Tunable Cavity for X-Band Oscillators

Rectangular waveguide tuner for external cavity reflex klystrons has generous clearances between moving parts. Cavity plunger and repeller voltage potentiometer are ganged for single-knob tuning over operating range of 8,500 to 9,600 mc

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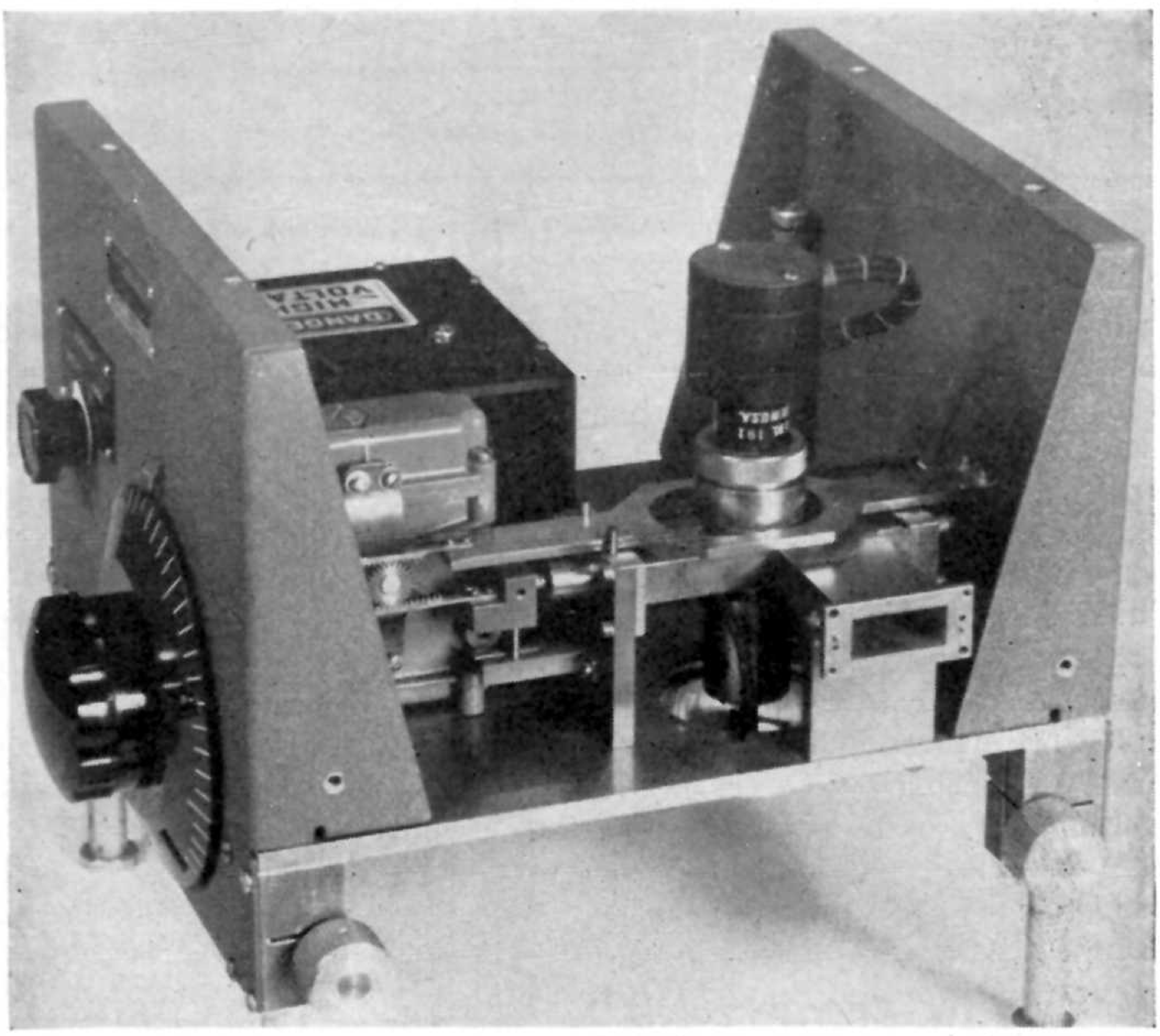

Commercial model of oscillator using waveguide tuner has push-pull rack drive, spring-loaded to reduce backlash

NEED HAS EXISTED, for some time, for an X-band oscillator with single-knob frequency control and accurate calibration. These features have been realized by the application of a newly developed waveguide tuner for external-cavity reflex klystrons. The tuner eliminates the need for sliding contacts in regions of high r-f intensity and is of simple, yet rugged, construction.

