

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) TUNING MEANS

(71) We, RCA CORPORATION, a corporation organized under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, 10020, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to tuners and more especially VHF television tuners, embody tunable resonant circuits adapted for tuning over a wide frequency range by variable capacitors such as variable capacitance diodes.

The bandwidth of a parallel resonant circuit is inversely proportional to the product of its shunt capacitance and resistance, and consequently, when a parallel resonant circuit is tuned by a variable capacitance, it will change its bandwidth inversely with the change in tuning capacitance. For this reason, where a relatively wide frequency range is to be tuned, and economy of the tuning circuits is important, it is common to tune resonant circuits by varying the inductance to maintain a substantially constant bandwidth as the circuit is tuned throughout its frequency range.

The use of variable capacitors such as voltage dependent variable capacitance diodes as the capacitive tuning elements for tuning resonant circuits over wide frequency bands creates problems because the capacitance variation alters the bandwidth of the circuit as noted above. In addition, with voltage dependent variable capacitance devices the resistance of the device may also change with variations of control voltage, aggravating the bandwidth change problem. The range of capacitance available from most voltage responsive capacitance devices is somewhat limited and makes the design of wide band tuners extremely difficult with economically feasible capacitance diodes.

In a tuner wherein RF signals are heterodyned in a mixer stage with locally generated

signals to produce an intermediate frequency signal, the present invention provides an electric circuit comprising an input and an output tunable resonant circuit each adapted to maintain a bandwidth of at least 6 MHz at all its tunable frequencies, each tunable resonant circuit including a first and a second inductor connected in series and a variable capacitor and a third inductor connected to form a tuning circuit coupled between the junction of said first and said second inductor and a point of reference potential; a first transistor having base collector and emitter electrodes and connected to form a common base amplifier with the first and second inductors of said input tunable resonant circuit coupled between a point of application of VHF television signals and the emitter electrode of said first transistor; a second transistor having base, collector and emitter electrodes with the first and second inductors of said output tunable resonant circuit coupled between the collector or emitter electrode of the second transistor and said mixer stage, and a wideband tuned circuit interconnecting the collector electrode of said first transistor and the base electrode of said second transistor.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic circuit diagram of a VHF television tuner embodying the invention:

FIGURE 2a is an equivalent circuit diagram of the tunable circuits of the VHF tuner shown in FIGURE 1;

FIGURE 2b is a schematic circuit diagram with the source, load and interconnecting impedances shown in FIGURE 2a combined into a single circuit branch; and

FIGURE 2c is a schematic circuit diagram with the series impedances shown in Figure 2b converted to the equivalent shunt impedance.

Referring now to FIGURE 1, a tuner includes an RF amplifier stage 52, an oscil-

5 lator stage 54, and a mixer stage 56. The tuner 50 is of the type wherein the RF signals from the amplifier stage 52 and the locally generated signals from the oscillator stage 54 are heterodyned in the mixer stage 56 to produce an IF signal which may be processed by IF signal processing circuits, not shown.

10 RF signals are intercepted by an antenna (not shown) and are coupled to a capacitively tuned circuit 60 through a terminal 62. The circuit includes two serially connected inductors 64 and 66 which interconnect the antenna terminal 62 and IF rejection circuits. An 15 inductor 68 and a tuning capacitor 70, shown as a variable capacitance diode, are connected to the junction 71 of the two inductors 64 and 66. The inductor 68 is connected to a point of reference potential, shown as ground, 20 and the variable capacitance diode 70 is connected to the point of reference potential for radio frequencies by means of a feedthrough capacitor 72.

25 The capacitively tuned circuit 60 has circuit components apportioned so that it will be resonant across a band of frequencies ranging from 216 MHz to 54 MHz with a substantially constant bandwidth. Tuning of the circuit 60 is controlled by the direct voltage 30 applied to the diode 70 via resistor 74. The resistor 74 is connected to a voltage divider circuit 76 which is the source of tuning potential for the diode 70. The divider circuit 76 includes a resistor 77, connected at its ends 35 to a stabilized voltage supply supply 75, and a variable tap 79. The stabilized supply may be designed to develop a voltage of +30 volts and -0.3 volts at two output terminals. The range of voltage required, however, is dependent upon the specific type of variable 40 capacitance diode used.

