

Jan. 19, 1943.

C. S. ROOT

2,309,014

MULTIBAND TUNING SYSTEM

Filed Aug. 29, 1941

3 Sheets-Sheet 1

Fig. 1.

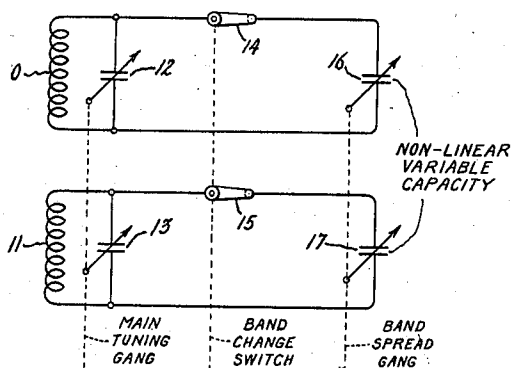


Fig. 2.

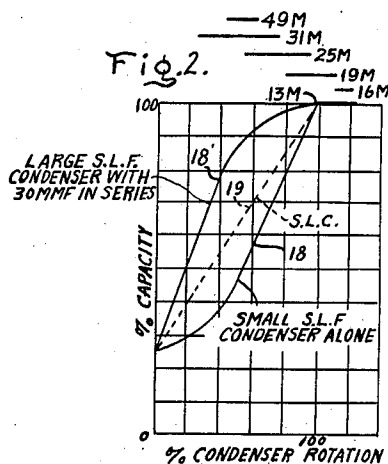


Fig. 4.

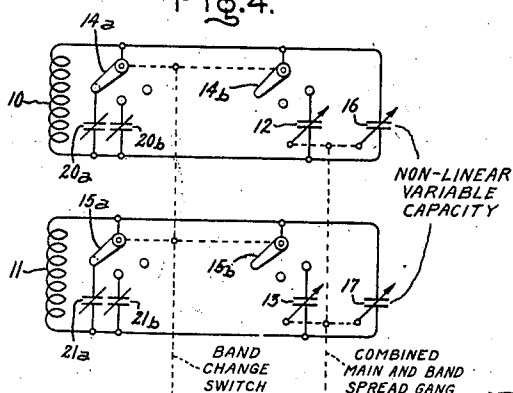


Fig. 3.

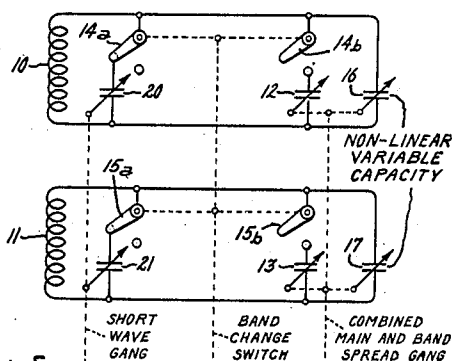
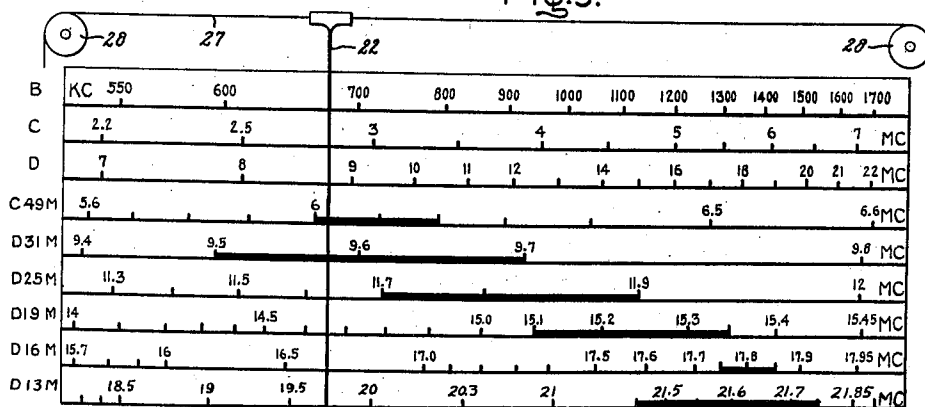


Fig. 5.



