LB - 816

COAXIAL LINE TRIPLE-TUNED UHF TUNER

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

INDUSTRY SERVICE LABORATORY

RADIO CORPORATION OF AMERICA

RCA LABORATORIES DIVISION

INDUSTRY SERVICE LABORATORY

LB-816

Coaxial Line Triple-Tuned UHF Tuner

Approved

Stuart Wm Seeley

Coaxial Line Triple-Tuned UHF Tuner

Introduction

This bulletin describes an experimental triple-tuned u-h-f preselector which maintains high selectivity, essentially zero insertion loss, and a uniform peak-to-peak bandwidth of 10 Mc over the frequency range of 490 to 760 Mc. Such a preselector can be used as the basis for a u-h-f tuner employing a crystal mixer and a 41-Mc low noise i-f amplifier. It provides image and other spurious-response rejections of the same order of magnitude as those usually obtained in current v-h-f television tuners. The high selectivity and inherent shielding characteristic of the coaxial line elements minimize oscillator radiation problems.

The approach exemplified by this tuner was adopted following unsuccessful efforts to achieve the requisite performance using low-frequency techniques. It was felt that if the desired electrical performance could be achieved without regard for practical manufacturing considerations, the ensuing design problems might be capable of solution. While these design problems have not been evaluated, experience with the unit described here has suggested variations which may be expected to provide similar electrical performance but with less difficult mechanical problems.

Triple-Tuned Preselector

Transmission line tuning elements were selected for this development work because of their simplicity and high Q. Coaxial lines allow maximum shielding and reduce feedthrough difficulties.

One form of transmission line preselector using three tuned coaxial-line elements is shown in Fig. 1. Coupling is provided by inductive loops which are located at critical points to provide constant bandwidth. A simplified diagram and the low-frequency equivalent circuit are shown in Fig. 2.

In order to maintain constant bandwidth, the effective operating Q of the lines and the coupling must be varied as the frequency is changed. Since the percentage desired bandwidth decreases with increasing frequency, the Q's must increase and the coupling decrease. To obtain this variation in Q, inductive links are used to load the input and output lines. As the line becomes shorter, the link is coupled to a lower current region of the line. Also, since the link couples to the magnetic field and this field varies directly as the current in the line, the loading of the line decreases with increasing frequency. For the same reason, the inductive links used for the couplings between transmission lines result in the coefficient of coupling decreasing with increasing frequency.

Fig. 3 shows the current distribution at the two limit frequencies, 500 Mc and 750 Mc. It is clear from this figure that if a coupling loop is placed near the base the coupling tends

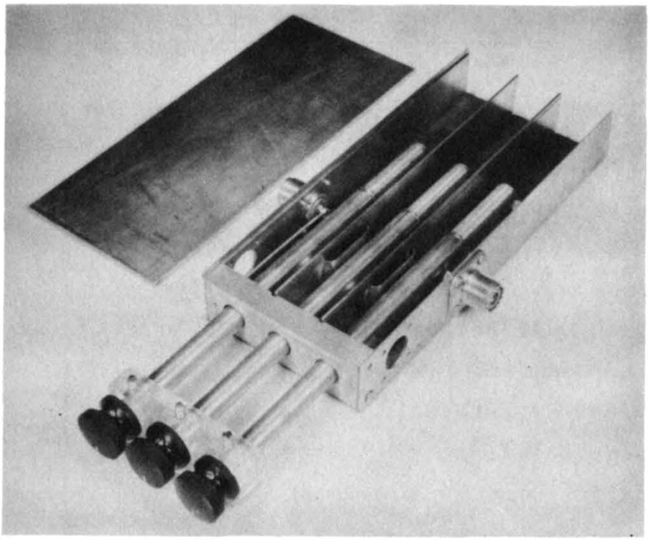

Fig. 1 – Triple-tuned transmission line preselector with 50-ohm input and output impedance. The wire interline couplings may be seen in Fig. 9 in place of the wide copper links which are used in the above unit.