45 Automatic frequency control for the tunable resonant circuits of the tuner 50 may be provided by a suitable automatic frequency control circuit 73, shown in block diagram form. It is desirable to provide AFC for all the varicap tunable resonant circuits of the tuner 50 to correct detuning of the resonant frequency of the circuits due to diode capacitance variations, as, for example, with temperature change. Changes in the voltage 50 applied to the diode 70 are effected by the AFC circuit to maintain the intermediate frequency signal from the mixer 56 at the desired frequency. The DC circuit loop for the diode 70, beginning at a point of reference potential, passes through the AFC circuit 73, the stabilized voltage supply 75, the divider circuit 76, and the resistor 74 to the cathode 55 of the diode 70. The DC loop is completed through the inductor 68 which interconnects the anode of the diode 70 and the point of reference potential.

60 The inductor 66 is coupled to the RF amplifier stage 52 by an IF rejection circuit. In-

cluded in the IF rejection circuit are the series combination of two parallel resonant circuits 78 and 80. The inductor and capacitor associated with each of the circuits 78 and 80 is apportioned to be resonant at television intermediate frequencies. A capacitor 82 is connected in series with the inductors associated with the IF rejection circuits 78 and 80 to prevent any DC from the diode 70 control circuit from flowing through the 75 inductors of the IF rejection circuits into the RF amplifier stage 52. At frequencies higher than IF, the series connected capacitors of the IF rejection circuits 78 and 80 in association with the inductor 81 act as a high pass filter. 80

The RF amplifier stage 52 includes two transistor amplifiers 84 and 86. Transistor 84 is connected in the common base configuration, having its base electrode connected to 85 the point of reference potential for radio frequencies by means of a feedthrough capacitor 88. An automatic gain control voltage (AGC) is applied to the base electrode of the transistor 84 via resistor 90. The emitter electrode of the transistor 84 is connected to the 90 IF rejection circuit 80, and to the point of reference potential through the series circuit including the inductor associated with the IF rejection circuit 80, the inductor 81, and a bias resistor 94. The bias resistor 94 is bypassed for radio signal frequencies by a feedthrough capacitor 96. 95

The collector electrode of the transistor 84 is coupled to the base electrode of the transistor 86 by a high frequency peaking network. 100 Included in the network are the parallel combination of a resistor 98 and an inductor 100, interconnecting the collector electrode of the transistor 84 and the base electrode of the transistor 86. The series combination of a resistor 102, an inductor 104, and a resistor 108, interconnect the base electrode of the transistor 86 and a terminal 110. The terminal 110 is adapted to be energized by a source 105 of operating potential for the tuner. The resistor 108 is bypassed to the point of reference potential for radio frequencies by the feedthrough capacitor 112.

115 The amplified RF signals from the amplifier stage 52 are developed across a load resistor 114 coupled between the collector electrode of the transistor 86 and the point of reference potential. The emitter electrode of the transistor 86 is connected by a resistor 120 120 116 to the source of operating potential applied at the terminal 110. The resistor 116 is bypassed to the point of reference potential for radio frequencies by a feedthrough capacitor 118. 125

A capacitively tuned circuit 120 is coupled to the collector electrode of the transistor 86. The circuit includes two serially connected inductors 122 and 124 which interconnect the collector electrode of the transistor 86 130

and the mixer stage 56. An inductor 126 and a tuning capacitor 128, shown as a variable capacitance diode, are connected to the junction 130 of the two inductors 122 and 124. The inductor 126 is connected to the point of reference potential, and the variable capacitance diode 128 is connected to the point of reference potential for radio frequencies by means of a feedthrough capacitor 132.

- 10 As in the case with the capacitively tuned circuit 60, the capacitively tuned circuit 120 has circuit components apportioned so that it will resonate across a band of frequencies ranging from 216 MHz to 54 MHz with a
15 substantially constant bandwidth. Tuning of the circuit 120 is controlled by the direct voltage applied to the diode 128 via resistor 134. The resistor 134 is connected to a voltage divider circuit 76 which is the source of tuning potential for the diode 128. The D.C. circuit loop for the diode 128, beginning at
20 the point of reference potential, passes through the AFC circuit 73, the stabilized voltage supply 75, the divider circuit 76, and the resistor 134 to the cathode of the diode 128. The DC loop is completed through the inductor 126 which interconnects the anode of the diode 128 and the point of reference potential.