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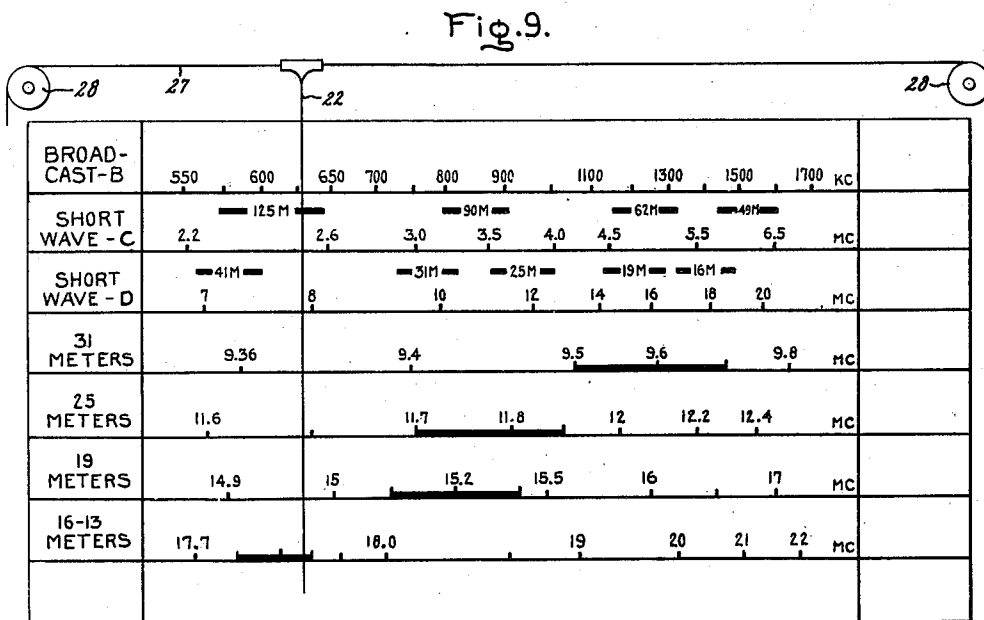
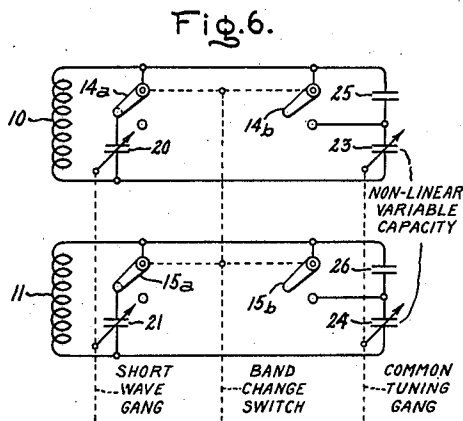
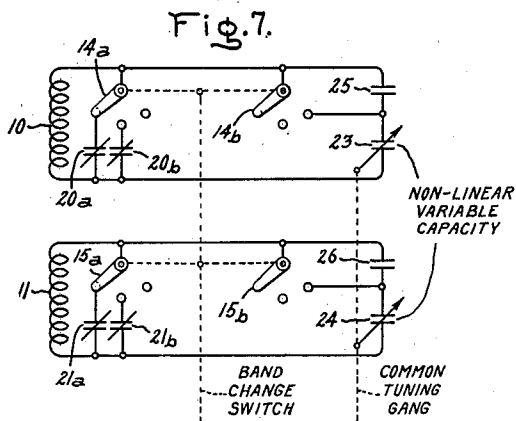
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2,309,014