Tube

A reflex-klystron tube was desired in the oscillator design because of its relatively simple requirement of only one tuning cavity and its adequate power output. The RK-5721 shown in Fig. 1A was designed for the 4 to 8-kmc range, but it has been found to give useful power to at least 10 kmc.

The grids of the tube are operated at d-c ground potential and the cathode structure at a negative potential of 1,000 volts. The electron stream passes through the interaction gap, after which it is turned around by a repeller electrode operated negatively with respect to the cathode.

Figure 1B shows the role of the repeller voltage for oscillation. The conditions where oscillation may occur are shown as lines. Actually, the lines are bands, indicating some latitude for adjustment.

It can be seen from Fig. 1B that at one frequency the conditions for oscillation are met for any of several values of repeller voltage (vertical dotted line). Also, for one value of repeller voltage, the conditions for oscillation are provided at many frequencies (horizontal dotted line).

The cavity provides a resonant circuit coupled to the tube, which permits r-f oscillation to be sustained. This condition is met when the cavity is short-circuited an odd number of quarter waves from the tube. A voltage loop then appears at the interaction gap, the proper condition for coupling. The proper values of repeller voltage and cavity length must be met simultaneously for oscillation to occur.

Two more features are required of the cavity. First, the cavity must not introduce any incidental, loosely coupled, low-loss resonances into the circuit; otherwise, irregularities in tuning or sharp dips in power output may occur. Secondly, the cavity must resonate at only one of the many frequencies at which the repeller will permit the tube to oscillate. This latter requirement is particularly difficult, as the resonant frequencies of a cavity are not too far separated.

A convenient method of observing compliance with this latter requirement is to construct an operating mode chart, as in Fig. 1C. This