- The local oscillator stage 54 includes a
30 transistor 136 which has a capacitively tunable resonant circuit connected to its collector electrode. Included in the resonant circuit are an inductor 138 with a tap connection 140, a capacitor 142, a variable capacitance diode 144 and a trimmer capacitor 146. Two
35 capacitors 148 and 150 are serially connected between the inductor tap 140 and the point of reference potential. The junction of the capacitors 148 and 150 is connected to the emitter electrode of the transistor 136. The capacitor 148 provides a regenerative feed-back path between the oscillator tank circuit and the emitter electrode of the transistor. The voltage developed at the tap
40 connection 140 is divided down by the voltage divider effect of the capacitors 148 and 150.

- A resistor 152 interconnects the cathode of the diode 144 and the source of tuning potential 76. The DC circuit loop for the diode 144, beginning at the point of reference potential, passes through the AFC circuit 73, the stabilized voltage supply 75, the divider circuit 76, and the resistor 152 to the cathode
50 of the diode 144. A lossy choke, shown as a resistor 154 and an inductor 156, complete the DC loop by interconnecting the anode of the diode 144 and the point of reference potential.

- 60 DC bias for the oscillator transistor 136 is obtained from a source of operating potential connected to a terminal 158. The source of operating potential may be the same as that employed to energize the terminal 110. The
65 base electrode of the transistor 136 is con-

nected to the source of operating potential through a voltage dividing network including the resistors 160 and 162 connected between the terminal 110 and the point of reference potential. A resistor 164 interconnects the
70 emitter electrode of the transistor 136 and the point of reference potential. The collector electrode of the transistor 136 is connected to the source of operating potential by the inductor 138. Several feedthrough capacitors
75 166 bypass radio frequency signals to the point of reference potential thereby completing the radio frequency paths in the oscillator circuit.

An injection circuit interconnects the mixer stage 56 and the oscillator stage 54. Specifically, the injection circuit includes a capacitor 168 and an inductor 170 serially connected between the emitter electrode of the transistor 136 and inductor 124 of the capacitively
80 tuned RF circuit 120.

Both the RF signals and the locally generated signals are coupled to the emitter electrode of a transistor 172 in the mixer stage 56 by a coupling capacitor 174. A bias resistor 176 is connected in parallel with the coupling capacitor 174. The RF signals and the locally generated signals are heterodyned in the transistor 172 to provide IF signals at the transistor 172 collector electrode.
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The collector electrode of the transistor 172 is connected to the source of operating potential at the terminal 158 by the primary winding 178 of a transformer 180. The base electrode of the transistor 172 is connected
90 to the source of operating potential at the terminal 158 by a voltage dividing network including the resistors 184 and 186. Two feedthrough capacitors 188 and 190 bypass signal frequencies to the point of reference potential to complete the signal frequency circuit path. The primary of the transformer 180 is tuned to IF signal frequencies by a feedthrough capacitor 182. The secondary winding 192 of the transformer 180 is coupled to IF signal processing circuitry, not shown.
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By adjusting the tap 79, the voltage applied to the variable capacitance diodes 70, 128 and 144 is varied to select any one of the VHF television channels. Specifically, the tunable
100 circuits 60 and 120 resonate in the VHF television band of 216 MHz to 54 MHz, and the oscillator circuit resonates in a range from 257 MHz to 101 MHz as is required for proper heterodyne action in the mixer stage 56. It should be noted that since all the variable capacitance diodes obtain their bias from one supply, a "ganging" effect is achieved in tuning the capacitively tuned circuits.
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The operation of the VHF tuner shown in
125 FIGURE 1 can best be understood by considering the equivalent circuit diagram of the tunable resonant circuits associated with the tuner.

In a parallel tuned resonant circuit, the figure of merit Q_p can be expressed in the form $Q_p = R_p/X_c$ where R_p is the shunt resistance and X_c is the shunt capacitive reactance. Q_p can also be expressed in the form $Q_p = f_o/BW$ where f_o is the resonant frequency of the parallel tuned circuit and BW is the bandwidth of the parallel tuned circuit. By equating both expressions for Q_p the following relationship obtains:

$$f_o/BW = R_p/X_c$$

however, the capacitive reactance X_c can be expressed in the form:

$$X_c = 1/2\pi f_o C$$

by making appropriate substitutions for X_c the equation becomes:

$$f_o/BW = R_p \left(\frac{1}{2\pi f_o C} \right)$$

solving for bandwidth and cancelling like terms the equation takes the form:

$$BW = 1/2\pi R_p C$$

From the equation $BW = 1/2\pi R_p C$ it can be observed, as previously indicated, that the bandwidth of a parallel tuned resonant circuit varies inversely with the tuning capacitance. As the capacitance varies from maximum capacity at the lowest frequency to which the parallel tuned circuit is resonant, to minimum capacity at the highest frequency to which the parallel tuned circuit is resonant, the bandwidth of the circuit becomes progressively larger.