MULTIBAND TUNING SYSTEM

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3 Sheets-Sheet 2



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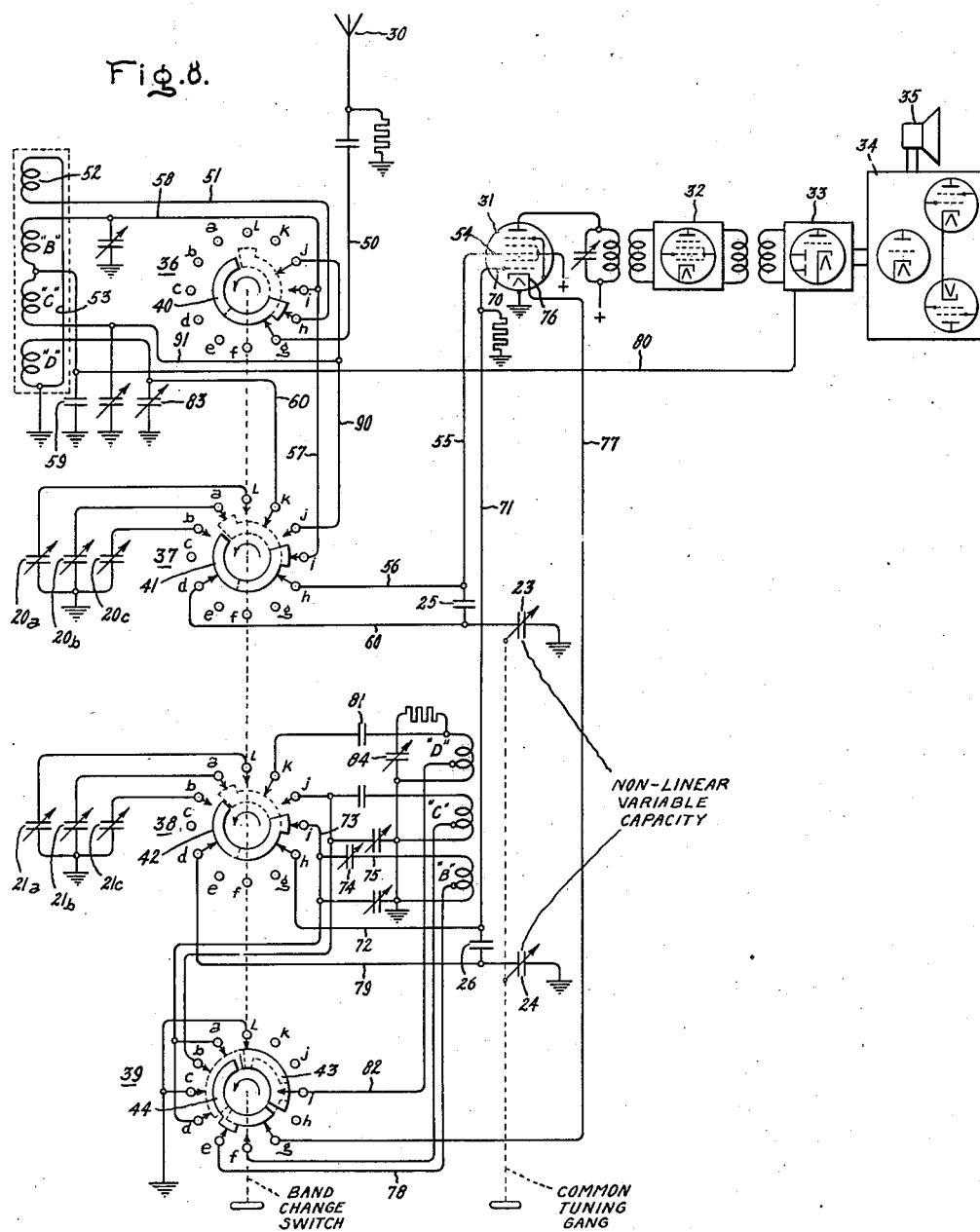
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2,309,014

MULTIBAND TUNING SYSTEM

Filed Aug. 29, 1941

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,309,014

MULTIBAND TUNING SYSTEM

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Application August 29, 1941, Serial No. 408,739

15 Claims. (Cl. 250—40)

My invention relates to a multi-band tuning system particularly suited to the requirements of a multi-band radio receiver adapted to receive programs within the standard broadcast band and also within one or more of the short wave broadcast bands.

The present standard American broadcast band is slightly wider than 1000 kilocycles, extending from about 550 kc. to 1600 kc. For convenience, this band may hereinafter be termed the "broadcast" or "B" band. The radio frequency spectrum is also sometimes arbitrarily divided into several broad high frequency bands. For the purposes of illustration I may hereinafter refer to the band extending from about 2.2 mc. to 7 mc. as the "C" band, and to the band extending from about 7 mc. to 22 mc. as the "D" band, since these subdivisions within the high frequency spectrum are those adopted in one commercial practice.

Within the "C" and "D" bands are to be found a number of widely separated bands, called the "short wave broadcast bands." They are also commonly known as the 49, 31, 25, 19, 16, 13 meter bands, etc., because each of these bands is relatively narrow, having a width of from 100 to 350 kc., and lies in the vicinity of a frequency corresponding to one of these wave lengths. The frequencies of the important short wave broadcast stations of the world are grouped within these narrow bands and there are few stations located in the relatively wide ranges between these bands which are of interest to the general public.

If coil switching is employed in conventional superheterodyne broadcast receivers in order to permit the usual gang tuning condenser to operate over the "C," "D," or higher frequency bands, as well as over the "B" band, large sections of the tuning scales for the high frequency ranges are inactive. Furthermore, the tuning adjustments become increasingly critical for the higher frequency short wave broadcast bands as the ratio of band width to mean band frequency decreases. Accordingly, various arrangements have heretofore been proposed to provide so-called band spread tuning. Such systems in general have incorporated switching means for selecting a desired short wave band and special tuning means for expanding the tuning range over each selected band in order to permit accurate selection of each short wave broadcast station. Each of these narrow bands is therefore sometimes termed a "spread band."

To the best of applicant's knowledge, it has

heretofore been thought that satisfactory band spread tuning could only be accomplished by the addition of receiver elements of special design to those normally required in the receiver. For example, some systems have used different inductance coils for each spread band, either tuned in conjunction with different padding capacitors in series with the main gang condenser, or in conjunction with a specially designed cut plate gang condenser; others have used variable inductance tuning devices of special design; still others have used special mechanical tuning drive arrangements in conjunction with band switching and indexing means.