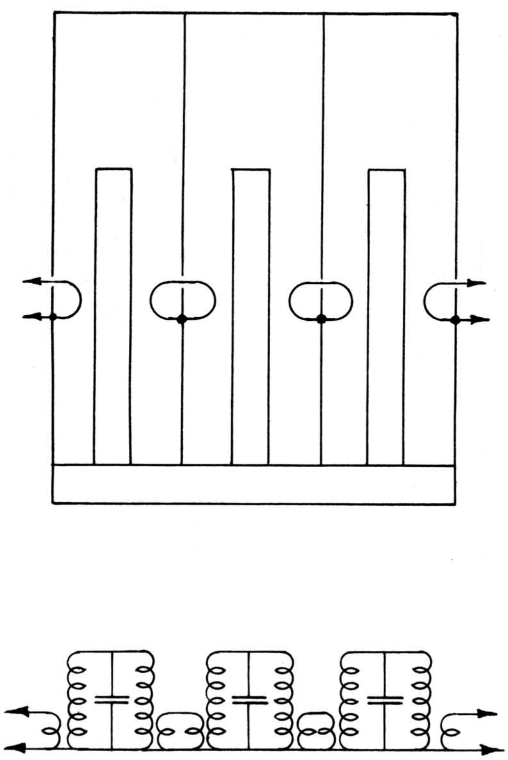

Fig. 2 – The triple-tuned transmission line preselector and its low frequency equivalent.

to remain constant with tuning changes. On the other hand, as the coupling loop is moved toward the open end of the line, a point is reached at a distance d_1 where the currents corresponding to the two limit frequencies are in the same ratio as the frequencies, 750/500 = 1.5. With the coupling loops located at this point, the interline couplings and the loading of the end lines will be such as to provide the same bandwidth at 500 Mc and 750 Mc.

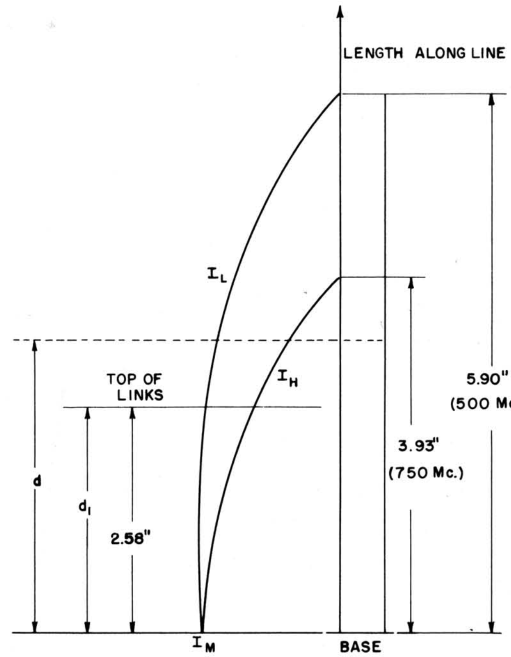

Fig. 3 – Current distribution on transmission line for high and low frequency settings.

