

Nov. 22, 1938.

N. P. CASE

2,137,266

MULTIBAND RECEIVER

Original Filed May 25, 1935

4 Sheets-Sheet 1

Fig. 1.

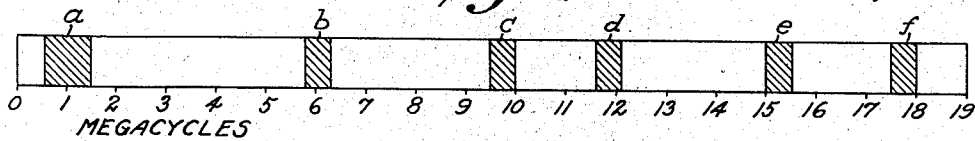
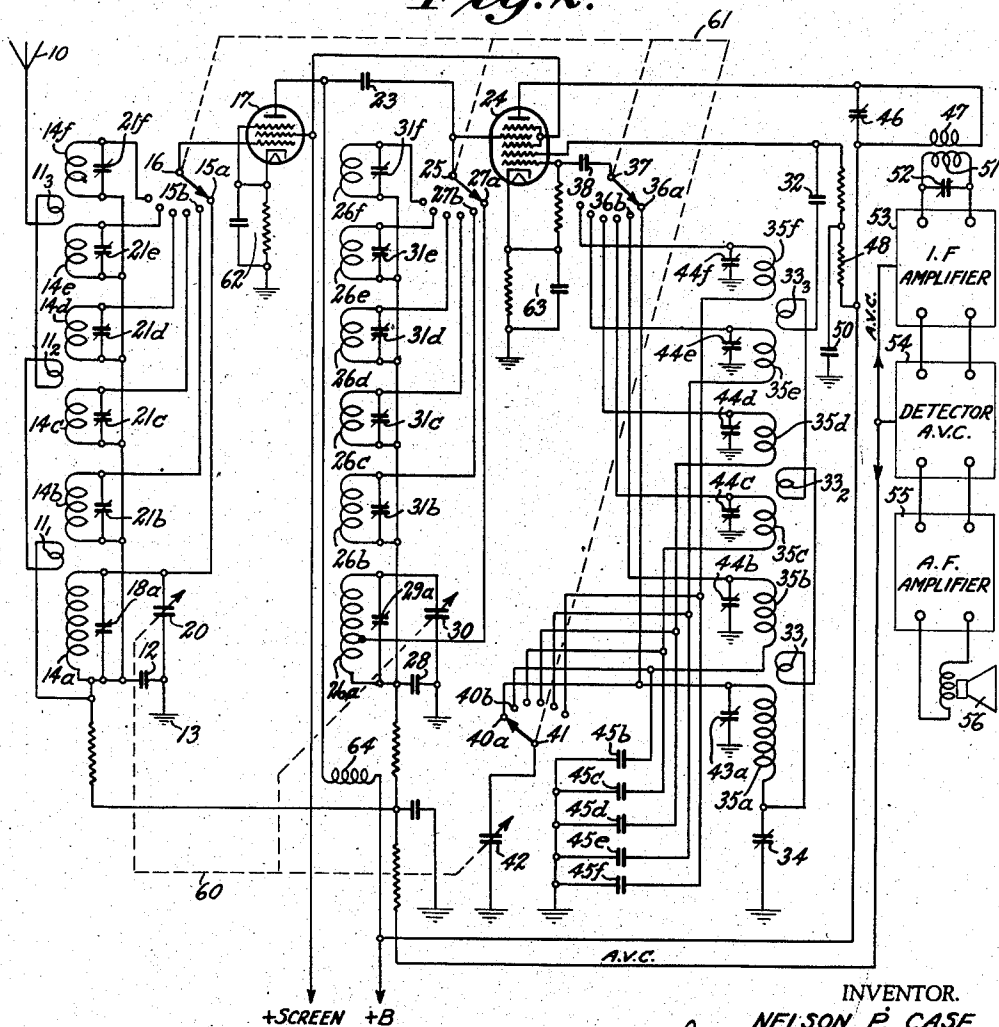


Fig. 2.



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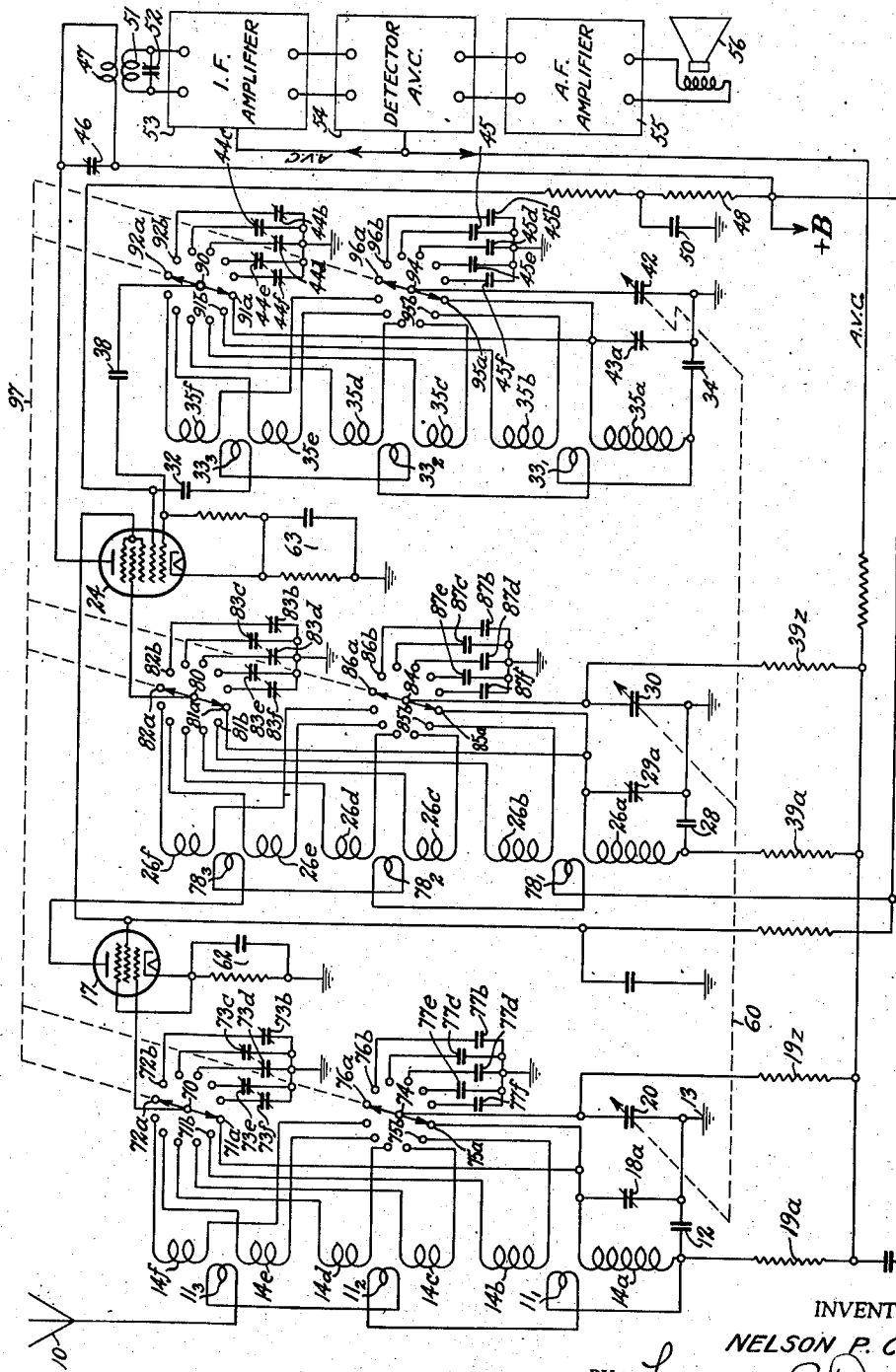


Fig. 3.