It is an important object of my invention to provide an improved band spread tuning system wherein the indexing and switching operations are greatly simplified and wherein a minimum number of circuit elements are required.

It is specifically an object of my invention to provide an improved tuning system for a multi-band radio receiver which requires no band spread tuning inductances of special design and which permits all of the desired spread bands to be tuned by a single variable capacity device.

Briefly, preferred embodiments of my invention incorporate a main tuning capacitor assembly which may be adjusted to any one of a plurality of preselected values so as to select any one of a corresponding plurality of short wave broadcast bands. A single variable tuning capacitor assembly is then utilized to provide band spread tuning over each band, the tuning variation characteristics of the variable tuning assembly being so correlated to the preselected capacity values of the main tuning assembly that adjustment to any station within each of the spread bands is easily and accurately accomplished.

It is specifically an object of my invention to provide an improved tuning system for a multi-band receiver which is capable of operation over the standard broadcast band and one or more of the short wave broadcast bands, or capable of operation over at least two of the short wave broadcast bands, and which employs only the usual tuning inductances and a single variable capacity device for spreading all frequency bands approximately the same amount.

Still another and more specific object of my invention is to provide an improved tuning system for a multi-band receiver wherein the same tuning capacitor assembly utilized for tuning over the broadcast band is also utilized to provide band spreading over a plurality of short

wave broadcast bands, without recourse to complicated switching arrangements or special band spreading inductance devices.

A further object of my invention is to provide an improved band spread tuning system for a multi-band receiver which gives high quality performance and yet requires only a few standard electrical parts that are relatively inexpensive and readily available on the market.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 is a simplified schematic diagram of one circuit arrangement embodying my invention; Fig. 2 is a graphical representation of the capacity variation characteristics of one form of variable capacity device which may be utilized in tuning systems constructed in accordance with my invention; Figs. 3 and 4 are simplified schematic diagrams illustrating other embodiments in my invention; Fig. 5 represents one form of straight-line tuning indicator and scale assembly which may be used with the embodiments illustrated in Figs. 3 and 4; Figs. 6 and 7 are simplified diagrammatic diagrams illustrating further modifications of my invention; Fig. 8 is a circuit diagram of a multi-band superheterodyne radio receiver in which those circuits necessary to a complete understanding of my invention are represented in detail and in which those circuits which may be conventional are merely indicated in simplified block form; and Fig. 9 represents one form of straight-line tuning indicator and scale assembly which may be used with the embodiments illustrated in Figs. 6, 7 and 8. Corresponding reference numerals have been applied to corresponding elements in the several figures of the drawings wherever possible.

Each of the switch elements associated with the band change switches in the schematic diagrams of Figs. 1, 3, 4, 6 and 7 is shown in such a position that band spread tuning may be accomplished over one or more selected short wave broadcast bands. For the purposes of illustration, each of these diagrams may be taken to illustrate the radio frequency and oscillator tuning circuits in a superheterodyne radio receiver of the type having a two-gang tuning capacitor assembly. For example, in each diagram the inductance 10 may be considered as the radio frequency tuned circuit inductance, and the inductance 11 as the oscillator tuned frequency determining circuit inductance. These inductances are tuned in the usual manner by means of variable capacitors 12 and 13, respectively, which are mechanically coupled together or ganged for simultaneous adjustment by a common actuating or uni-control means, indicated conventionally by the dashed line interconnecting their rotors.

As is well understood in the art, in a superheterodyne receiver the tuning capacitors 12 and 13 are arranged to "track" over their tuning ranges so as to maintain a constant frequency difference between the resonant frequencies of the circuits tuned thereby, this frequency difference being equal to the intermediate frequency of the receiver. It will be obvious that the usual padding and trimming capacitors, omitted to simplify the diagrams, may be utilized to assist in securing this result. It will also be

obvious that one or more additional tuned circuits may also be included, as where the receiver incorporates one or more radio frequency amplifying stages. To further simplify the sketches, only a single fixed inductance has been shown in each tuned circuit, although it will be understood that compound or tapped inductances, or a plurality of inductances, may be used in accordance with common practice and that these may be switched by the operation of the band change switch. While as a practical matter my invention is particularly applicable to the superheterodyne type of receiver, it will be appreciated that it might be applied to a tuned radio frequency type of receiver, in which case each of the tuned circuits is maintained tuned to the same radio frequency. It is believed that these and other obvious details and modifications will be apparent to those skilled in the art of radio receiver design.

Referring now particularly to Fig. 1, when it is desired to tune the receiver over one of the short wave spread bands, the movable contact members 14 and 15 of the band change switch are moved to the position shown by means of a suitable mechanical uni-control member, indicated schematically by the dashed line. It will be observed that the variable capacitors 16 and 17 are thereby connected respectively in shunt to the main tuning capacitors 12 and 13. These capacitors 16 and 17 are similarly ganged together for uni-control operation and comprise the two sections of a band spread gang assembly.