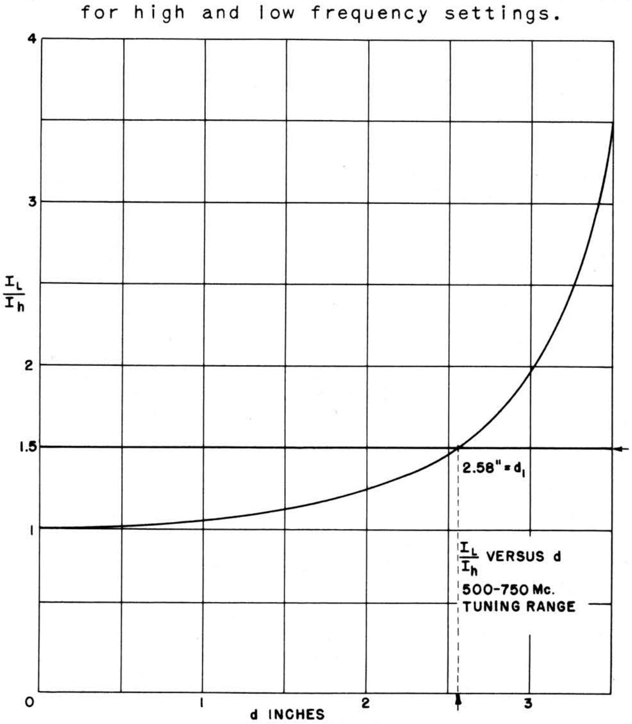

Fig. 4 – Ratio of current at 500 Mc and 750 Mc as a function of distance from the base (current maximum).

The ratio of the currents at the coupling loop points as a function of the distance of the loop from the base (current maximum) is shown in Fig. 4 for the limit frequencies 500 and 750 Mc. For this condition locating the loop 2.58 inches from the base results in the desired current ratio of 750/500 = 1.5.

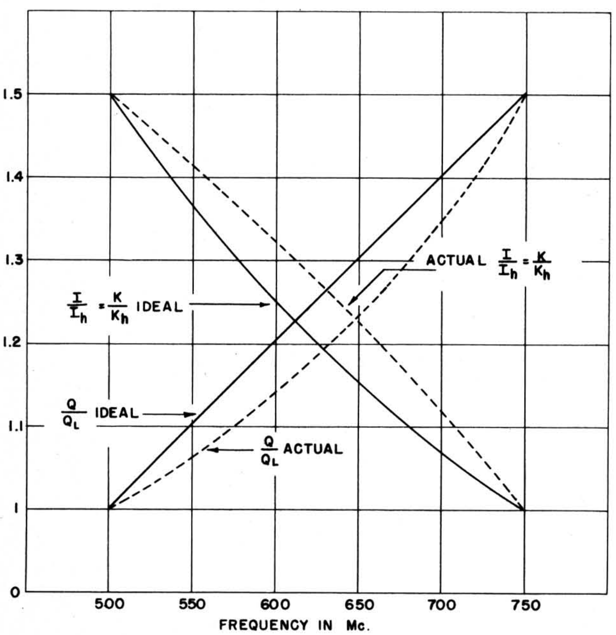

Fig. 5 – Variation of Q and coupling when position of the coupling loop is adjusted for constant bandwidth at the limit frequencies of 500 and 750 Mc.

Placement of the coupling loops at this point insures equal bandwidth at the limit frequencies of the tuning range. The variation in coupling and the resulting change in loading (Q) are shown in Fig. 5. The dotted curves represent the actual variation in these quantities over the band, while the solid curves represent the ideal variation required for maintenance of constant bandwidth over the entire tuning range as well as at the limit frequencies.

If the effect of these variations on the response is calculated, it is found that the peak-to-valley ratio remains constant over the entire band. Calculations also show that a 10-Mc bandwidth should increase by about 0.6 Mc near the center of the range. Similar curves are shown in Figs. 6 and 7 when the frequency range is extended to cover from 500 to 890 Mc. Again the peak-to-valley ratio remains constant over the band and the maximum bandwidth change is from 10 to 11.6 Mc.[1]

[1] Milton Dishal, "Exact Design and Analysis of Double and Triple-Tuned Bandpass Amplifiers" – *Proc. IRE*, June 1947.