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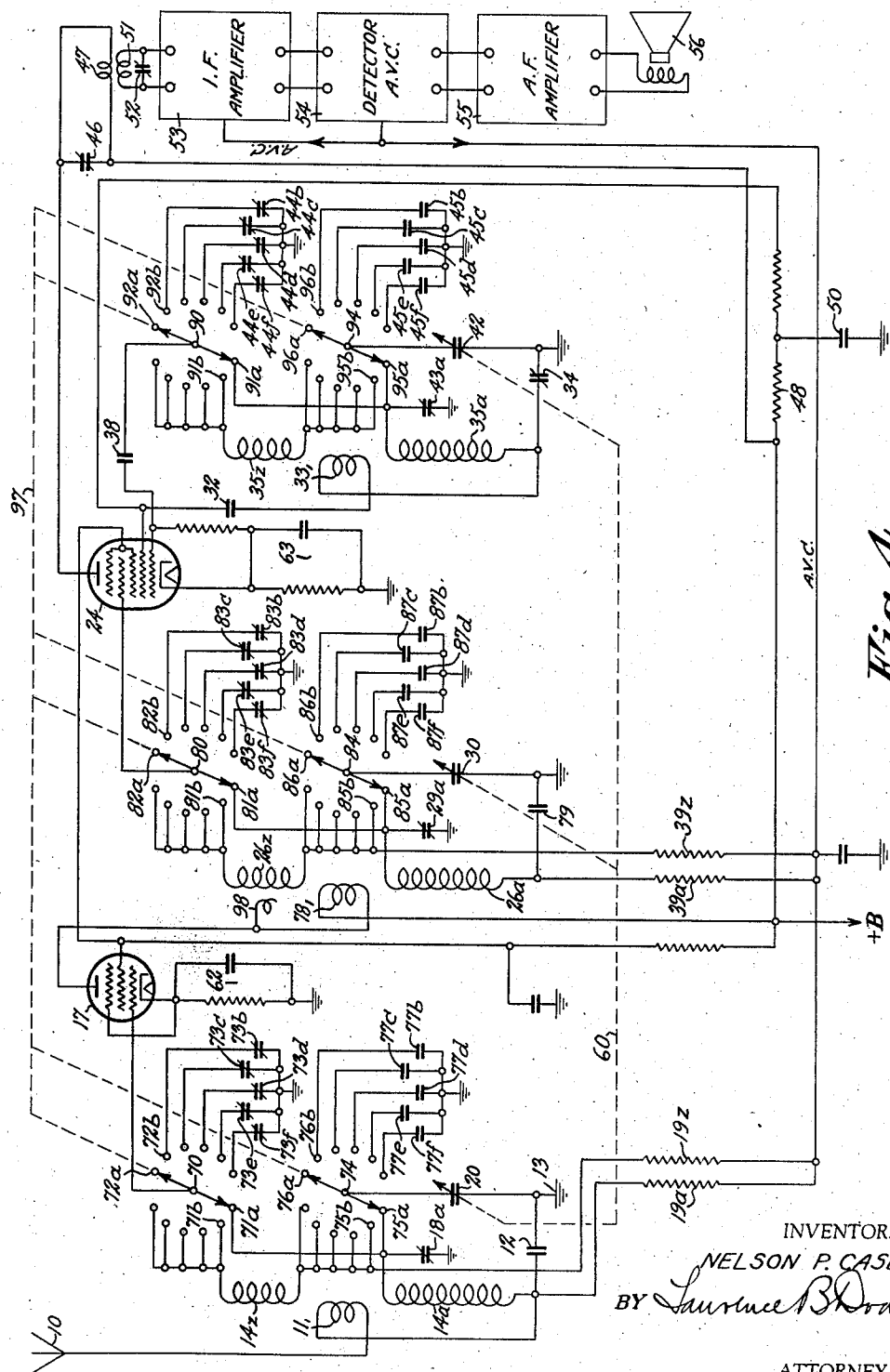


Fig. 4.

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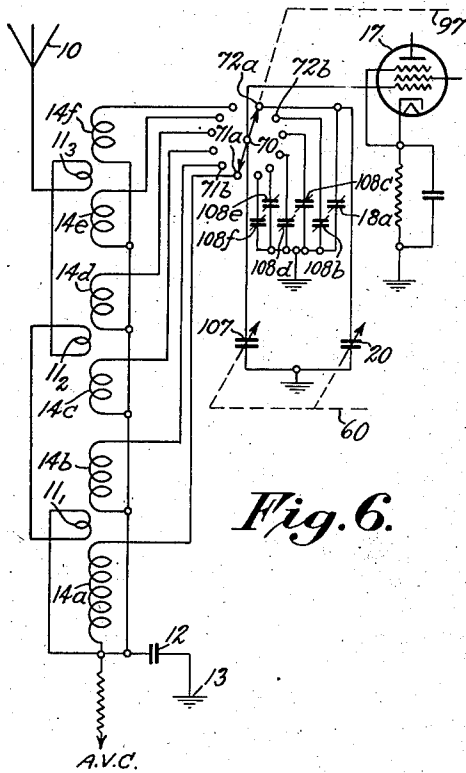
N. P. CASE

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MULTIBAND RECEIVER

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UNITED STATES PATENT OFFICE

2,137,266

MULTIBAND RECEIVER

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Application May 25, 1935, Serial No. 23,376
Renewed October 27, 1936

11 Claims. (Cl. 250-40)

This invention relates to multi-band radio receivers, and particularly to multi-band tuning systems for radio receivers and to methods of operating the same.

Popular interest in radio reception now includes not only those programs transmitted in the general broadcast bands, but those programs transmitted in the various high-frequency bands. In response to this interest, radio receivers, tunable over wide frequency ranges, have been placed on the market. These receivers, commonly termed all-wave receivers, are generally difficult to tune to any particular channel in the high-frequency bands due to the fact that small displacements of the tuning element tune over a large number of channels. Slow motion equipment of some character is, therefore, customarily provided between the operating control and the tuning element or elements actuated thereby. Such slow motion equipment, however, adds considerably to the expense of the receiver, especially when made so that there is no backlash therein. In addition, such slow motion equipment impedes rapid shifts between widely separated frequencies and is generally unnecessary and objectionable when tuning in the general broadcast band.

It is an object of this invention to provide a method of tuning a receiver by which tuning to individual channels in the high-frequency portions of the radio spectrum is as easy as tuning to individual channels in the low-frequency portions.

It is a further object of this invention to provide a radio receiver which is easy to tune in each of two or more frequency bands widely separated in the frequency spectrum, either by other bands of the receiver or by bands over which the receiver is not tunable, which has a high gain per stage in each frequency band, and which is simple in construction and relatively inexpensive to build.

Other objects of this invention will become apparent from the specification taken in conjunction with the accompanying drawings and the subjoined claims.

The invention contemplates either a radio receiver which is tunable both over the general broadcast band and over one or more relatively narrow bands in the high-frequency portion of the radio spectrum, or is tunable over two or more relatively narrow high-frequency bands, at least some of which are widely spaced from each other along the frequency spectrum. The general broadcast band, in the United States, is a band of about 1000 kilocycles (1.0 megacycle)

frequency coverage extending from around 550 kilocycles to around 1550 kilocycles (0.55-1.55 megacycles). The relatively narrow high-frequency bands are preferably so located and of such frequency coverage as to include only the high-frequency broadcasting channels, domestic and foreign, inasmuch as the overwhelming majority of the general public is interested only in the reception of programs from broadcast stations. In receivers for such broadcast reception, the tunable ranges of the receiver, in the high-frequency bands, are preferably bands of 500 kilocycles (0.5 megacycle) frequency coverage. Although the invention is not limited to a receiver tunable over bands of equal frequency coverage in any two bands, the preferred tunable ranges of an all-broadcast receiver, in accordance with this invention, are the following:

0.55- 1.55 megacycles	
5.8 - 6.3 megacycles	
9.5 -10.0 megacycles	
11.6 -12.1 megacycles	
15.0 -15.5 megacycles	
17.5 -18.0 megacycles	

The invention further contemplates, in the incorporation of the above features in a receiver tunable over two or more such broadcast and high-frequency bands by the operation of the same tuning member, proportioning the reactive elements utilized for tuning each of the two or more such bands so that operation of the tuning member between its limiting positions tunes the receiver, for each of such bands, substantially exactly between the limits of the selected bands. This provision of the invention results in great ease of tuning in all bands as all the channels within the limits of each of the selected bands are, in each band, spread over the complete operating range of the tuning member. Further, the channels in each band are spread over the full range of the indicating dial, and the individual channels within the respective bands are separated on the dial by spacings having magnitudes in a ratio, from band to band in the order of decreasing frequency, which is substantially greater than the inverse ratio of the mean frequencies of the bands, it being understood that adjacent signal channels in each of the bands are generally separated by a constant frequency difference, such as 10 kilocycles. Thus, when the frequency coverage of the several bands is the same, as is the case for the high-frequency bands of the example given above, the individual channels within the respective bands are separated on the dial by spacings of the same order of magni-

tude for all of the bands and tuning of the receiver is thus as easy in any one band as in another, even though widely separated therefrom in the frequency spectrum and in any event tuning over the high-frequency bands is greatly facilitated over that with arrangements of the prior art. Furthermore, the dial of the receiver may be permanently calibrated for each band so as to enable quick tuning of the receiver to individual channels in the respective bands.

