Mc band-pass filter with frequency markers placed every 25 Mc along the sweep from about 3050 to 3200 Mc. Trace C, Figure 9, shows the response of the same filter inserted in the test setup with a larger amplitude signal from the sweep generator.

CONCLUSIONS

A low-power S-band sweep frequency generator and detector has been built which provides a visual representation of the frequency response of S-band components on a long-persistence cathode-ray tube. With this unit and an external frequency meter, bandwidths may be measured with an accuracy of a few percent and tunable components may be easily tuned by direct observation of their insertion loss or impedance match over a wide bandwidth.

The flatness of the detector output could be improved by as much as 0.5 db at the ends of the 1000-Mc band by using a bolometer mount having a better match at these frequencies. Bolometer mounts which use fine Wollaston wires mounted on a thin mica disc as the absorbing element are now available commercially and better matches are possible because of their lower r-f impedance.

The major cause of the reduced power at the extremities of the 1000-Mc band is due to a decrease in conversion efficiency at the mixer because of a drop-in local oscillator power at the extremities of its sweep. The power output from the 2K50 klystron is lower at the ends of the band and the crystal is not as well matched at these frequencies, thus reducing the effective power at the crystal.

It is expected that this unit will be combined in a single cabinet of moderate size so that it will be a portable test unit.

If it is desired to shift the range of this sweep to the region from 4000 to 5000 Mc, it can readily be done by setting the QK306 klystron at a lower frequency. This tube is tunable from 18,000 to 22,000 Mc, and instead of operating at 20,900 Mc to give a center frequency of 3100 Mc, it could then be set at 19,500 Mc to give a center frequency of 4500 Mc. This change would also necessitate the replacement of the stub in the mixer output for crystal current return and the use of a different bolometer mount. Broadband stubs can readily be designed for this frequency region and broadband bolometers are commercially available so no serious problems should be presented in going to this frequency range.

ACKNOWLEDGMENTS

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