As previously mentioned, the capacitors 12 and 13 may be utilized in conjunction with one set of inductance coils for tuning over the "B" band and in conjunction with other sets of coils for tuning over the "C," "D" or other high frequency ranges. In Fig. 1 it may be assumed that the circuits 10, 12, and 11, 13 are capable of adjustment so that the receiver may be tuned over one of the higher frequency ranges, for example, the "D" band, which band in turn includes the 31, 25, 19, 16, and 13 meter short wave broadcast bands.

One of these narrow short wave bands is next selected or "spotted" by indexing the main tuning gang assembled to a predetermined angular position. This position is such that, in the absence of the capacitors 16 and 17, the circuits would be tuned to frequencies slightly higher than those required to tune the receiver to the desired short wave band. This operation may be carried out by any one of a large number of mechanical indexing or push button tuning mechanisms which are well known and commonly employed in present-day entertainment receivers.

In accordance with my invention it is proposed to secure vernier tuning over any one of the selected short wave bands through operation of the capacitors 16 and 17 of the band spread gang assembly. It has heretofore been thought that satisfactory band spreading could not be accomplished in this manner because a variation of approximately 20 micromicrofarads is required for tuning over the 31 meter band, whereas successively smaller capacity ranges are required for the higher frequency spread bands, down to a tuning range of only about 1.5 micromicrofarads for the 13 meter band. Thus it has been thought that a variable capacitor having the range required for the 31 meter band would give successively less band spread on the higher frequency bands, or conversely that a variable capacitor having the range required for the 13 meter band

would give more and more incomplete coverage of the lower frequency spread bands. Contrary to these beliefs, applicant has found it possible to secure satisfactory band spread tuning over all of these bands with only the circuit elements shown in Fig. 1. The manner in which this is achieved will now be explained in greater detail.

It will be recalled that the various short wave broadcast bands are only from 100 to 350 kilocycles wide, whereas the broadcast band is over 1000 kilocycles wide. Experience has shown that it is unnecessary to spread these short wave banks so that they occupy much greater space on the receiver tuning scale than 100 to 350 kc. occupies on the scale for the broadcast band. Otherwise, it would be equally desirable to employ further spreading of the broadcast band, which has been shown to be uneconomical and unnecessary. Consequently, none of the short wave broadcast bands need occupy more than about one-third of the total range of the tuning indicator scale associated with the receiver, assuming that the dial calibration for the broadcast band occupies the entire tuning range.

In accordance with my invention the plates of each of the variable capacitors 16 and 17 are given such shapes that within approximately the first third of the capacitor rotation a wide enough capacity variation is secured to cover the lowest one of the bands to be spread, e. g., the 31 meter band, whereas within approximately the last third of its rotation the capacity variation is only sufficient to cover the highest one of the bands to be spread, e. g., the 13 meter band. Intervening bands can then be positioned at intervening positions of the capacitor rotations so as to give the necessary intermediate capacity variation. It then only remains to preset the main tuning gang capacitors 12 and 13 at such values that rotation of the band spread gang capacitors 16 and 17 takes place over the proper portions of their ranges for each of the spread bands.

It is customary in present practice to calibrate radio receiver tuning scales in terms of frequency. Hence, the tuning capacitors commonly employed have plates so shaped as to provide an approximation to a straight-line frequency curve. The curve 18 in Fig. 2 illustrates the manner in which the capacity varies with angular position of the rotor in a capacitor of this type. This curve is of course a non-linear capacity curve. A linear capacity curve, or straight-line capacity curve, is indicated by the dashed line 19 for purposes of comparison. Near the minimum capacity setting, corresponding to the full open position, the rate of change of capacity is relatively slow. It continuously increases up to the maximum capacity setting, corresponding to the full closed position, where the slope of the curve is relatively great.

It so happens that the capacity curve produced by a straight-line frequency capacitor is very close to the ideal curve which will provide equal spreading for all bands in accordance with my invention. In a system using this type of capacitor each spread band may be so "spotted" on the band spread capacitor by presetting the main tuning gang capacitors 12 and 13, that it includes a point in the range of movement of the rotor at which the rate of frequency variation is the same as for a point in each of the other spread bands. These points will necessarily occur progressively nearer the position of slowest capacity variation as the band frequency

increases. This spotting of the spread bands on the non-linear variable capacitor the characteristic of which is indicated at 18 in Fig. 2 is shown by the heavy horizontal lines in the upper portion of the figure. These lines have legends agreeing with the spread bands indicated in Fig. 5. However, the shape of the capacity curve is not critical and I may use capacitors having other non-linear capacity curves giving only approximately uniform band spread where it is more economical to do so. For example, there is on the market a so-called "modified straight-line frequency" capacitor which is often used in lower-priced superheterodyne receivers. I have found that in a particular receiver, such a capacitor can be used to spread the 13 meter band from about .1 to .3 of its total rotation and to spread the 31 meter band from about .4 to .8 of its total rotation. This type of capacitor therefore gives proportionately less spread over the 13 meter band, but even so this is greater than the spread which is obtained when using such a capacitor for tuning over the same frequency range, i. e., 350 kc., near the high frequency end of the broadcast band.