In accordance with the invention, a high gain is procured by maintaining a high L/C ratio for each tuned circuit, not only in the general broadcast band but also in each high-frequency broadcast band.

Further, in accordance with the invention, the same variable tuning element may be utilized for tuning a receiver over both the general broadcast band and one or more high-frequency bands, or, alternatively, a tuning element having a smaller value and/or a smaller range of values may be provided for the high-frequency bands. In the latter case, the two tuning elements preferably are controlled by the same tuning member and have their displacement indicated on the same scale member, although, less desirably, the two tuning elements may be controlled by individual tuning members.

In accordance with another provision of the invention, certain of the tunable systems of the receiver may, for reception in certain bands, be simplified in certain cases, particularly in the case of a superheterodyne receiver, by utilizing, in one or more of the signal-selecting circuits, fixed tuned circuits resonant substantially to the mid-frequency of the band selected for reception.

In the drawings, Fig. 1 is a chart of the radio-frequency spectrum to aid in explaining the invention; Fig. 2 is a circuit diagram, partly schematic, illustrating one embodiment of the invention as incorporated in a multi-band superheterodyne receiver; Fig. 3 is a similar circuit diagram illustrating another embodiment of the invention; Fig. 4 is a circuit diagram of a multi-band receiver similar to, but somewhat less complex than, that illustrated in Fig. 3; Fig. 5 is a circuit diagram of a portion of the receiver of Fig. 3 illustrating another modification thereof; Fig. 6 is a circuit diagram of a portion of the receiver of Fig. 3 illustrating still another modification thereof; and Fig. 7 is a circuit diagram of a portion of the receiver of Fig. 3 illustrating another embodiment of the invention.

Referring to Fig. 1, the radio-frequency spectrum is therein plotted in megacycles. The cross-hatched portion designated *a* represents the general broadcast band. The other cross-hatched portions, designated *b*, *c*, *d*, *e* and *f*, are non-contiguous bands of 0.5 megacycle frequency coverage in the high-frequency portion of the radio-frequency spectrum, positioned therein so as to include all, or substantially all, of the high-frequency broadcast channels of the world. In this connection, the term "high-frequency portion of the radio spectrum" is herein defined as including all radio frequencies above 5.0 megacycles and as excluding all frequencies below 5.0 megacycles, and the term "high frequency" is herein defined as any radio frequency above 5.0 megacycles. The preferred limits of bands *a*, *b*, *c*, *d*, *e* and *f* are, respectively, those set forth in the previous tabulation of preferred tunable ranges. As may be seen from Fig. 1, these bands are bands of the same order of frequency cover-

age. However, in terms of relative values, in which the relative width of a band is defined by the ratio of the frequency coverage of the band to the minimum frequency of the band, band *a* is quite a wide band (the ratio being 1.82), while bands *b*, *c*, *d*, *e* and *f* are relatively narrow bands (the ratios ranging from 0.086 to 0.029). As herein employed, the term "relative band width" refers to the relative measure of the band width as defined above, and the term "frequency coverage" is herein employed to indicate the absolute range of frequencies included within a band, independently of its position in the radio-frequency spectrum. A "relatively narrow band" is herein defined as a band in which the ratio of the frequency coverage of the band to the minimum frequency of the band is a minor fraction (i. e., less than 0.5). In accordance with this invention, and as will be seen from Fig. 1, the relative widths of the several high-frequency bands are less than that of the general broadcast band, so that the frequency coverages or tuning ranges of the several bands are substantially less than directly proportional to the mean frequencies of the bands, and the magnitudes of the displacements of the tuning means required to effect separation of adjacent signal channels within the respective bands are in a ratio, from band to band in the order of decreasing band frequency, which is substantially greater than the inverse ratio of the mean frequencies of the corresponding bands. Such an arrangement is to be contrasted with the conventional arrangements of the prior art in which the relative widths of all the bands are approximately equal, the frequency coverages are directly proportional to the mean frequencies of the bands, and the magnitudes of the displacements of the tuning means required to effect separation of adjacent signal channels within the respective bands are in a ratio, from band to band in the order of decreasing frequency, which is inversely proportional to the mean frequencies of the corresponding bands. Although not limited thereto, it is desirable that the several high-frequency bands be relatively narrow bands having a frequency coverage of the same order as, preferably between one-half and twice, that of the general broadcast band, and having band widths equal to a minor fraction, preferably not greater than two-tenths. While each of the receivers herein described is tunable within the relatively broad, general broadcast band *a* and five relatively narrow high-frequency bands the limits of which substantially correspond respectively to the above-described limits of bands *b*, *c*, *d*, *e* and *f* having equal frequency coverages, it will be understood that the invention is equally applicable to any receivers designed to tune over any number of high frequency bands of either equal or unequal frequency coverage having relative band widths substantially narrower than those of the arrangements of the prior art. In case the bands are of unequal frequency coverage, the displacements of the tuning element of the receiver required to effect separation of adjacent signal channels within the several high-frequency bands may be less than for the lower frequency band but still they will be substantially greater than inversely proportional to the mean frequencies of the bands, as in the conventional arrangements of the prior art. With bands of such limits and location as are given in the example specifically mentioned above, it is to be observed that the separation between at least some of the high-frequency bands and

others thereof is large compared to the frequency coverage of such bands, being of the order of at least several times the frequency coverage.

Referring to Fig. 2, the antenna or first radio-frequency selecting circuit of the superheterodyne receiver therein illustrated includes antenna 10, a plurality of primary inductances 11, individually designated 11₁, 11₂ and 11₃, fixed condenser 12 and ground 13. Primary inductances 11 are inductively coupled to a plurality of secondary inductances 14, individually designated 14a, 14b, 14c, 14d, 14e and 14f, the physical arrangements of these inductances preferably being that indicated, in which primary inductance 11₁ is coupled principally to secondary inductances 14a and 14b, in which primary inductance 11₂ is coupled principally to secondary inductances 14c and 14d, and in which primary inductance 11₃ is coupled principally to secondary inductances 14e and 14f. Adjustably fixed condensers 18a, 21b, 21c, 21d, 21e and 21f are connected across secondary inductances 14a, 14b, 14c, 14d, 14e and 14f, respectively, to form tuned radio-frequency selective circuits. The high potential terminals of these tuned circuits are selectively connected through contacts 15 of a switch 16 to the control grid of a vacuum tube 17, illustrated as of the pentode type and connected to operate as a radio-frequency amplifier. The other terminals of these circuits are connected to ground 13 through condenser 12. A variable condenser 20 is connected across secondary inductance 14a, between ground 13 and the terminal of inductance 14a that is connected to switch contact 15a.

The anode of vacuum tube 17 is connected through coupling condenser 23 to the control grid of the signal-translating portion of the vacuum tube 24, illustrated as a heptode utilized as an oscillator-modulator. Arranged to be selectively connected in the signal input circuit of vacuum tube 24, as by the switch 25 having contacts 27, are a plurality of tuned radio-frequency circuits comprising inductances 26, individually designated 26a, 26b, 26c, 26d, 26e and 26f, and adjustably fixed condensers 29a, 31b, 31c, 31d, 31e and 31f, respectively. One terminal of each of the inductances 26a-26f, inclusive, is connected to ground through a fixed condenser 28. A variable condenser 30 is connected across inductance 26a. The anode of the oscillator portion of the oscillator-modulator tube 24 is connected to ground through serially connected blocking condenser 32, a plurality of primary inductances 33, individually designated 33₁, 33₂ and 33₃, and an adjustably fixed condenser 34. Primary inductances 33 are inductively coupled to a plurality of secondary inductances 35, individually designated 35a, 35b, 35c, 35d, 35e and 35f, the physical arrangement of these inductances preferably being that indicated, in which primary inductance 33₁ is coupled principally to secondary inductances 35a and 35b, in which primary inductance 33₂ is coupled principally to secondary inductances 35c and 35d, and in which primary inductance 33₃ is coupled principally to secondary inductances 35e and 35f.