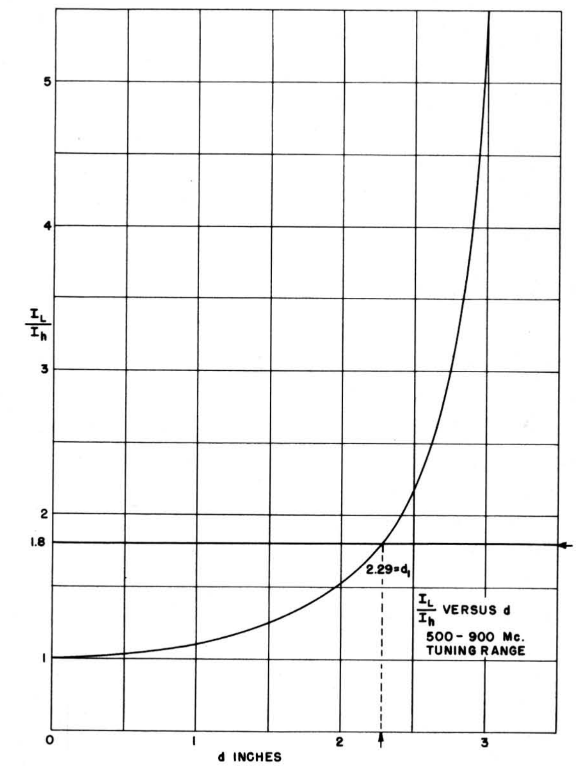

Fig. 6 – Ratio of currents at 500 Mc and 900 Mc as a function of distance from the base (current maximum).

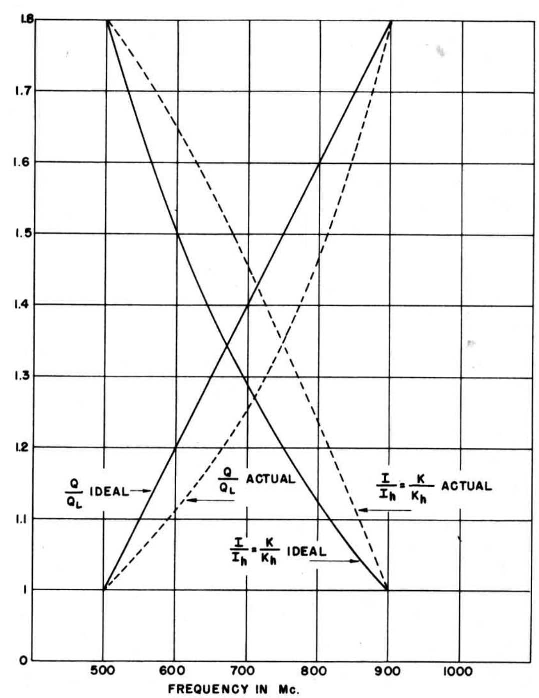

Fig. 7 – Variation of Q and coupling when position of the coupling loop is adjusted for constant bandwidth at the limit frequencies of 500 and 900 Mc.

Initially very small coupling links were placed at the critical point. The bandwidth remained constant but was much too narrow. When the links were made larger symmetrically about the 2.58-inch point, the Q's and the couplings were found to change in a manner which caused an increase in bandwidth with an increase in frequency. However, it was found that if the top ends of the links were set at the critical point, proper Q and coupling were maintained regardless of the position of the lower ends. The final unit contains links which extend to the base or shorted end of the transmission line. To obtain more or less coupling, the links may be moved closer to or farther from the lines. This allows adjustment to any desired bandwidth which then remains essentially constant throughout the tuning range.