It will be appreciated that the tuning system of Fig. 1 requires one scale pointer and drive mechanism for the main tuning gang assembly and a separate scale pointer and drive mechanism for the band spread gang assembly. Figs. 3 and 4 show modifications of my invention which permit a single tuning indicator and scale assembly to be used for all bands. In these embodiments both the main tuning gang and the band spread gang are combined in one assembly and mechanically interconnected for simultaneous movement. A single tuning indicator or pointer may therefore be used with this common tuning assembly. In these modifications each section of the band change switch has two movable members, 14a, 14b, and 15a, 15b, for switching the various capacitors in and out of circuit with the inductances 10 and 11, respectively.

In the modification of Fig. 3 a separate short wave gang assembly, comprising the variable capacitors 20 and 21, is provided for presetting or "spotting" the circuits in order to select the various short wave broadcast bands. The capacitors 20 and 21 may be indexed by any of the many suitable mechanical push button arrangements known to the art, in which case no tuning indicator is required for them. With the band change switch in the position illustrated, only the band spread capacitors 16 and 17 are connected in shunt to the tuned circuits 10, 20 and 11, 21, respectively. Band spread tuning may now be accomplished in the same manner as in the modification of Fig. 1. When the band change switch is moved to its alternate position, the capacitors 20 and 21 are removed from the circuit and the main tuning capacitors 12 and 13 are switched into the circuit. The inductances 10 and 11 may now be tuned over one of the "B," "C" or "D" bands by the capacitors 12, 16, and 13, 17, in parallel. In a practical construction the capacitors 16 and 17 may comprise a few rotor and stator plates which are carried by the same frame assembly as the rotor and stator plates of the main tuning capacitors 12 and 13 but electrically isolated from them.

In the modification of Fig. 4 a plurality of individual capacitors 20a, 21a and 20b, 21b are provided instead of the short wave gang assembly 20, 21 of Fig. 3. The capacitors in each of

these pairs are preset for "spotting" the short wave spread bands on the band spread condenser in the same manner as the mechanically indexed gang capacitor assembly of Fig. 3. Each pair is selectively switched into circuit by operation of the band change switch. There will of course be as many groups of these capacitors as there are spread bands to be covered, although only two groups are shown in the diagram to simplify the drawings. The band change switch will also necessarily have as many groups of contact as there are spread bands, plus the additional contacts required for tuning over the "B," "C" and "D" bands. Otherwise the adjustments and operation of the circuits of Fig. 4 are essentially the same as those of Fig. 3.

Fig. 5 represents a straight-line tuning indicator and scale assembly suitable for a commercial receiver utilizing the basic circuit arrangement of either Fig. 3 or Fig. 4. A single vertical pointer 22 is arranged to be moved horizontally over all of the scales in direct proportion to the movement of the combined main and band spread tuning gang assembly. Any conventional pointer drive arrangement may be employed. Hence this is not shown, but merely indicated by a pointer drive cord 27 passing over pulleys 28. It will be observed that the scale calibrations are those resulting when both the main and band spread capacitors are of the "modified straight-line frequency" type. In a particular receiver in which this scale assembly was used, different coils were switched to permit tuning in the conventional manner over the "B," "C" and "D" bands. The upper three scales show the calibrations obtained for these bands. The "C" band coils were then utilized in conjunction with the band spread gang for spreading the 49 meter band. The approximate spread obtained for this band is represented by the heavy horizontal bar on the fourth scale. Similarly, the "D" band coils were employed in conjunction with the band spread gang for spreading the 31, 25, 19, and 16 meter bands, the scale calibrations for these bands being represented by the lower four scales. It will be observed that the positions of these latter four bands, as indicated by the heavy horizontal bars, are progressively displaced toward the high frequency end of the tuning range in accordance with the invention. The frequencies covered by the heavy horizontal bars are those specified by the Federal Communications Commission for the respective bands.

All of the embodiments heretofore described require both main tuning capacitors and band spread tuning capacitors. Figs. 6 and 7 illustrate further modifications in which a single tuning gang assembly is used for all bands. A conventional tuning capacitor suitable for operation over the "B," "C" and "D" bands may have a range from about 10 micromicrofarads to about 500 micromicrofarads. In the modifications of Figs. 6 and 7 the variable capacitors 23 and 24 may be of this type. For band spread tuning their capacity variation range is reduced by switching relatively small padding capacitors 25 and 26 in series with the capacitors 23 and 24, respectively. In a typical receiver these padding capacitors may be of the order of about 30 micromicrofarads. The addition of a series capacitor of this value results in a very non-linear capacity variation. However, in this case the resultant capacity variation curve has the opposite curvature from that produced by a straight-line frequency or "modified straight-line frequency" capacitor.