The high potential terminals of the secondary inductances 35a-35f, inclusive, are connected to ground through adjustably fixed condensers 43a and 44b-44f, respectively, while the low potential terminals of these inductances are connected to ground through the adjustably fixed condensers 34 and 45b-45f, respectively, to form a plurality of oscillation circuits for the several

selected bands. These oscillation circuits are selectively connected to the control grid of the oscillator portion of the tube 24 through a coupling condenser 38 and the contacts 36 of a switch 37. A tuning condenser 42 is selectively connected in parallel with the condenser 43a between the high potential terminal of the secondary inductance 35a and ground, and in parallel with condensers 45b-45f, inclusive, between the low potential terminals of the secondary inductances 35b-35f, inclusive, through the contacts 40 of a switch 41.

The output of oscillator-modulator tube 24 is coupled, by means of a transformer 47, 51, tuned by the adjustably fixed condensers 46 and 52 to the intermediate frequency, to the input of the intermediate-frequency amplifier 53. The output of amplifier 53 is connected to a detector and source of automatic volume control bias voltage 54. The output of detector 54 is connected to an audio-frequency amplifier 55, which in turn feeds into a suitable sound reproducer 56.

Preferably, variable tuning condensers 20, 30 and 42 are ganged for uni-control, as indicated by the dotted line 60. Also, switches 16, 25, 37 and 41 are preferably ganged for uni-control, as indicated by the dotted line 61.

It is not believed necessary to describe the conventional connections by which the various operating voltages are applied to the elements of the vacuum tubes, or by which the AVC bias voltage is applied to the control grid of vacuum tube 17 and to the control grid of the modulator portion of the tube 24. All these connections, unimportant to this invention, are clearly indicated in the diagram. It is believed sufficient to note that the cathode of vacuum tube 17 is connected to ground through a biasing circuit 62, that the cathode of vacuum tube 24 is connected to ground through a biasing circuit 63, and that the element 64 in the direct-current feed to the anode of vacuum tube 17 is a radio-frequency choke coil.

In considering the operation of the above-described system, it is assumed that the switches 16, 25, 37 and 41 are initially in the positions in which they are illustrated in Fig. 2. Under these conditions, inductance 14a is connected in circuit in the input section of the tube 17, inductance 26a is connected in circuit between the output section of the tube 17 and the modulator section of the tube 24, and inductance 35a is connected in circuit in the oscillator portion of the tube 24. With these connections, variable tuning condenser 20 tunes the circuit 20, 12, 14a; variable tuning condenser 30 tunes the circuit 30, 28, 26a; and variable tuning condenser 42 tunes the circuit 42, 35a, 34. Condensers 12 and 34 serve as capacitive coupling devices to complement the electromagnetic couplings in their respective circuits, in a manner well understood in the art. Condenser 28, and also condenser 34, serve as series padding condensers and may be adjustably fixed condensers. Adjustably fixed condensers 18a, 29a and 43a serve as parallel padding condensers. The padding condensers, once adjusted by the manufacturer, are not ordinarily altered.

The values of inductance 14a, variable tuning condenser 20, fixed condenser 12 and adjustably fixed condenser 18a in the first radio-frequency selecting circuit, the values of inductance 26a, variable tuning condenser 30, fixed condenser 28 and adjustably fixed condenser 29a in the second radio-frequency selecting circuit, and the values

of inductance 35a, variable tuning condenser 42 and adjustably fixed condensers 34 and 43a in the tuned oscillator circuit, are so chosen as to obtain satisfactory operation of the superheterodyne receiver in the general broadcast band *a* (Fig. 1), utilizing all, or substantially all, of the full range of variation of variable condensers 20, 30 and 42. During such operation in the general broadcast band, the radio-frequency selecting circuits are tuned to resonance with the signal frequency by variable condensers 20 and 30. The incoming signal frequency is thus selectively amplified and applied to the control grid of the modulator portion of vacuum tube 24. The signal frequency is therein modulated by the frequency produced in the oscillator portion of vacuum tube 24, the frequency of the oscillations being controlled by the tuning of the oscillation circuit by variable condenser 42. As is well understood in the art, such modulation of a signal frequency produces a constant intermediate or beat frequency, which frequency is amplified in the intermediate-frequency amplifier 53 and is detected or rectified in the detector 54 to produce audio frequencies of modulation of the incoming signal wave. These audio frequencies are amplified in the audio-frequency amplifier 55 and are then translated into sound by reproducer 56. Automatic control of the amplification of the received signals is effected by the action of automatic volume control bias potentials produced in the detector and automatic volume control unit 54, and applied to the control grids of vacuum tubes 17 and 24 and of the vacuum tubes in the intermediate-frequency amplifier 53.

When switches 16, 25, 37 and 41 are actuated so that the arms of these switches are in engagement with contacts 15b, 27b, 36b and 40b, respectively, inductance 14b is connected in circuit in the input section of the tube 17, inductance 26b is connected in circuit between the output section of tube 17 and the modulator section of the tube 24, and inductance 35b is connected in circuit in the oscillator portion of the tube 24. Inductance 14b, together with adjustably fixed condenser 21b, functions as a fixed tuned circuit. Similarly, inductance 26b and adjustably fixed condenser 31b function as a fixed tuned circuit. Inductance 35b is an element in the circuit 44b, 35b, 42, 45b, which circuit is variably tuned by variable condenser 42. The variable tuning condenser 42 is connected in parallel with the fixed condenser 45b, the two being connected in series with the adjustably fixed condenser 43b across the inductance 35b.

The values of inductance 14b and adjustably fixed condenser 21b in the first radio-frequency selective circuit, and the values of inductance 26b and adjustably fixed condenser 31b in the second radio-frequency selective circuit, are so chosen and/or adjusted as to obtain in each of these stages a fixed tuned circuit tuned substantially to the mid-frequency of high-frequency band *b* (Fig. 1). The values of inductance 35b, adjustably fixed condenser 44b and fixed condenser 45b in the oscillator stage are so chosen and/or adjusted, having consideration for the maximum and minimum values of variable tuning condenser 42, that the frequency of the oscillations generated in the oscillator portion of the tube 24 varies between such limits as to produce the predetermined intermediate frequency for received signals falling between the limits of high-frequency band *b*, as variable tuning condenser 42 is varied between its maximum and minimum values. In

accomplishing this, condensers 44b and 45b reduce the maximum effective capacitance of the oscillation circuit and also the effectiveness of variable tuning condenser 42. As herein employed, the term "effectiveness" of a tuning element is used to denote the ratio of the maximum effective value of circuit reactance of the same type as that of the tuning element to the minimum effective value of such circuit reactance, as the tuning element is varied between its maximum and minimum values.

Thus, as a result of the action of condensers 44b and 45b in reducing the maximum effective value of the capacitance of the oscillation circuit and in reducing the effectiveness of variable tuning condenser 42, the maximum effective capacitance in the oscillation circuit is considerably smaller than the maximum capacitance of variable condenser 42 and the net effective capacitance variation in the oscillation circuit incident to variation of condenser 42 between its maximum and minimum values is considerably less than the difference between the maximum and minimum capacitances of tuning condenser 42.

In a similar manner, when switches 16, 25, 37 and 41 are actuated so that the arms of these switches are in engagement with other contacts, the inductances connected to such other contacts are connected in the circuits with which the respective switches are associated. Thus, only those individual inductances of inductances 14, 26 and 35, having the same lettered suffix, are connected in circuit at any one time. Furthermore, each individual inductance connected in the first and second radio-frequency selective circuits, except inductances 14a and 26a, is shunted by a separate adjustably fixed tuning condenser (21 for the first radio-frequency selective circuit and 31 for the second radio-frequency selective circuit) to form a fixed tuned circuit tuned substantially to the mid-frequency of the band of corresponding letter (Fig. 1). Also, each individual inductance connected in the oscillator circuit (except inductance 35a) is provided with a separate, adjustably fixed condenser 44 in series with, and a separate fixed condenser 45 in parallel with, the tuning condenser 42, properly to fix the tuning limits of the corresponding oscillation circuit by appropriately reducing the effectiveness of the variable tuning condenser 42. There is thus produced a predetermined intermediate frequency for received signals falling between the limits of the high-frequency band of the corresponding letter, as variable tuning condenser 42 is, for each of such bands, varied between its maximum and minimum values. This relationship is obtained by selectively reducing the effectiveness of the variable tuning condenser 42 as an inverse function of the mean frequency of the respective received-signal bands.

The absolute values of the various elements are, of course, subject to variation over a comparatively wide range depending on design, the location and frequency coverage of the bands, and other factors, so that a table of definite values for the various elements will be of but little assistance. Certain practical considerations may be mentioned, however, and the relative order of magnitudes of certain elements indicated.