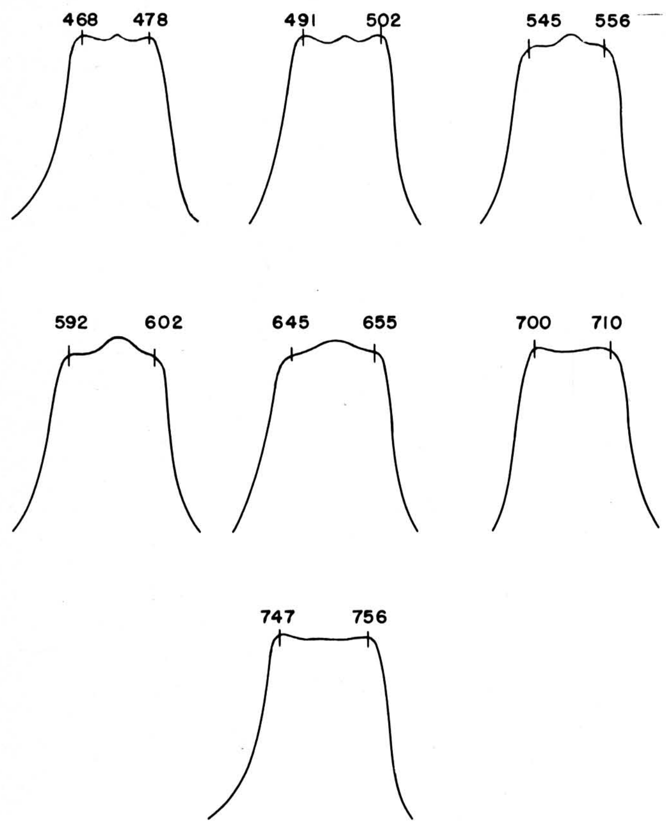

Fig. 8 - Response curves for 50 to 50 ohm preselector shown in Fig. 1

Response curves for a triple-tuned unit having 50-ohm input and output impedances are shown in Fig. 8. At first it was found that the attenuation outside the pass band was less than would be expected on the basis of the calculated behavior of a triple-tuned circuit using lumped constants. The feedthrough which caused this effect was reduced by changing the coupling links between the transmission lines from wide copper strips to longer and narrower loops of No. 14 tinned copper wire. It seems probable that further investigation of the direct feed-through problem can result in even greater skirt selectivity.

The principles described here apply equally well to a preselector using any number of transmission-line elements. Actually, the initial phase of this development employed a double-tuned arrangement otherwise similar to that shown in Fig. 1.

Preselector Construction Details

Mechanical details of a 50-ohm input and output unit may be seen in Fig. 1. The input (antenna) is fed to a link which couples to the first transmission line. This in turn is inductively coupled to the intermediate element and a similar coupling connects it to the third (output) line. Another wire link feeds to an output connector. Each of the inner conductors of the transmission lines consists of two telescoping hollow tubes. In this experimental preselector the outside tube is made of brass and is soldered to a solid brass base which serves as the shorting arm of a quarter-wave tuned circuit. The inside tube, which passes through the base, is made of aluminum to prevent binding which would occur if two similar metals were used. Contact is made between the two tubes at the top of the outside brass tube. The outside section is slotted to form flexible fingers which are pressed against the aluminum tube by means of a piano wire spring. To minimize noise, this contact area is made at the lowest current point permitted by the high-frequency line length.

The insertion loss of this unit measured less than 0.5 db throughout the tuning range at a bandwidth of 10 Mc. At bandwidths less than 5 Mc, the attenuation is somewhat greater. The attenuation for smaller bandwidths could be lowered if the losses were reduced to maintain a higher ratio between the loaded and unloaded Q's.

Incorporating the Triple-Tuned Preselector in a Tuner

In order to incorporate the 50-to-50-ohm preselector in a u-h-f tuner, it was modified as shown in Figs. 9 and 10. The preselector is followed by a crystal mixer, which feeds into a low-noise i-f amplifier. The two i-f stages are mounted close to the preselector.

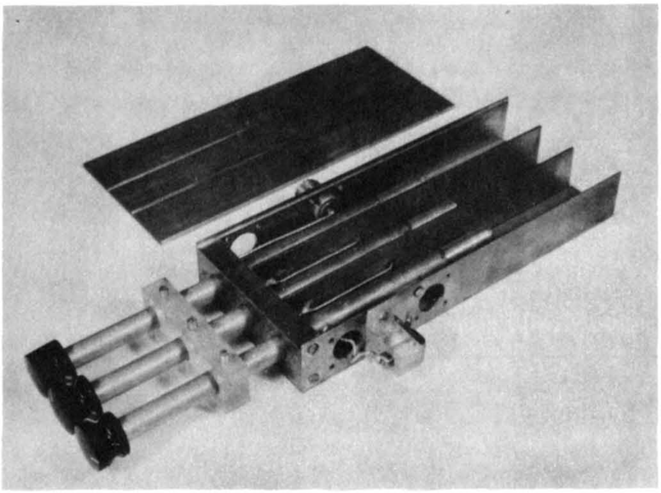

Fig. 9 - Modified preselector with 72-ohm input and crystal holder installed.