In other words, the region of slower capacity change occurs with the capacitors 23 and 24 near their fully closed positions. A characteristic of this type is represented by the curve 18' of Fig. 2. In these modifications the tuning scales are therefore positioned progressively nearer the fully closed position of the capacitors for progressively higher spread bands. This will be apparent from an inspection of Fig. 9 which shows a straight-line indicator and scale assembly generally similar to that of Fig. 5 but adapted for use with a circuit of the type shown in Figs. 6 and 7.

The circuits of Figs. 6 and 7 not only eliminate the need for a separate band spread gang but provide somewhat greater spread for the high frequency bands than when the commercial "modified straight line frequency" type of capacitor is used in the circuits of Figs. 1, 3 or 4. This will be apparent from a comparison of the corresponding scales of Figs. 5 and 9. The addition of the series padding capacitors causes the resultant capacity curve to have a more pronounced non-linearity than the capacity curve of the variable gang capacitor assembly alone. In both cases the degree of band spread for all the short wave bands is considerably greater than the degree of spread obtained over the same frequency ranges near the high frequency end of the broadcast band, as will be apparent from an inspection of Figs. 5 and 9.

However, it will be appreciated that these are merely effects obtainable with commercially available gang capacitors, with and without series padding capacitors. Obviously any desired curve of capacity variation for spreading the higher frequency spread bands either more or less than the low frequency spread bands may be provided by simply utilizing capacitors having suitably shaped plates.

For tuning over the "B," "C" and "D" bands in the circuits of Figs. 6 and 7, the band change switch elements 14a, 15a, and 14b, 15b are moved to their extreme right-hand positions. It will be observed that the series padders 25 and 26 are thereby short-circuited and only the main tuning capacitors 23 and 24 are placed in circuit with the coils 16 and 11. The left-hand portions of the circuits of Figs. 6 and 7 may be identical to the left-hand portions of the circuits of Figs. 3 and 4, respectively.

It will be observed that the present capacitors 20a, 21a and 20b, 21b are similar to the usual trimmer capacitors employed to assist in "tracking" the tunable circuits of a superheterodyne receiver. They differ only in that their capacities will be somewhat larger, e. g., the preset capacitors required for the lower frequency spread bands may have values approaching those of the main tuning capacitor itself. The circuits of Fig. 7 are therefore generally to be preferred because the number of component parts can be reduced to a minimum. The preset capacitors may be employed not only to "spot" the short wave spread bands on the band spread capacitor but also to assist in aligning the receiver for operation within these bands. The band spreading circuits then require, in addition, only certain switch contacts and connections and a single series padding capacitor for each tuned circuit in order to give satisfactory spreading of all bands.

Fig. 8 is a circuit diagram of one form of commercially practicable multi-band superheterodyne receiver embodying my invention. The

tuning circuits of Fig. 8 are fundamentally the same as those represented by the simplified diagram of Fig. 7. Corresponding reference numerals have been employed where possible. The high frequency circuits between the antenna and the intermediate frequency amplifiers are shown in detail, whereas the remaining circuits, whose details are not material to a complete understanding of the principles of my invention, are merely indicated in conventionalized block form.

In this particular receiver the signal-modulated carrier waves are received on the antenna 30 and are converted to carrier waves of the fixed intermediate frequency in the converter 31 and associated circuits. The remaining portions of the receiver may comprise the usual intermediate frequency amplifier 32, second detector and audio frequency amplifier 33, audio power amplifier 34, and loud speaker 35. The particular receiver illustrated is arranged to provide continuous tuning over the "B," "C" and "D" bands and band spread tuning over the 31, 25, 19, and 16 meter bands. Fig. 9 represents the tuning indicator and scale assembly used with an actual receiver having the circuit arrangement of Fig. 8.

The band change switch in the receiver of Fig. 8 has four sections, 36, 37, 38 and 39. This switch may conveniently be of the so-called "two-wafer" type wherein the sections 36 and 37 represent the front and back portions of one of the wafers, and the sections 38 and 39 represent the front and back portions of the other of the wafers, respectively. The switch is of the twelve-position type, each section having twelve stationary contacts which have been designated by reference letters *a-l*, inclusive. Only seven positions are utilized in this receiver, corresponding to the seven scales of Fig. 9. Band switching is accomplished by the simultaneous rotation of a bridging member or contact shoe 40 associated with section 36, a contact shoe 41 associated with section 37, a contact shoe 42 associated with section 38, and contact shoes 43 and 44 associated with the section 39. These shoes are shown in solid outlines to indicate their positions when the receiver is conditioned for the reception of stations within the standard broadcast or "B" band, and in dashed outlines to indicate their positions when the receiver is conditioned for band spread tuning over the 25 meter band. For a better understanding of the arrangement and operation of the receiver, the essential circuit connections will be briefly traced for these two positions of the band change switch.