For satisfactory operation of a superheterodyne receiver over the general broadcast band *a*, each of the variable tuning condensers 20, 30 and 42 may have a maximum value of the order of 450 micro-microfarads and a minimum value of the order of 15 micro-microfarads. Adjustably fixed

condensers 18a, 29a and 43a generally are small single-leaf padding condensers having a range from 2.5 to 30 micro-microfarads. Fixed condensers 12 and 28 generally are of the order of 2000 micro-microfarads. Adjustably fixed condenser 34 generally is a multiple-leaf padding condenser having a range from 200 to 500 micro-microfarads and set to a value around 450 micro-microfarads.

The satisfactory operation of the superheterodyne receiver of Fig. 2 in high-frequency bands b, c, d, e and f generally requires that in each radio-frequency selective circuit and in the oscillator circuit of the receiver the inductances having correspondingly lettered suffixes decrease in value progressively in the band order mentioned. Adjustably fixed condensers 21b-21f, inclusive, 31b-31f, inclusive, and 44b-44f, inclusive, are preferably small, single-leaf condensers having a range from 2.5 to 30 micro-microfarads. Fixed condensers 45b-45f, inclusive, increase in value progressively in the order mentioned and generally are at least several times greater than the value to which the corresponding series condenser 44 is set. Illustrative of one set of values of fixed condensers 45 which has been used satisfactorily, when the intermediate frequency was approximately 460 kilocycles, are the following:

	Micro-microfarads
45b	100
45c	150
45d	175
45e	200
45f	210

In summary, tuning of the superheterodyne receiver of Fig. 2 is effected by first actuating the control member 61 for the ganged switches 16, 25, 37 and 41 to the position corresponding to the band desired and then actuating the control member 60 for the ganged tuning condensers 20, 30 and 42 to tune the receiver to individual channels in the selected band. It is to be observed that, as a result of the system described, the individual channels in the various bands are separated by displacements of the tuning member 60 and of the scale co-operating therewith, having magnitudes in a ratio, from band to band in the order of decreasing frequency, which is substantially greater than the inverse ratio of the mean frequencies of the bands. Specifically, in the arrangement described, the individual signal channels in the several bands are separated by displacements of the tuning member which are of the same order of magnitude for all of the bands, thus equally facilitating tuning of the receiver in all of its tunable ranges. This feature has been obtained in the receiver of Fig. 2 without increasing the number of variable condensers over that customarily provided in a receiver tunable only over the general broadcast band.

Furthermore, the superheterodyne receiver of Fig. 2 has a high over-all gain in all bands. This is because of the fact that, in the first and second radio-frequency selective circuits, the values of the inductance and capacitance for each fixed tuned circuit therein are so chosen for the several bands as to provide high L/C ratios. High L/C ratios of the same order of magnitude for all bands are also obtained in the oscillator circuits, notwithstanding the use, in the high-frequency bands, of the same relatively large variable tuning condenser 42 that is used for tuning the oscillator circuit in the general broadcast band. These high L/C ratios in the oscillator circuit are ob-

tained by the use of different inductances 35 for the different bands and by utilizing across the respective inductances for the high-frequency bands the relatively large variable tuning condenser 42 in series with a small adjustably fixed condenser 44 and in shunt with successive ones of the fixed condensers 45b-45f, inclusive, of greater value progressively in the order named.

It is to be observed that in the superheterodyne receiver of Fig. 2, not only may the frame and rotor of variable condenser 42 be maintained at ground potential, but also one terminal of each adjustably fixed condenser 44b-44f, inclusive, may be maintained at ground potential. Adjustment of condensers 44b-44f, inclusive, may thus be made without the introduction of error due to the body capacity of the person making such adjustments. The arrangement of the circuits by which this is accomplished results in no substantial sacrifice of the available voltages across the secondary inductances, for most of the voltage across the secondary inductance of the oscillation circuit for each high-frequency band is impressed upon the control grid of the oscillator portion of tube 24. This desirable result occurs notwithstanding the subtractive effect of variable condenser 42 and fixed condenser 45 in the inductive leg of the oscillation circuit, since in the high-frequency bands the reactances of these condensers are small relative to those of the condensers 44.

It is to be observed further that, in the superheterodyne receiver of Fig. 2, the selection of individual channels in the general broadcast band a is effected by the tuning action of the ganged variable tuning condensers 20, 30 and 42, while the selection of individual channels in the high-frequency bands b, c, d, e and f is effected by the tuning action of variable tuning condenser 42 alone. The physical actuation of variable tuning condensers 20 and 30 simultaneously with the actuation of variable tuning condenser 42 has no effect when tuning in the high-frequency bands as, at such times, the former are disconnected and fixed tuned circuits are employed in the radio-frequency selective circuits of the receiver. The use of such fixed tuned circuits, tuned substantially to the mid-frequencies of the respective high-frequency bands, contributes materially to the simplicity of the receiver of Fig. 2 and is not an objectionable expedient for use in low price receivers inasmuch as the frequency coverage of the respective high-frequency bands is relatively small, so that the attenuation of signal frequencies at the upper and lower limits of such bands is not excessive.

In receivers of better quality, it is preferred to vary the tuning of the radio-frequency selective circuits in each high-frequency band as well as in the general broadcast band. Fig. 3 illustrates a superheterodyne receiver in which this is accomplished. Elements in Fig. 3 corresponding to similar elements in Fig. 2 are similarly designated.

The principal difference between Figs. 2 and 3, relative to the radio-frequency selective circuits, is that in Fig. 3 the secondary inductances 14 and 26 are variably tuned within each high-frequency band, as in the case of the secondary inductances 35 of the oscillation circuit of Fig. 2. A further difference between Figs. 2 and 3 is that in Fig. 3 the condensers for each high-frequency band of both the radio-frequency selective circuits and of the oscillator stage are connected to their respective inductances only when the

tuned circuits formed thereby are connected in circuit in the several stages. This provision insures that the response of the receiver is not influenced by absorption dips which might otherwise be present due to the action of unused, spuriously energized, tuned circuits.

Referring more particularly to the first radio-frequency selective circuit, adjustably fixed condensers 73b-73f for inductances 14b-14f, respectively, in the first radio-frequency selective circuit of Fig. 3, correspond to adjustably fixed condensers 44b-44f for inductances 35b-35f, respectively, in the oscillator circuit of Fig. 2 and serve selectively to limit the maximum capacitances in the several tuned circuits of the first radio-frequency selective circuit to values considerably smaller than the maximum capacitance of tuning condenser 20 and to reduce the effectiveness of this condenser. The condensers 73 are selectively connected, through the contacts 71, 72 of a switch 70, between the high potential terminals of the inductances 14 and ground, the arm of switch 70 being connected to the control grid of vacuum tube 17.

Fixed condensers 77b-77f in the first radio-frequency selective circuit of Fig. 3 also serve selectively to reduce, in the high-frequency bands, the effectiveness of variable tuning condenser 20, and correspond to fixed condensers 45b-45f, for variable tuning condenser 42 in the oscillator circuit of Fig. 2. The condensers 77 are selectively connected, through the contacts 75, 76 of a switch 74, between the low potential terminals of the inductances 14 and ground and effectively in parallel with the tuning condenser 20. It is to be noted that no condensers 73 or 77 are provided for the secondary inductance 14a corresponding to the general broadcast band.

Referring now to the second radio-frequency selective circuit, it will be seen that it differs further from the corresponding selective circuit of Fig. 2 in that inductances 26 are inductively energized by primary inductances 78₁, 78₂ and 78₃. In this selective circuit, adjustably fixed condensers 83b-83f, selectively connected in circuit with inductances 26b-26f, respectively, in the high-frequency bands by means of a switch 80 having sets of contacts 81 and 82, correspond to adjustably fixed condensers 73b-73f for inductances 14b-14f, respectively, in the first radio-frequency selective circuit, and serve selectively to limit the maximum capacitance in the several tuned circuits of the second radio-frequency selective circuit to values considerably smaller than the maximum capacitance of tuning condenser 30 and to reduce the effectiveness of this condenser. Fixed condensers 87b-87f, selectively connected in circuit with inductances 26b-26f by means of a switch 84 having sets of contacts 85 and 86, also serve selectively to reduce, in the high-frequency bands, the effectiveness of variable tuning condenser 30, and correspond to fixed condensers 77b-77f for variable condenser 20 in the first radio-frequency selective circuit. Further description of the second radio-frequency selective circuit is believed unnecessary since it is fundamentally similar to the first radio-frequency selective circuit.