Since the objective of this work was to develop a preselector with sufficient selectivity to permit the use of a single conversion circuit with a 41-Mc intermediate frequency, development of a low drift oscillator was subordinated to this end. As an expedient, a signal generator (operating above the signal frequency) was used as the local oscillator source.

To obtain proper loading of the output transmission line similar to that of the 50-ohm output link, a small inductance was connected in series with the crystal mixer circuit and this inductance connected to a point ½ inch from the bottom of the output transmission line. The crystal holder and the side of the preselector case formed the two plates for a low inductance capacitor (12 μμf) used in the mixer load circuit. The input impedance of the preselector was modified to 72 ohms by moving the input coupling link closer to the inner conductor of the line.

The tuner setup from which measurements were taken is shown in Fig. 11, and the schematic in Fig. 12. To minimize direct i-f pickup

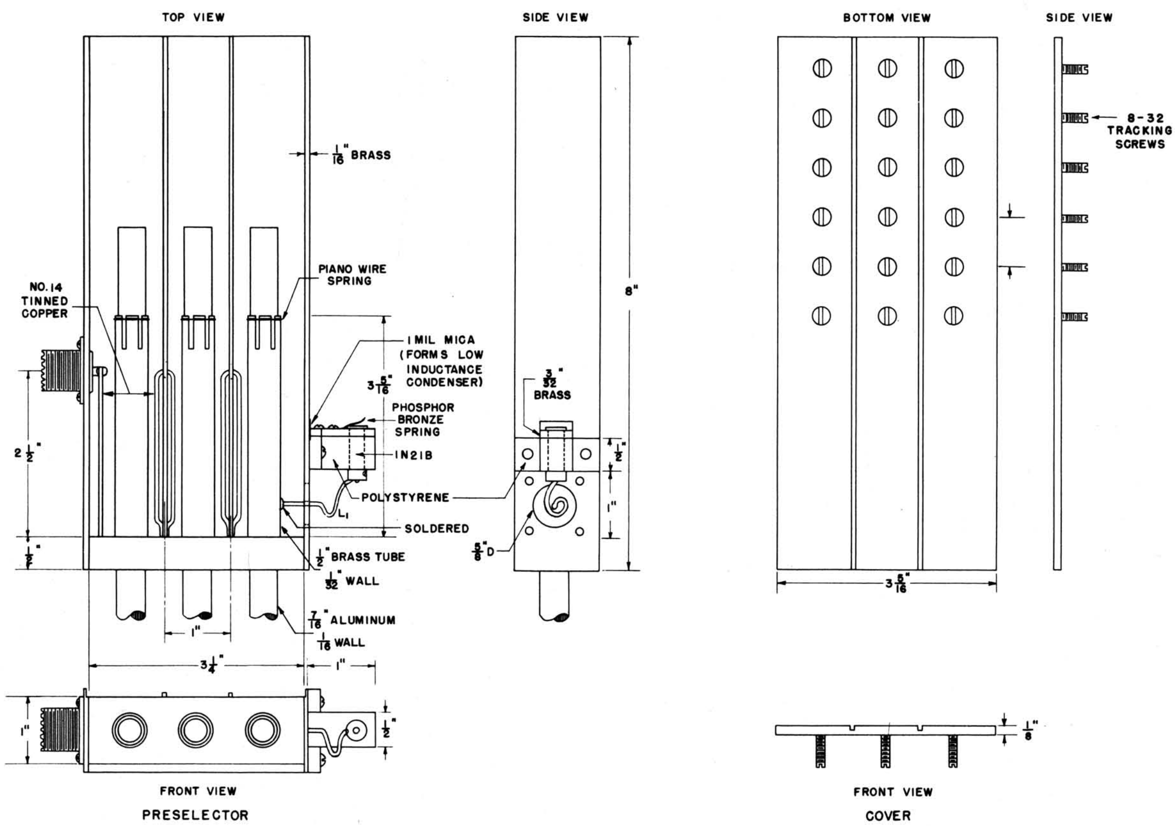

Fig. 10 - Details of preselector with crystal holder and 72-ohm input.