To offset the change in bandwidth as a parallel tuned resonant circuit is tuned by a varying capacitance, the shunt resistance can be made to vary and maintain the bandwidth substantially constant. The shunt resistance must vary in the opposite direction as the variable capacitance, that is, the shunt resistance of the parallel tuned circuit must be made to increase as the parallel tuned circuit is made to resonate at higher frequencies by a decreasing shunt capacitance. While variation in the shunt resistance can be obtained by physically adding or subtracting shunt resistance to thereby maintain a constant bandwidth, this is generally undesirable.

Referring now to FIGURE 2a, a source of signals 12 including a signal generator 14 having an internal impedance 16, shown as a resistance, is coupled to a load circuit 18, shown as a resistance 20, by a tunable circuit 22. The tunable circuit 22 includes two serially connected inductors 24 and 26, their junction point 27 being connected to a point of reference potential by the parallel combination of an inductor 28 and a variable capaci-

tor 30, which may be considered a tuning capacitor.

For ease of analysis, the circuit branch which includes resistor 16 and inductor 24 and the circuit branch which includes resistor 20 and inductor 26 can be combined into a single branch as shown in FIGURE 2b. The combined circuit branch includes an inductor 32 and a resistor 34 connected between the junction point 27 and a point of reference potential. Since the schematic circuit diagrams shown in FIGURES 2b and 2c will be considered in regard to their resonant frequency and bandwidth, the signal generator 14 may be neglected.

The series connected inductor 32 and resistor 34 can be converted to the equivalent shunt impedances as shown in FIGURE 2c by the series-parallel transformation equations. The transformation equations provide:

$$X_p = X_s(1 + R_s^2/X_s^2)$$

and

$$R_p = R_s(1 + X_s^2/R_s^2)$$

where R_p is the equivalent shunt resistance of series resistance R_s and X_p is the equivalent shunt reactance of series reactances X_s . A complete treatment of series-parallel transformation equation is given on page 72 of *Electrical Communications*, by Arthur L. Albert, Third Edition, published by John Wiley and Sons, New York. The transformation equations can be applied to the series components of FIGURE 2b to determine the value of the equivalent shunt components in FIGURE 2c.

For inductor 32, the equivalent shunt inductance 38 may be obtained from the transformation equation:

$$X_{38} = X_{32}(1 + R_{34}^2/X_{32}^2)$$

however, the inductive reactance of X_{32} and X_{38} can be expressed in the form:

$$X_L = 2\pi fL$$

by making appropriate substitutions and cancelling like terms the equation reduces to:

$$L_{38} = L_{32}(1 + R_{34}^2/4\pi^2 f^2 L_{32}^2)$$

For resistor 34, the equivalent shunt resistance 40 is given by:

$$R_{40} = R_{34}(1 + X_{32}^2/R_{34}^2)$$

however, the inductive reactance of X_{32} can be expressed in the form:

$$X_L = 2\pi fL$$

by making the appropriate substitutions the equation becomes:

$$R_{40} = R_{34}(1 + 4\pi^2 f^2 L_{32}^2 / R_{34}^2)$$

For inductor 28 and variable capacitor 30, no transformation is necessary because they are in parallel with the series connected inductor 32 and resistor 34 and they, therefore, retain their values in the equivalent parallel tuned resonant circuit shown in FIGURE 2c.