Referring now to the oscillator circuit, the condensers 44 and 45 are selectively connected in circuit with their respective inductances 35 by means of the switches 90 and 94, having sets of contacts 91, 92 and 95, 96, respectively, and connected similarly to the selector switches 70 and 74 or 80 and 84 of the radio-frequency selective

circuits. Further discussion of the oscillator circuit of Fig. 3 is believed unnecessary. The remainder of the circuit illustrated in Fig. 3 is similar to, and functions similarly to, that of similar designation illustrated in Fig. 2, so no further description thereof is given.

It may be noted that two automatic volume control connections are provided for the first radio-frequency selective circuit; one, including high resistance 19a, is connected to the low potential end of inductance 14a and is effective when the receiver is operating in the general broadcast band a; the other, including high resistance 19z, is connected to the ungrounded terminal of variable tuning condenser 20 and is effective when the receiver is operating in any of the high-frequency bands b, c, d, e or f. Resistance 19a may be of the order of 0.2 megohm. Resistance 19z is preferably of the order of 2.0 megohms in order to minimize the loading effect on the tuned circuit when operating in band a. The second radio-frequency selective circuit is provided with two automatic volume control connections, similar to those associated with the first radio-frequency selective circuit, the first connection including resistance 39a and the second connection including resistance 39z.

In general, the operation of the superheterodyne receiver of Fig. 3 is the same as that previously described for the receiver of Fig. 2; that is, the switches (70, 74, 80, 84, 90 and 94 in this instance, and preferably ganged for unicontrol, as indicated by the dotted line 97) are set to the position corresponding to the band desired, and then ganged tuning condensers 20, 30 and 42 are actuated to tune the receiver to the individual channels in the selected band. Further, the receiver of Fig. 3 has the feature of the receiver of Fig. 2 by which the individual channels in the various bands are, in general, separated by displacements of the tuning control member 60, and of the scale co-operating therewith, having magnitudes in a ratio, from band to band in the order of decreasing frequency, which is substantially greater than the inverse ratio of the mean frequencies of the bands. The Fig. 3 arrangement is similarly specific to the feature of proportioning the auxiliary reactance elements of the radio-frequency selector system, so that the individual signal channels in the several bands are separated by displacements of the tuning condenser that are of the same order of magnitude for all of the bands. The principal additional feature of the receiver of Fig. 3 is that the radio-frequency selective circuits are variably tuned in each high-frequency band by the same variable tuning condenser employed to tune the corresponding selective circuit in the general broadcast band. To this end, the minimum and maximum values of variable tuning condensers 20 and 30 are such that, when the receiver is adjusted for reception in general broadcast band a, all the individual channels within such band are covered by substantially the entire motion of these variable condensers between their minimum and maximum values. Further, the values of the inductances 14b-14f, adjustably fixed condensers 73b-73f and fixed condensers 77b-77f associated with the tuning condenser 20, and the values of the inductances 26b-26f, adjustably fixed condensers 83b-83f and fixed condensers 87b-87f associated with the tuning condenser 30, are such that all the individual channels within each of the high-frequency bands are also covered by substantially

the entire motion of the variable tuning condensers between their minimum and maximum values.

A compromise between the simplicity of the receiver of Fig. 2 and the advantages of the receiver of Fig. 3 is illustrated in the receiver of Fig. 4. In this latter receiver the radio-frequency selective circuits and the oscillator tuned circuit are variably tuned in each high-frequency band as well as in the general broadcast band, and this by the same variable tuning condenser in each circuit that is utilized to tune the corresponding circuit in the general broadcast band. Further, in the receiver of Fig. 4 the condensers for each high-frequency band are connected to their respective inductances only when the tuned circuits formed thereby are connected in the related circuits of the receiver. However, in this case only one inductance is used in each circuit for all high-frequency bands. This, of course, somewhat reduces the gain obtained in certain bands (particularly in bands *b* and *c*) due to the lower L/C ratio, but the resulting receiver still possess a moderately high over-all gain, as well as possessing great ease in tuning to the individual channels in all bands.

The principal difference between Figs. 3 and 4 is that the separate secondary inductances 14, 26 and 35, each with lettered suffixes *b* to *f*, inclusive, are replaced by three secondary inductances 14₂, 26₂ and 35₂, in the first and second radio-frequency selective circuits and the oscillator circuit, respectively. Incident to this difference is the further difference that primary inductances 11₂, 11₃, 78₂, 78₃, 33₂ and 33₃ are dispensed with. To improve the operation of the receiver in the higher frequency bands, an open-ended primary winding 98 for secondary inductance 26₂ is preferably provided.

All of the elements in Fig. 4, corresponding to similar elements in Fig. 3, are similarly designated. It is believed that a detailed description of Fig. 4 and its operation is unnecessary.

When the variable tuning condenser employed in tuning in the general broadcast band is also employed in tuning in the high-frequency bands, the arrangements heretofore described have been such as to connect the variable condenser in the inductive leg of the tuned circuit when operating in the high-frequency bands. As explained in connection with the variable tuning condenser 42 of the receiver of Fig. 2, no substantial sacrifice of the available voltage across the tuned inductance results from such arrangements. If it is desired, however, to utilize in any circuit all the available voltage across each tuned inductance, the circuit arrangement for such circuit or circuits may be as illustrated in Fig. 5, which is a modification of the first radio-frequency selective circuit of Fig. 3.

All the elements in Fig. 5 corresponding to similar elements of Fig. 3 are similarly designated. The basic change in Fig. 5 over Fig. 3 is that for the high-frequency bands, adjustably fixed condensers 73 and their respective fixed condensers 77 are connected in series between the high potential terminals of the windings 14 and ground, while the variable tuning condenser 20 is connected in parallel with the fixed condensers 77 through the contacts 76 of switch 74. By this expedient, the second arm of switch 74, and contacts 75 engaged thereby, are dispensed with, the low potential terminals of secondary inductances 14_b—14_f, inclusive, being connected through condenser 12 to ground.

With the arrangement of Fig. 5, it is to be observed that adjustably fixed condensers 73 are selectively connected in series with variable tuning condenser 20 selectively to reduce the maximum effective capacitance of the selective circuits, as in Fig. 3. Further, the effectiveness of variable condenser 20 is selectively reduced in each high-frequency band by the fixed condensers 77 selectively connected in parallel therewith, and by the adjustably fixed condensers 73 as well, as in Fig. 3. The full voltage across each tuned inductance is thus impressed upon the control grid of the tube 17, the subtractive effect of condenser 12 being entirely negligible due to its extremely small capacitive reactance at the high frequencies.

The circuit diagram of Fig. 6 illustrates, for the first radio-frequency selective circuit of the receiver of Fig. 3, an embodiment of the invention utilizing a relatively large variable tuning condenser 20 for tuning the receiver over the general broadcast band and utilizing a very small variable tuning condenser 107 for tuning the receiver over each of the high-frequency bands. All the elements of Fig. 6 corresponding to similar elements of Fig. 3 are similarly designated.

The principal difference between the first radio-frequency selective circuit of Fig. 6 and the corresponding circuit of Fig. 3 is the substitution of the small variable condenser 107 for the combination, in the several high-frequency bands, of variable tuning condenser 20 and the condensers 73 and 77. As a result, condensers 73_b—73_f and 77_b—77_f, and also switch 74, are dispensed with. Further differences are: the addition of adjustably fixed condensers 108_b—108_f, connected similarly to condensers 73_b—73_f in Fig. 3, to provide predetermined fixed capacitance selectively in parallel with the small variable tuning condenser 107 selectively to reduce the effectiveness of the small variable condenser 107 for the respective high-frequency bands; the connection of the low potential terminals of secondary inductances 14_b—14_f, inclusive, to ground through fixed condenser 12; and a rearrangement of the connection for variable tuning condenser 20 so that it is connected in circuit only when switch 70 is in the position corresponding to general broadcast band *a*. If desired, adjustable condenser 18_a, used as a parallel padding condenser for variable tuning condenser 20 in the general broadcast band, may be connected, as illustrated, so that it is in circuit only when variable tuning condenser 20 is in circuit.

Variable tuning condenser 107 is preferably arranged to operate conjointly with variable tuning condenser 20, in which case condenser 107 is conveniently constructed by insulating an end stator plate of condenser 20 from the other stator plates of the condenser, and utilizing such separately insulated end stator plate and the adjacent end rotor plate as variable condenser 107. As a result, actuation of variable tuning condenser 107 is effected (as illustrated) by operation of the same tuning control member 60 that serves to control the tuning of the receiver to the individual channels in the general broadcast band. An electrostatic shield is preferably interposed between the separately insulated end stator plate and the other stator plates in order to minimize undesirable couplings between such stators when operating in the high-frequency band. Alternatively, but less desirably, variable tuning condenser 107 may be a structurally separate condenser the control of which is effected by a con-

control member individual thereto, with provision that the displacements thereof are indicated on the same scale as the displacements of tuning control member 60. Still less desirably, the control of a structurally separate variable tuning condenser 107 may be effected by a control member individual thereto having its own indicating scale. It is essential, however, in each case that variable tuning condenser 20 be excluded from the tuned circuit for each high-frequency band and that the entire tuning in each such band be obtained exclusively by variable tuning condenser 107.