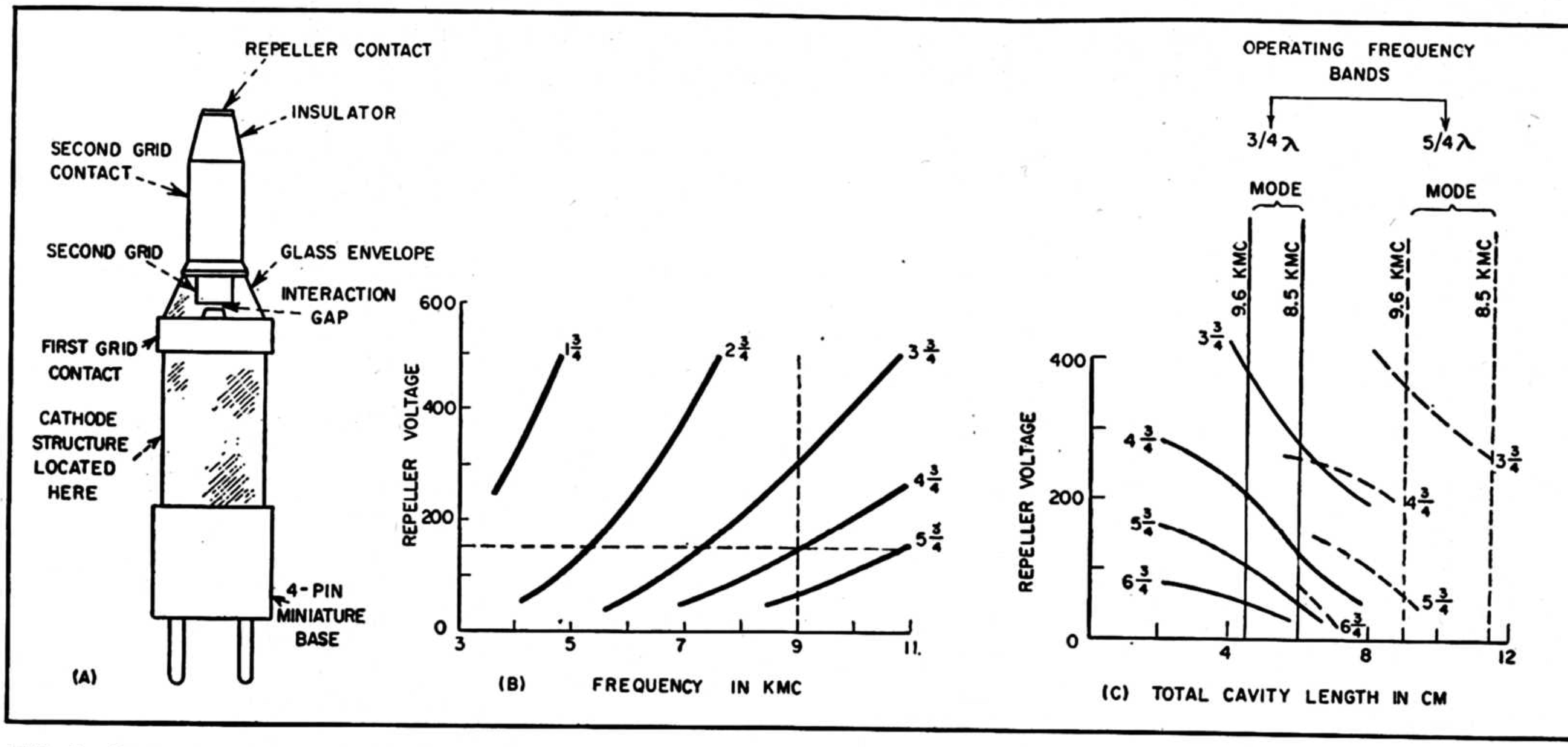

FIG. 1—Outline drawing of Raytheon RK-5721 reflex klystron (A) and repeller characteristics (B, C). Repeller voltages are shown as volts below cathode voltage

chart shows the two frequency-determining variables, repeller voltage and cavity length. Oscillation is represented by a family of lines. The solid lines indicate oscillation for a $\frac{3}{4}$-λ cavity in the various repeller modes and the dashed lines indicate oscillation as a $5/4$-λ cavity in the various repeller modes. Other cavity modes could be constructed.

The interference-free region is readily indicated by the absence of crossing or closely adjacent lines. For example, the $\frac{3}{4}$-λ cavity mode and the $4\frac{3}{4}$-cycle repeller mode (heavy line) are free from spurious oscillations over the required frequency band. A check of power output in the selected mode is also necessary to test its level and uniformity.

Cavity

In designing the cavity, two designs were explored, a coaxial line and a rectangular-waveguide cavity. The coaxial-line cavity was of usual design but the high frequency of operation imposed several problems. The most troublesome of these was mechanical. For a noncontact tuning plunger, the clearance gaps must be small and the center conductor accurately aligned within the outer conductor. When the clearance between conductors was made large enough to reduce this problem, trouble was encountered with higher modes.

In the waveguide cavity the absence of an inner conductor greatly simplified design of the tuning plunger and enabled specification of larger mechanical tolerances.

Simplified cross-sectional views of the oscillator are shown in Fig. 2. The tube is placed across the wide faces of a section of rectangular waveguide. The first grid ring is connected firmly to the cavity by a collet-type clamp. The second grid ring is connected to the cavity by a choked r-f coupling and a set of spring fingers for d-c paths. Since this grid ring can be only lightly clamped without danger of breaking the tube, the choke is employed to enable the contact fingers to be located at a low-current point.

The tuned choke, which incorporates a block of powdered-iron absorbing material, narrows the band of possible oscillation so that the oscillator may not operate in spurious modes far removed from the desired frequency band. This is one reason for showing only two cavity modes in Fig. 1C.