From the foregoing equations for the equivalent shunt values of the components shown in FIGURE 2c, it will be observed that as variable capacitor 30 is made smaller to tune the circuit to a higher resonant frequency, the equivalent shunt resistance 40 becomes larger. This is because the term $4\pi^2 f^2 L_{32}^2 / R_{34}^2$ in the equation for the equivalent shunt resistance 40 increases as the resonant frequency becomes higher. Moreover, as the frequency increases, the equivalent shunt inductance 38 decreases because of the term $R_{34}^2 / 4\pi^2 f^2 L_{32}^2$ in the transformation equation. Consequently, the total shunt inductance, which can be expressed in the form $L_{38} L_{28} / (L_{38} + L_{28})$, also decreases. The decreasing shunt inductance with increasing frequency results in a reduction in the range of capacity that is required to make the circuit resonant across a given frequency band and eases design requirements for tuning across a wide band of frequencies.

It should be noted that the schematic circuit diagram shown in FIGURE 2a can be modified to be a double-tuned circuit. This may be achieved by placing a second network between the source and load circuits. The second network would be similar to the network including the capacitor 30 and the inductors 24, 26 and 28. The mutual coupling between each of the tuned circuits is supplied by the adjacent inductors. Thus, in the double-tuned circuit configuration, the source and load circuits would be interconnected by four inductors 24, 26 and a new 24' and 26' all connected in series.

To demonstrate the manner in selecting the proper component values and, moreover, that when the proper component values are selected for given conditions, the tuned circuit will maintain a substantially constant bandwidth as the circuit resonant frequency is made to vary over a large frequency range by capacitive tuning, an example will be given. First, proper component values will be selected to permit the tuned circuit to resonate throughout the entire television VHF band, 216 MHz to 54 MHz; and then it will be demonstrated that with these component values the effective shunt resistance required for a substantially constant bandwidth which is in excess of the 6 MHz bandwidth typically employed in television tunable circuits is present at both the high and low ends of the VHF band.

For the purpose of the example, at 213 MHz, the center frequency for channel 13

(210 to 216 MHz), a desired bandwidth of 8 MHz and, a minimum value of capacitance for C_{30} of 5 pf will be chosen (the minimum value of capacitance was chosen to be within the operating range of variable capacitance diodes). In addition, it will be assumed that resistors 16 and 20 are each equal to 50 ohms and that the inductors 24 and 26 are equal in value. Consequently, the circuit branch including resistor 34 and inductor 32 shown in FIGURE 2b, which is the result of combining the circuit branch including resistor 16 and inductor 24 with the circuit branch including resistor 20 and inductor 26, will have component values equal to one-half the value of the components of the actual circuit branches. It should be noted that once the desired component values for inductor 32 and resistor 34 have been determined, other values of circuit components in each of the two branches which combine to give the desired values for inductor 32 and resistor 34 will result in proper operation of the circuit.

The figure of merit Q_p of the parallel tuned resonant circuit can be obtained from the equation:

$$Q_p = f_0 / BW$$

whence

$$Q_p = \frac{213 \text{ MHz}}{8 \text{ MHz}} = 26.62$$

Q_p is now utilized to obtain the desired value of shunt resistance R_{40} from the equation:

$$Q_p = \frac{R_p}{X_c} \quad Q_p = R_p / X_c$$

which with appropriate substitutions becomes:

$$Q_p = 2\pi f C_{30} R_{40}$$

by substituting component values, the shunt resistance R_{40} may be found. Thus:

$$26.62 = 2(3.14)(213 \times 10^6)(5 \times 10^{-12})R_{40}$$

$$R_{40} = 3978.88 \text{ ohms.}$$

Having obtained the value of R_{40} and having

assumed R_{34} equals $\frac{1}{2}R_{16}$ or $\frac{1}{2}R_{20}$ which is 25 ohms, the appropriate value for L_{32} can be determined from the expression:

$$R_{40} = R_{34}(1 + 4\pi^2 f^2 L_{32}^2 / R_{34}^2)$$

by substituting component values, the inductance L_{32} may be found. Thus:

$$3978.88 = 25 [1 + 4(3.14)^2 (213 \times 10^6)^2 L_{32}^2 / (25)^2]$$

$$L_{32} = 0.235 \mu\text{h}$$

Utilizing the value for L_{32} , the value of L_{38} the equivalent shunt inductance can be calculated from the expression:

$$5 \quad L_{38} = L_{32} (1 + R_{34}^2 / 4\pi^2 f^2 L_{32}^2)$$

again, by substituting component values, the equivalent shunt inductance L_{38} may be found. Thus:

$$L_{38} = 0.235 \times 10^{-6} [1 + (25)^2 / 4(3.14)^2 (213 \times 10^6)^2 (0.235 \times 10^{-6})^2]$$