The minimum and maximum values of tuning condenser 107, together with the values of the inductances 14b-14f and adjustably fixed condensers 108b-108f, are so chosen that the individual channels in each high-frequency band are separated by displacements of tuning control member 60, and of the scale operated therewith, having magnitudes in a ratio to the magnitude of the displacement of the variable tuning condenser 20 required to effect separation of the individual channels in the general broadcast band which is greater than the ratio of the mean frequency of the broadcast band to the mean frequencies of the respective high-frequency bands. Preferably, the values of the elements enumerated are such that all the individual channels within each band are, for each band, spread over the complete operating range of tuning control member 60. In effecting this relationship, adjustably fixed condensers 108b-108f are set so that they progressively reduce the effectiveness of variable tuning condenser 107 as the band within which the receiver is arranged to tune is higher in the frequency spectrum.

The principles of the modification illustrated in Fig. 6 may be utilized in any one or more of the tuned circuits of the receivers heretofore described.

The diagram of Fig. 7 illustrates, for the first radio-frequency selective circuit of a receiver, a modification of the circuit diagram of Fig. 6. All the elements of Fig. 7, corresponding to similar elements of Fig. 6, are similarly designated. There are two principal differences between Fig. 6 and Fig. 7. The first of these differences is the elimination of the small variable tuning condenser 107 for tuning within each of the high-frequency bands, and the assumption of the functions of condenser 107 by the relatively large variable tuning condenser 20. This is effected by inserting a small fixed condenser 109 in series with variable tuning condenser 20 when switch 70 is in the position corresponding to any high-frequency band, together with an arrangement such that switch 70 short-circuits small fixed condenser 109 when it is in a position corresponding to the general broadcast band a. This first difference may be incorporated directly in the diagram of Fig. 6 by dispensing with variable condenser 107 and connecting small fixed condenser 109 between the control grid of tube 17 and the ungrounded terminal of variable tuning condenser 20. In Fig. 7 condenser 109 is so connected. The extra variable tuning condenser 107 of the modification illustrated in Fig. 6 is thus eliminated and tuning of the first radio-frequency selective circuit in all bands is thereby effected entirely by variable tuning condenser 20.

The second principal difference between Fig. 6 and Fig. 7 is the permanent connection of the ungrounded terminals of adjustable condensers 18a and 108b-108f, inclusive, to their respective

secondary inductances 14, and the permanent connection of contact 71a of switch 70 with the ungrounded side of variable tuning condenser 20, thereby eliminating the necessity of contacts 72 of switch 70. To insure that the response of the receiver is not influenced by absorption dips which might otherwise be present, due to the action of any unused, spuriously energized, circuits, switch 110 having contacts 111 is provided. In practice, switch 110 may be on the same switch deck with switch 70. In such case, switch 110 and its contacts 111 correspond structurally to the portion of switch 70 in Fig. 6 having contacts 72. To avoid confusion, however, switch 110 is illustrated and designated in Fig. 7 as a separate switch. Switch 110 is arranged to short-circuit the secondary inductance 14 for the high-frequency band next below the high-frequency band to which the receiver is tuned, as a result of the position of switch 70. The short-circuiting of only the secondary inductance corresponding to the adjacent lower high-frequency band is sufficient for many commercial purposes, since it is found that such objectionable absorption dips as may occur are due primarily to the unused tuned circuit involving such adjacent inductance.

When switch 70 is in the position illustrated, corresponding to general broadcast band a, the arm of switch 70 is in engagement with contact 71a to connect the control grid of vacuum tube 17 with the high potential terminal of secondary inductance 14a and to short-circuit fixed condenser 109. Under these conditions, variable tuning condenser 20 serves to tune the illustrated stage of the receiver over the general broadcast band a.

When switches 70 and 110 are in the position corresponding to any high-frequency band, the tuning of the illustrated selective circuit of the receiver over such high-frequency band is effected by variable tuning condenser 20 having fixed condenser 109 in series therewith, the operation in other respects being similar to the operation of Fig. 6 except that in high-frequency bands c, d, e and f the secondary inductances 14b, 14c, 14d and 14e, respectively, are shorted.

If it is desired to short-circuit the secondary inductances for all high-frequency bands below that in which the receiver is tunable, this may readily be effected in a conventional manner by means of an arcuate follower at the outer end of the arm of switch 110 arranged to maintain circuit between such arm and the contacts 111 for bands below that for which switch 110 is positioned, or in any other conventional manner.

It is to be observed that in the diagram of Fig. 7, secondary inductance 14a, together with coupling condenser 12, is always connected across variable tuning condenser 20, irrespective of the band to which the receiver is tuned. No substantial difficulty results from such an arrangement, however, due to the fact that when the receiver is operating in any high-frequency band the reactance of secondary inductance 14a is relatively so high in comparison to that of variable tuning condenser 20 that its effect on the circuit is negligible.

The circuit elements illustrated in Fig. 7 are so proportioned, as in Fig. 6, to obtain the previously described desirable operating characteristics in the several bands.

The radio-frequency selective circuit of Fig. 7 lends itself to a simple, compact and inexpensive construction for secondary coils 14 and adjustable condensers 18 and 108. Furthermore, such an ar-

rangement utilizes only one switch bank, only one fixed condenser and no tuning condenser other than the tuning condenser 20 necessary to tune the receiver in the general broadcast band. In addition, the gain obtained with the selective circuit of Fig. 7 is considerably higher, particularly in the higher frequency bands, than that customarily obtained in multi-band receivers, and fairly uniform for the several bands.

If it is desired to obtain gains for the high-frequency bands greater than those obtained with the selective circuit of Fig. 7, and to have such gains still more uniform for the several bands, the selective circuit of Fig. 7 may be modified by employing a separate condenser 109, preferably of the adjustably fixed variety, for each of the high-frequency bands, and selectively connecting such condensers 109 in series with variable tuning condenser 20, preferably at the low potential terminals of such condensers 109, by a suitable switch ganged with switch 70. In the resulting circuit, condensers 109 serve selectively to reduce the maximum effective capacitance in the tuned circuits for the several bands to values considerably less than the maximum capacitance of variable tuning condenser 20 (similarly as do condensers 44 for the variable tuning condenser 42 of Fig. 2), while condensers 108, assisted by condensers 109, serve selectively to reduce the effectiveness of the variable tuning condenser 20 similarly, respectively, as do condensers 45 and 44 for the variable tuning condenser 42 of Fig. 2. In Fig. 2, however, the condensers 45 are in parallel with the variable condenser 42 alone, while in Fig. 7 (both as illustrated and as modified as outlined above) the corresponding condensers 108 are in parallel with the combination of the variable tuning condenser and the small series condenser. In the latter cases, therefore, the relatively large and somewhat expensive fixed condensers 45 are not required.

Although the invention has been described in connection with the tunable systems of super-heterodyne receivers, the invention is applicable to the tunable system of any type of receiver. Further, although the invention has been described in connection with certain preferred bands of frequencies, the invention is applicable where other bands of frequencies are involved. Thus, the location and/or frequency coverage of such other bands of frequencies may differ from those herein described, but so long as the receiver is to tune to the general broadcast band and to at least one high-frequency band, or is to tune to at least two high-frequency bands widely spaced in the frequency spectrum either by other bands of the receiver or by frequency ranges over which the receiver is not tunable, this invention provides that in such cases the receiver will be tunable with ease, and with substantial dial spacings, to individual channels in all such bands.

Inasmuch as many changes could be made in the above constructions and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The method of operating a multi-band radio receiver having band-selecting means and tuning means adjustable between minimum and maximum settings, which comprises adjusting the re-
active constants of the receiver selectively to tune

it to any one of a plurality of bands while maintaining L/C ratios for the several bands that are of the same order of magnitude, and varying the effectiveness of said tuning means in accordance with the band selected to effect separation of adjacent signal channels of the same frequency separation within the respective bands by displacements of said tuning means that are of the same order of magnitude for all of said bands.