Connection to the repeller lead is by a banana plug at the top of the tube.

The tuning plungers are located

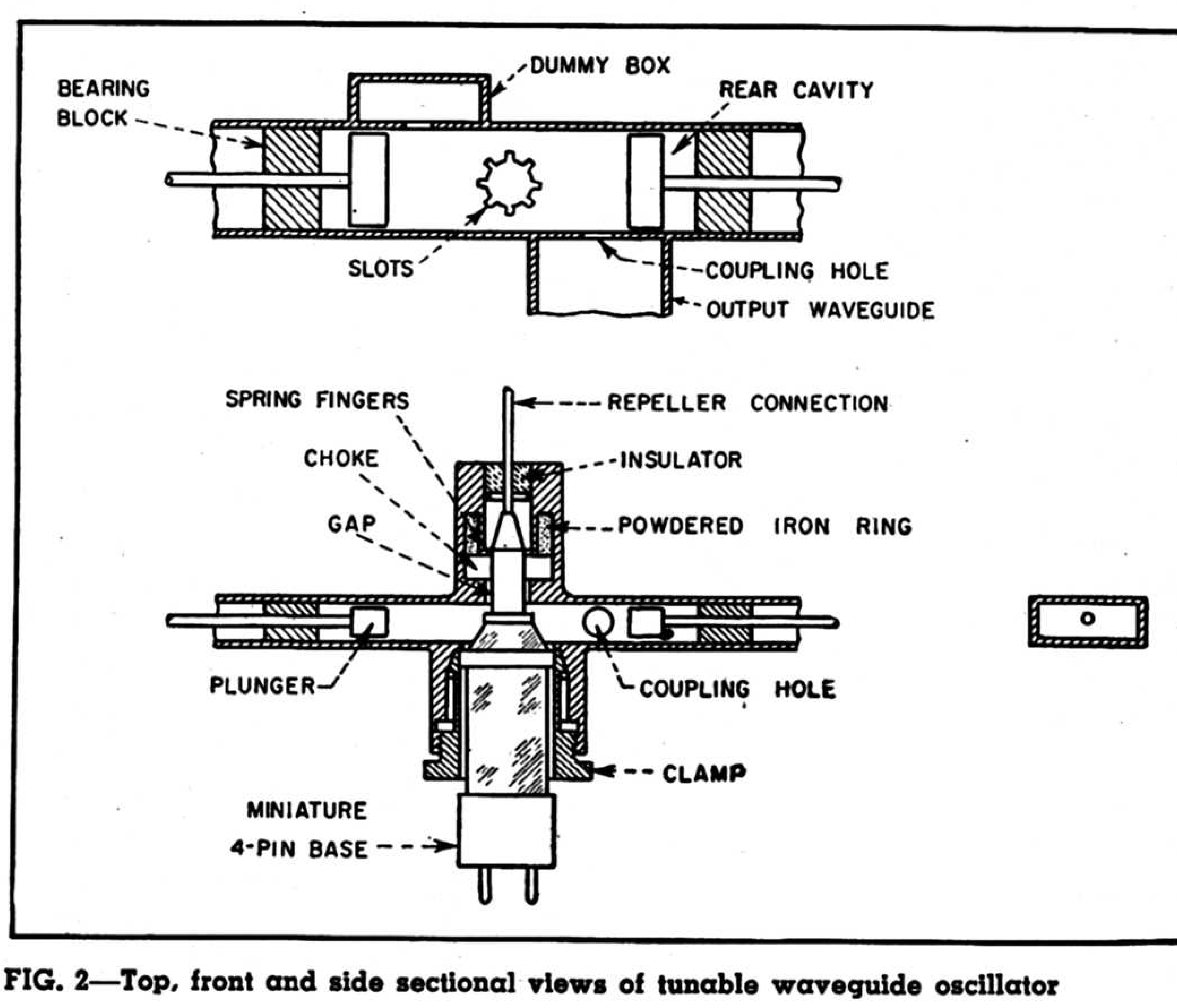

FIG. 2—Top, front and side sectional views of tunable waveguide oscillator

effectively $\frac{3}{4}$ wavelength in the guide from the tube, making the cavity effectively $1\frac{1}{2}$ wavelengths long. The plungers are solid blocks, $\frac{1}{4}$ wavelength long.