$$L_{38} = 0.25 \mu\text{h}$$

- 10 The appropriate value for L_{28} is obtained from the condition that total shunt inductance L_T must resonate with the capacitance of the shunt capacitor C_{30} at 213 MHz. The conditions for resonance are:

$$X_L = X_C$$

however, inductive reactance can be expressed in the form:

$$15 \quad X_L = 2\pi f L$$

and capacitive reactance can be expressed in the form:

$$X_C = 1 / 2\pi f C_{30}$$

with appropriate substitutions the equation for resonance becomes:

$$2\pi f L_T = 1 / 2\pi f C_{30}$$

- 20 by substituting component values, the total inductance L_T may be found. Thus:

$$2(3.14)(213 \times 10^6) L_T = 1 / 2(3.14)(213 \times 10^6)(5 \times 10^{-12})$$

$$L_T = 0.114 \mu\text{h}$$

- It is now possible to determine the proper value for L_{28} because the total shunt inductance equals the combined inductance of inductors L_{38} and L_{28} . The expression for the total inductance takes the form:

$$L_T = L_{38} L_{28} / (L_{38} + L_{28})$$

by substituting component values, the proper inductance for inductor L_{28} may be found. Thus:

$$(0.114 \times 10^{-6}) = (0.25 \times 10^{-6}) L_{28} / [(0.25 \times 10^{-6}) + L_{28}]$$

$$30 \quad L_{28} = 0.21 \mu\text{h}$$

The proper values for all the circuit components shown in FIGURE 2a have now been determined to establish resonance at 213 MHz with the desired bandwidth: $R_{16} = 50$ ohms; $R_{20} = 50$ ohms; $L_{24} = 2L_{32} = .47 \mu\text{h}$; $L_{26} = 2L_{32} = .47 \mu\text{h}$; $L_{28} = .21 \mu\text{h}$ and $C_{30} = 5$ pf (minimum value).

To tune the circuit to resonate at 57 MHz

by capacitive tuning, variable capacitor 30 must be made to change to a value of capacitance that will resonate with the total shunt inductance at 57 MHz. As has been shown, the conditions for resonance can be expressed in the form:

$$2\pi f L_T = 1 / 2\pi f C_{30}$$

by substituting component values, the proper capacitance for capacitor C_{30} may be found. Thus:

$$2(3.14)(57 \times 10^6)(.114 \times 10^{-6}) = 1/2(3.14)(57 \times 10^6)C_{30}$$

$$C_{30} = 69.82 \text{ pf (maximum value)}$$

- 5 The value of the shunt resistance R_{40} at 57 MHz can be determined from the expression:

$$R_{40} = R_{34}(1 + 4\pi^2 f^2 L_{32}^2) / R_{34}^2$$

by substituting component values, the shunt resistance R_{40} may be found. Thus:

$$R_{40} = (25)[1 + 4(3.14)^2(57 \times 10^6)^2(0.235 \times 10^{-6})^2 / (25)^2]$$

10 $R_{40} = 308.15 \text{ ohms}$

Consequently, it has now been established that the tuned circuit will resonate at 57 MHz when the variable capacitor 30 displays a capacitance of 69.82 pf and, in addition, that the tuned circuit will resonate at 213 MHz when the variable capacitor 30 displays a capacitance of 5.00 pf.

- 15 Having selected the proper component values for the tuned circuit, it can now be demonstrated that the shunt resistance R_{40} required to maintain a substantially constant bandwidth is present at both the high and the low end of the VHF band. As previously shown, bandwidth can be expressed in the form:

$$BW = 1/2\pi R_{40} C_{30}$$

or, by substituting the expression for the equivalent shunt resistance R_{40} , bandwidth can also be expressed in the form:

30 $BW = 1/2\pi [R_{34}(1 + 4\pi^2 f^2 L_{32}^2 / R_{34}^2)] C_{30}$

At 213 MHz the bandwidth was selected to be 8 MHz ($R_{40} = 3978.88 \text{ ohms}$ and $C_{30} = 5.00 \text{ pf}$). At 57 MHz, $R_{40} = 308.15 \text{ ohms}$ and $C_{30} = 69.82 \text{ pf}$, and by substituting the component values, the equation for bandwidth $1/2\pi R_{40} C_{30}$ becomes:

$$BW_{57\text{MHz}} = 1/2(3.14)(308.15)(69.82 \times 10^{-12})$$

$$BW_{57\text{MHz}} = 7.4 \text{ MHz}$$

- 40 The selected and calculated bandwidth ($BW_{213\text{MHz}} = 8\text{MHz}$ and $BW_{57\text{MHz}} = 7.4 \text{ MHz}$) are substantially equal for capacitive tuning at the extreme ends of the VHF band and, moreover, are in excess of the 6 MHz bandwidth typically employed in television tunable circuits. By varying the capacitance of the tuning capacitor C_{30} between 5.00 pf and 69.82 pf, the tuned circuit, when the proper circuit component values are employed, can be made to resonate over a frequency band

which is more than 160MHz wide with no substantial change in bandwidth. Similar calculations can be made for the selection of component values to permit tuning across the UHF band (890 MHz to 470 MHz).

A circuit as shown in FIGURE 2a has been constructed using the component values shown and tested for capacitive tuning across the VHF band. A substantially constant bandwidth was observed ($BW_{213\text{MHz}} = 8 \text{ MHz}$ and $BW_{57\text{MHz}} = 7.4 \text{ MHz}$). In addition, a circuit as shown in FIGURE 2a has been constructed and tested for capacitive tuning across the UHF band. The component values used were: $R_{12} = 50 \text{ ohms}$; $L_{24} = 0.1 \mu\text{h}$; $L_{26} = 0.1 \mu\text{h}$; $R_{20} = 50 \text{ ohms}$; $L_{28} = 0.008 \mu\text{h}$ and $C_{30} = 4 \text{ pf}$ (at 890 MHz) and $C_{30} = 14.4 \text{ pf}$ (at 470 MHz). Again, a substantially constant bandwidth was observed experimentally

$$(BW_{890\text{MHz}} = 15 \text{ and } BW_{47\text{MHz}} = 13).$$

It should be noted that the circuits shown in FIGURE 2 are particularly suited for use with variable capacitance diodes. Variable capacitance diodes have an internal resistance which may be represented in FIGURE 2 as a resistance in series with the variable capacitor 30. The diode's series resistance presents an equivalent shunt resistance the size of which can be determined by the series-parallel transformation equations. Circuit components can be apportioned such that the diode's equivalent shunt resistance is substantially higher than the equivalent shunt resistance of the source and load circuits. The relationship of the shunt resistances holds across the frequency band, and, consequently, it is the equivalent shunt resistance of the source and load circuits which predominates in its effects on the circuit operation.

WHAT WE CLAIM IS:—

1. In a tuner wherein RF signals are heterodyned in a mixer stage with locally generated signals to produce an intermediate frequency



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by substituting component values, the proper capacitance for capacitor C_{30} may be found. Thus:

$$2(3.14)(57 \times 10^6)(.114 \times 10^{-6}) = 1/2(3.14)(57 \times 10^6)C_{30}$$

$$C_{30} = 69.82 \text{ pf (maximum value)}$$

- 5 The value of the shunt resistance R_{40} at 57 MHz can be determined from the expression:

$$R_{40} = R_{34}(1 + 4\pi^2 f^2 L_{32}^2) / R_{34}^2$$

by substituting component values, the shunt resistance R_{40} may be found. Thus:

$$R_{40} = (25)[1 + 4(3.14)^2(57 \times 10^6)^2(0.235 \times 10^{-6})^2 / (25)^2]$$

$$10 \quad R_{40} = 308.15 \text{ ohms}$$

Consequently, it has now been established that the tuned circuit will resonate at 57 MHz when the variable capacitor 30 displays a capacitance of 69.82 pf and, in addition,

- 15 that the tuned circuit will resonate at 213 MHz when the variable capacitor 30 displays a capacitance of 5.00 pf.