2. In a multi-band radio receiver, a tunable system comprising reactance means of a given type, variable tuning reactance means of the opposite type connected in circuit with at least a portion of said first-named reactance means to form a circuit tunable over a given frequency band, auxiliary reactance means of said opposite type, and switching means for including said auxiliary reactance means in circuit with said tuning reactance means and at least a portion of said first named reactance means to form a circuit tunable over a second frequency band and to modify the effectiveness of said tuning means in tuning the circuit, said auxiliary reactance means being so proportioned, relative to the first two reactance means and their circuit relation, that the L/C ratios of the circuits for the respective bands are of the same order of magnitude.

3. In a multi-band radio receiver, a tunable system comprising reactance means of a given type, variable tuning reactance means of the opposite type connected in circuit with at least a portion of said first-named reactance means to form a circuit tunable over a given frequency band, auxiliary reactance means of said opposite type, and switching means for including said auxiliary reactance means in circuit with said tuning reactance means and at least a portion of said first two reactance means to form a circuit tunable over a second frequency band and to modify the effectiveness of said tuning means in tuning the circuit, said auxiliary reactance means being so proportioned, relative to the first two reactance means and their circuit relation, that the L/C ratios of the circuits for the respective bands are of the same order of magnitude and adjacent signal channels of the same frequency separation within the respective bands are separated by displacements of said tuning means of the same order of magnitude.

4. In a multi-band radio receiver, a tunable system comprising a plurality of reactance means of a given type, variable tuning reactance means of the opposite type, a plurality of auxiliary reactance means of said opposite type, and switching means for connecting, in one position thereof, a selected one of said first reactance means in circuit with said tuning means to form a circuit tunable over a given frequency band and for connecting, in the several other positions thereof, selected ones of said first reactance means in circuit with said tuning means and selected ones of said auxiliary reactance means to form circuits severally tunable over different high-frequency bands each widely spaced upwardly in the radio-frequency spectrum from said given band, each of said auxiliary reactance means being so proportioned relative to said other reactance means and so connected in circuit therewith by said switching means that the L/C ratios of the circuits for the respective bands are of the same order of magnitude and adjacent signal channels of the same frequency separation within the respective bands are separated by displacements of said tuning means of the same order of magnitude.

5. In a multi-band radio receiver, a tunable system comprising; a plurality of inductance elements of different values; two variable condensers of substantially different maximum values; a plurality of auxiliary condensers, one for each of said inductance elements; and means for connecting said auxiliary condensers effectively in shunt with their corresponding inductance elements and for selectively connecting the larger variable condenser effectively in shunt with the largest inductance element to form a circuit tunable over a relatively wide low-frequency band, or the smaller variable condenser effectively in shunt with the other inductance elements individually to form circuits severally tunable exclusively by the smaller variable condenser over different and relatively narrow high-frequency bands, said inductance elements and condensers being relatively so proportioned that adjacent signal channels of the same frequency separation within the several bands are separated by displacements of the variable condensers tuning the respective bands having magnitudes in a ratio, from band to band in the order of decreasing frequency, which is substantially greater than the inverse ratio of the mean frequencies of said bands.

6. In a multi-band radio receiver, a tunable system comprising; a plurality of inductance elements of different values; two variable condensers of substantially different maximum values and having common adjusting means; a plurality of auxiliary condensers, one for each of said inductance elements; and means for connecting said auxiliary condensers effectively in shunt with their corresponding inductance elements and for selectively connecting the larger variable condenser effectively in shunt with the largest inductance element to form a circuit tunable over a given wide low-frequency band, or the smaller variable condenser effectively in shunt with the several other inductance elements individually to form circuits severally tunable exclusively by the smaller variable condenser over different high-frequency bands each widely spaced upwardly in the radio-frequency spectrum from said given band, said inductance elements and condensers being relatively so proportioned that the displacements of the larger variable condenser in tuning between adjacent signal channels within the given band are of the same order of magnitude as are the displacements of the smaller variable condenser in tuning between adjacent signal channels of the same frequency separation in the several high-frequency bands.

7. In a multi-band radio receiver, a tunable system comprising; two inductance elements of substantially different inductance; a variable condenser; two auxiliary condensers; and means for connecting said variable condenser effectively in shunt with the larger inductance element to form a circuit tunable over a given wide low-frequency band and for selectively connecting one of said auxiliary condensers in series with said variable condenser and said series-connected condensers and said second auxiliary condenser effectively in shunt with the smaller inductance element to form a circuit tunable over a high-frequency band widely spaced upwardly in the radio-frequency spectrum from said given band, said inductance elements and condensers being relatively so proportioned that adjacent signal channels of the same frequency separation within the high-frequency respective band are separated by a displacement of said variable con-

denser having a magnitude in a ratio to the magnitude of the displacement of said variable condenser required to produce separation of adjacent signal channels of the same frequency separation within said given frequency band, which is substantially greater than the ratio of the mean frequency of the given frequency band to the mean frequency of the high-frequency band.

8. In a multi-band radio receiver, a tunable system comprising; two inductance elements of substantially different inductance; a variable condenser having a relatively large ratio of maximum to minimum capacitance; two auxiliary condensers each having a capacitance substantially smaller than the maximum capacitance of said variable condenser; and means for connecting said variable condenser effectively in shunt with the larger inductance element to form a circuit tunable over a relatively wide low-frequency band and for selectively connecting one of said auxiliary condensers in series with said variable condenser and said series-connected condensers and said second auxiliary condenser effectively in shunt with the smaller inductance element to form a circuit tunable over a high-frequency band widely spaced upwardly in the frequency spectrum from said low-frequency band, said inductance elements and condensers being relatively so proportioned that adjacent signal channels of the same frequency separation within the high-frequency band are separated by a displacement of said variable condenser having a magnitude in a ratio to the magnitude of the displacement of said variable condenser required to produce separation of adjacent signal channels of the same frequency separation within said low-frequency band which is substantially greater than the ratio of the mean frequency of the low-frequency band to the mean frequency of the high-frequency band.

9. In a multi-band radio receiver having a vacuum tube input circuit one side of which is effectively grounded, a tunable system comprising; two inductance elements of substantially different inductance; a variable condenser having one terminal thereof effectively grounded; two auxiliary condensers; and means for connecting said variable condenser effectively in shunt with the larger inductance element with the ungrounded terminal of said variable condenser connected to the ungrounded side of said vacuum tube input circuit to form a circuit tunable over a relatively wide low-frequency band, and for selectively connecting one of said auxiliary condensers in series with said variable condenser at the high potential side thereof and said series-connected condensers and said second auxiliary condenser effectively in shunt with the smaller inductance element with the high potential terminals of both said auxiliary condensers connected to the ungrounded side of said input circuit to form a circuit tunable over a high-frequency band widely spaced upwardly in the frequency spectrum from said low-frequency band, said inductance elements and condensers being relatively so proportioned that adjacent signal channels of the same frequency separation within the high-frequency band are separated by a displacement of said variable condenser having a magnitude in a ratio to the magnitude of the displacement of said variable condenser required to produce separation of adjacent signal channels of the same frequency separation within said low-frequency band which is substantially greater than the ratio of the mean

frequency of the low-frequency band to the mean frequency of the high-frequency band.

10. The method of operating a multi-band radio receiver having band-selecting means and a tuning element variable between minimum and maximum values, which comprises adjusting the reactive constants of the receiver selectively to tune it to any one of a plurality of bands while maintaining L/C ratios for the several bands that are of the same order of magnitude, and varying the effectiveness of said tuning element in accordance with the band selected to effect separation of adjacent signal channels of the same frequency separation within the respective bands by displacements of said tuning element having magnitudes in a ratio, from band to band in the order of decreasing frequency, which is substantially greater than the inverse ratio of the mean frequencies of the said bands.

11. In a multi-band radio receiver, a tunable system comprising reactance means of a given type, variable tuning reactance means of the opposite type connected in circuit with at least

a portion of said first-named reactance means to form a circuit tunable over a given frequency band, auxiliary reactance means of said opposite type and switching means for including said auxiliary reactance means in circuit with said tuning reactance means and at least a portion of said first-named reactance means to form a circuit tunable over a second frequency band and to modify the effectiveness of said tuning means in tuning the circuit, said auxiliary reactance means being so proportioned, relative to the first two reactance means and their circuit relation, that the L/C ratios for the respective bands are of the same order of magnitude and adjacent signal channels of the same frequency channel within the respective bands are separated by displacements of said tuning means having magnitudes in a ratio from one of the bands to the other in the order of decreasing band frequency, which is substantially greater than the inverse ratio of the mean frequencies of the corresponding bands.

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