The oscillator is coupled to the output waveguide by a hole in the side wall of the cavity, located $\frac{1}{4}$ wavelength in front of the mid-position of the plunger. A second hole on the other side of the tube is incorporated to maintain symmetry. This port may be used for a second output; otherwise, it is shielded by an antiresonant box.

Resonance Elimination

For smooth, continuous operation the cavity must be free from incidental, loosely coupled undamped

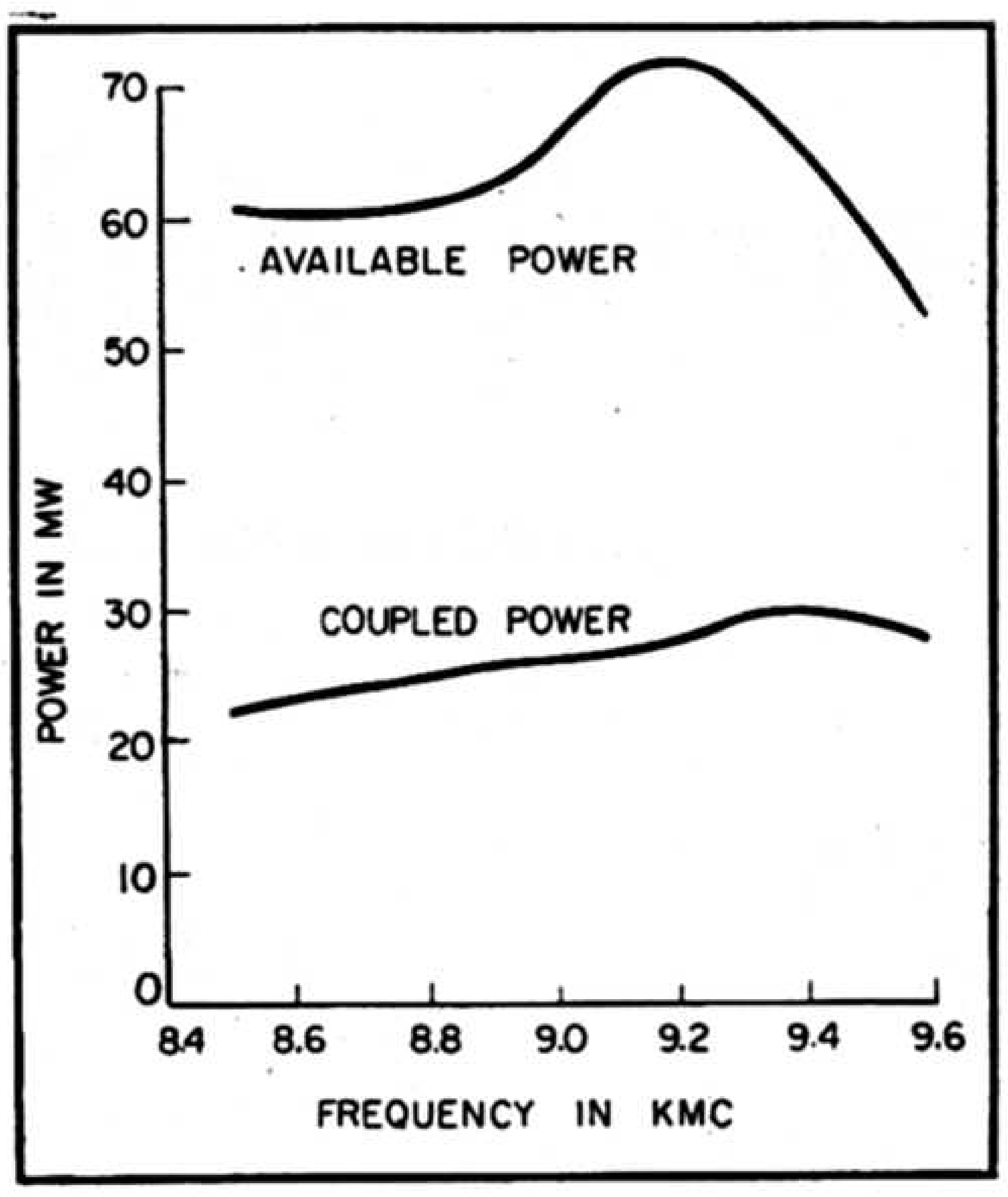

FIG. 3—Typical power output characteristic for tunable cavity oscillator

resonances. Theory and experiment disclosed four such resonances in the oscillator.

The first resonance occurs in the choke coupling to the second grid ring. Here, a thin circular gap exists which is 1 wavelength in circumference in the band. This resonance was moved below the band by slots, which effectively increase the circumference.

A second resonance occurs in the thin gap between the tuning plungers and the cavity walls. The perimeter of this gap is 2 wavelengths in the band. Here, too, the resonance was moved below the band by slots.

A third resonance could occur in the region behind the tuning plungers (the rear cavity). This space is intentionally lossless so that a simple block plunger may be used. The limited tuning range, however, permits the choice of an antiresonant length of the rear cavity at midband with assurance that no resonance occurs in the band.

Finally there is a resonance caused by tube loading. The loading is such that, for oscillation to occur, the plungers must physically be $\frac{1}{2}$ wavelength from the tube; although they are still effectively $\frac{3}{4}$ wavelength away. In the symmetrical-waveguide tuner, this means that the two plungers would be 1 wavelength apart. The cavity can now support a new mode which is uncoupled to the tube except by slight asymmetries. This mode is damped by the output coupling, but not sufficiently to prevent its causing a hole in power output. In the cavity chosen, this resonance is at 10 kmc and has no effect in the desired frequency band.

Model Oscillator