and regeneration, the low-noise i-f preamplifier is mounted near the mixer. The output of this amplifier is link-coupled to the main i-f amplifier by means of a shielded 100-ohm twin-conductor cable. A switch was used to enable measurement of crystal current due to oscillator injection and observation of the r-f bandpass characteristics of the preselector across an 18-ohm resistor connected in series with the first i-f coil.

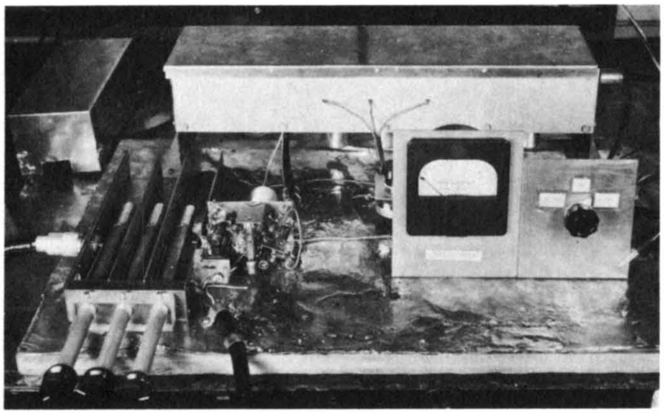

Fig. 11 - Tuner test setup.

The low noise preamplifier uses a 6BQ7 double triode. Although Fig. 12 shows one form of what has been popularly termed a cascode circuit, the 6BQ7 better lends itself to a recently developed simplified direct-coupled circuit which requires fewer components and provides higher gain due to the reduction in interstage capacitance.[2]

Performance of the Tuner

Noise factor and spurious-response rejection are listed in Table I. As noted in Table I the response at all possible single-signal spurious frequencies other than the image was down by at least 70 db. However, it should be pointed out that measurements were confined to the range below 1000 Mc due to limitations of laboratory equipment. The possibility exists that incoming signals whose frequency approximates the third or higher odd harmonic of the desired signal frequency may cause some response. These would be above 1500 Mc.

Table I

PERFORMANCE OF TUNER

Frequency	Noise Factor	Image Rejection
475 Mc	12.0 db	71 db
527	11.0	70
650	13.5	69
755	13.5	66

Other than the image, no single-signal spurious responses greater than -70 db were found in the range below 1000 Mc.

Bandpass curves for the preselector for various frequencies are shown in Fig. 13.