- Having selected the proper component values for the tuned circuit, it can now be demonstrated that the shunt resistance R_{40} required to maintain a substantially constant bandwidth is present at both the high and the low end of the VHF band. As previously shown, bandwidth can be expressed in the form:

$$BW = 1/2\pi R_{40} C_{30}$$

or, by substituting the expression for the equivalent shunt resistance R_{40} , bandwidth can also be expressed in the form:

$$30 \quad BW = 1/2\pi [R_{34}(1 + 4\pi^2 f^2 L_{32}^2 / R_{34}^2)] C_{30}$$

At 213 MHz the bandwidth was selected to be 8 MHz ($R_{40} = 3978.88$ ohms and $C_{30} = 5.00$ pf). At 57 MHz, $R_{40} = 308.15$ ohms and $C_{30} = 69.82$ pf, and by substituting the component values, the equation for bandwidth $1/2\pi R_{40} C_{30}$ becomes:

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$$BW_{57\text{MHz}} = 1/2(3.14)(308.15)(69.82 \times 10^{-12})$$

$$BW_{57\text{MHz}} = 7.4 \text{ MHz}$$

- The selected and calculated bandwidth ($BW_{213\text{MHz}} = 8\text{MHz}$ and $BW_{57\text{MHz}} = 7.4 \text{ MHz}$) are substantially equal for capacitive tuning at the extreme ends of the VHF band and, moreover, are in excess of the 6 MHz bandwidth typically employed in television tunable circuits. By varying the capacitance of the tuning capacitor C_{30} between 5.00 pf and 69.82 pf, the tuned circuit, when the proper circuit component values are employed, can be made to resonate over a frequency band

which is more than 160MHz wide with no substantial change in bandwidth. Similar calculations can be made for the selection of component values to permit tuning across the UHF band (890 MHz to 470 MHz).

A circuit as shown in FIGURE 2a has been constructed using the component values shown and tested for capacitive tuning across the VHF band. A substantially constant bandwidth was observed ($BW_{213\text{MHz}} = 8 \text{ MHz}$ and $BW_{57\text{MHz}} = 7.4 \text{ MHz}$). In addition, a circuit as shown in FIGURE 2a has been constructed and tested for capacitive tuning across the UHF band. The component values used were: $R_{12} = 50$ ohms; $L_{24} = 0.1 \mu\text{h}$; $L_{26} = 0.1 \mu\text{h}$; $R_{20} = 50$ ohms; $L_{28} = 0.008 \mu\text{h}$ and $C_{30} = 4$ pf (at 890 MHz) and $C_{30} = 14.4$ pf (at 470 MHz). Again, a substantially constant bandwidth was observed experimentally

$$(BW_{890\text{MHz}} = 15 \text{ and } BW_{470\text{MHz}} = 13).$$

It should be noted that the circuits shown in FIGURE 2 are particularly suited for use with variable capacitance diodes. Variable capacitance diodes have an internal resistance which may be represented in FIGURE 2 as a resistance in series with the variable capacitor 30. The diode's series resistance presents an equivalent shunt resistance the size of which can be determined by the series-parallel transformation equations. Circuit components can be apportioned such that the diode's equivalent shunt resistance is substantially higher than the equivalent shunt resistance of the source and load circuits. The relationship of the shunt resistances holds across the frequency band, and, consequently, it is the equivalent shunt resistance of the source and load circuits which predominates in its effects on the circuit operation.

WHAT WE CLAIM IS:—

1. In a tuner wherein RF signals are heterodyned in a mixer stage with locally generated signals to produce an intermediate frequency



- signal, an electric circuit comprising: an input and an output tunable resonant circuit each adapted to maintain a bandwidth of at least 6 MHz at all its tunable frequencies, each tunable resonant circuit including a first and a second inductor connected in series and a variable capacitor and a third inductor connected to form a tuning circuit coupled between the junction of said first and said second inductor and a point of reference potential; a first transistor having base collector and emitter electrodes and connected to form a common base amplifier with the first and second inductors of said input tunable resonant circuit coupled between a point of application of VHF television signals and the emitter electrode of said first transistor; a second transistor having base, collector and emitter electrodes with the first and second inductors of said output tunable resonant circuit coupled between the collector or emitter electrode of the second transistor and said mixer stage, and a wideband tuned circuit interconnecting the collector electrode of said first transistor and the base electrode of said second transistor.
2. A tuner according to Claim 1 wherein said variable capacitor is a voltage dependent variable capacitance device.
3. A tuner according to Claim 1 or Claim 2 wherein said input and output tunable resonant circuits are tunable across a band of frequencies ranging from 216 to 54 MHz.
4. A tuner according to claim 1, Claim 2 or Claim 3 wherein said tuning circuit is a parallel resonant circuit.
5. A VHF television tuner according to any preceding claim.
6. A VHF television tuner substantially as herein described with reference to Figure 1 of the accompanying drawings.

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