An oscillator embodying the principles described is shown in the photograph. This model has a push-pull rack drive, which is spring loaded to reduce backlash. The push-pull drive reduces the effect of bearing backlash in that only the angle of the pinion is important—not its inadvertent lateral motion. The cavity is driven by a National PW-O dial and gear box to provide an expanded scale with approximately 6-mc divisions. A potentiometer voltage control ganged to the cavity drive provides proper repeller voltage at every frequency. The voltage control and its adjustments are located in the Bakelite box behind the gear box. Tuning is resettable to within about 5 mc and free from sharp variations.

Figure 3 is a plot of the coupled power output and available power output for a typical tube in the band from 8.5 to 9.6 kmc. Coupled power is that power which is delivered to a load matched to the output waveguide. If the impedance of the matched load is adjusted by a tuner, it is possible to obtain more power and even to overload the oscillator until it stops oscillating.

Maximum power obtainable by tuning the load is called the available power. For an average tube, the coupled power is about 20 mw, with a variation of less than ±1 db, from 8.5 to 9.6 kmc.

The oscillation frequency can be changed slightly by varying the repeller voltage. When this is done, however, the power output drops. For oscillators tuned entirely by mechanical means, such as this one, it is desirable for stability to keep this electronic tuning as small as possible.

The electronic tuning range between half-power points is about 8 mc. This is obtained with a variation of about 25 volts on the repeller. The sensitivity to voltage fluctuations is, therefore, 0.3 mc per volt. In contrast, the internally-tuned tube usually used at these frequencies, the 2K25, tunes at least 25 mc between half-power points, or over three times as much.

A natural extension of this oscillator is the addition of a motor drive and sweeping the entire X-band rapidly enough for oscilloscopic presentation.[7]

This oscillator was designed for Bell Telephone Laboratories under a prime contract between Western Electric Company and the Ordnance Corps of the U. S. Department of the Army. It has been used extensively in laboratory test equipment and in factory testing of components. More recently it has been used as the basis for a rapid-sweeping oscillator now being manufactured by Polarad Electronics Corp. from Wheeler Laboratories design information.

The author acknowledges the efforts of H. A. Wheeler, who directed the overall program and D. Dettinger, under whose supervision the work was performed.

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