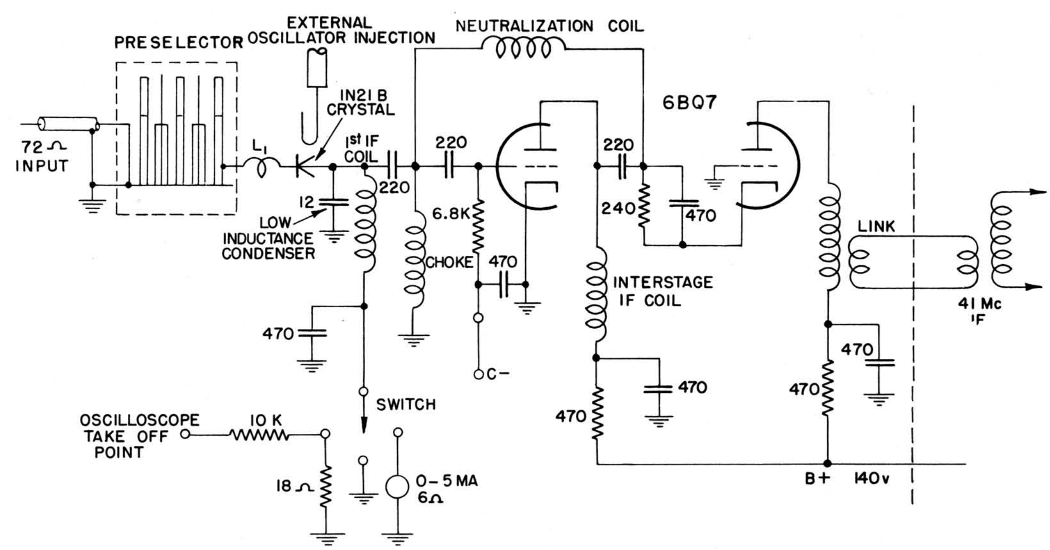

Fig. 12 - Tuner circuit diagram.

[2] "The application of a New Low-Noise Double Triode as an RF and IF Amplifier in Television Receivers" - Robert M. Cohen, Radio Corporation of America - Paper delivered at Syracuse Fall IRE and RTMA Meeting, Oct.31, 1950.

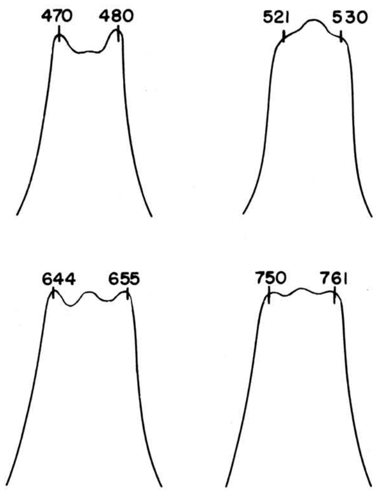

Fig. 13 - Preselector bandpass characteristics of tuner with 1 ma oscillator injection.

Oscillator injection was first adjusted to 1 ma on the meter which indicates rectified crystal current. The output of the u-h-f sweep generator was increased so the meter read 1.1 ma and then the curves were observed across the 18-ohm resistor. Slight variations in the bandpass characteristics were noted with changes in injection as a result of modification of the crystal impedance. These variations are minimized by always providing optimum injection (1 ma or over) and by keeping the sweep generator level low so as to simulate an actual signal through the tuner.

Tracking

The bandpass characteristic curves were taken after the preselector lines were individually aligned. It was noted that the total individual line tracking errors were less than 1/8-inch over the entire range of the tuner. One of the many possible tracking arrangements consists of changing the capacity at the ends of the transmission lines by a series of evenly spaced flat-head screws mounted in the cover. Details of the cover with the tracking screws in place are shown in Figs. 10 and 14. This method was found to be satisfactory.

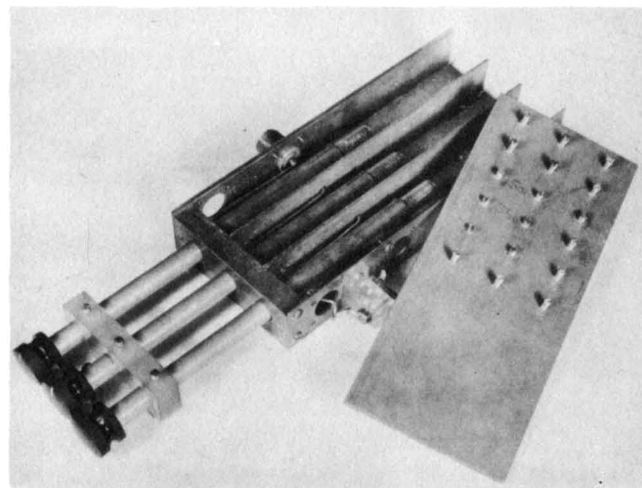

Fig. 14 - Preselector with tracking screws installed on cover.

Murray Braverman