Consider first the circuits completed with the movable elements of the band change switch in their solid line positions for "B" band tuning. The antenna to ground circuit extends from the antenna 30 through conductor 50, contact *g* of section 36, shoe 40, contact *h*, conductor 51, antenna coupling coil 52, and conductor 53 to ground. The signal grid to ground circuit for the converter 31 extends from the signal grid 54 through conductors 55 and 56, contact *h* of section 37, shoe 41, contact *i*, conductors 57 and 58, the "B" band antenna coil and a blocking capacitor 59 to ground. It will be observed that the series padding capacitor 25 is short-circuited through the conductor 56, contact *h* of section 37, shoe 41, contact *d*, and conductor 60. The grid circuit is tuned by means of the variable capacitor 23.

The local oscillation circuits associated with

the converter 31 may also be traced as follows: A circuit may be traced from the oscillator grid 70 through conductors 71 and 72, contact *h* of section 38, shoe 42, contact *i*, conductor 73, a series "tracking" capacitor 74, conductor 75 and the "B" band oscillator coil to ground. The cathode to ground portion of the converter circuit may be traced from the cathode 76 through conductor 77, contact *g* of section 39, shoe 44, contact *e*, and conductor 78 to an intermediate tap on the "B" band oscillator coil, and through the lower portion of this coil to ground. It will be observed that the series padding capacitor 26 is likewise short-circuited through the conductor 72, contact *h* of section 38, shoe 42, contact *d*, and conductor 79. The oscillator circuit is tuned by the variable capacitor 24.

The next two switch positions in counterclockwise rotation of the band change switch provide circuit connections for tuning over the "C" and "D" bands, respectively. The circuits may be traced for these bands in similar manner and will not be detailed. It will be noted that when the receiver is being tuned over the "C" band, the "B" band antenna coil is connected in the antenna to ground circuit, and likewise, when the receiver is being tuned over the "D" band, the "C" band antenna coil is connected in the antenna to ground circuit, to provide antenna coupling in accordance with common practice. Automatic volume control potentials are supplied from the second detector 33 over the conductor 89 when operating on the "B" and "C" bands. It will also be apparent upon inspection that the shoe 43 of section 39 provides means for short-circuiting various unused portions of the "B," "C" and "D" band oscillator coils as is necessary to prevent undesirable reaction between them.

Next assume that circuits are completed with the movable elements of the band change switch in the dashed line positions so that spread band tuning may be accomplished over the 25 meter band. The antenna to ground circuit may be traced from the antenna 30 through conductor 50, contact *g* of section 36, shoe 40, contact *j*, conductors 90 and 91, the "C" band antenna coil, and blocking capacitor 59 to ground. The signal grid to ground circuit may be traced from the signal grid 54 through conductors 55 and 56, contact *h* of section 37, shoe 41, contact *k*, conductor 60, and the "D" band antenna coil to ground. It will be observed that in this position of the band change switch the contact *d* of the section 37 is disengaged from the shoe 41 so that the padding capacitor 25 in series with the variable tuning capacitor 23 is connected between the grid 54 and ground. Also the presetting or "spotting" trimmer capacitor 26b required for this band is connected in shunt to the series capacitors 25 and 23 through a circuit which may be traced from the conductor 56 through contact *h* of section 37, shoe 41, contact *a*, and capacitor 26b to ground.

The oscillator grid to ground circuit for the 25 meter band may be traced from the oscillator grid 70 through conductors 71 and 72, contact *h* of section 38, shoe 42, contact *k*, a series "tracking" capacitor 81, and the "D" band oscillator coil to ground. The cathode to ground circuit may be traced from the cathode 76 through conductor 77, contact *g* of section 39, shoe 44, contact *i*, and conductor 82 to an intermediate tap on the "D" band oscillator coil, and through the lower portion of this coil to ground. Since the contact *d* of section 38 of the band change switch

is disengaged from the shoe 42, the series padding capacitor 26 is now effectively in series with the oscillator tuning capacitor 24 across the "D" band oscillator coil. A circuit for the trimmer capacitor 21b, which "spots" the 25 meter band for the oscillator tuning circuit, is also completed from the conductor 72 through contact *h* of section 38, shoe 42, contact *a*, and capacitor 21b to ground.

It is believed unnecessary to trace the circuits for the other short wave spread bands. It will be observed that the "D" band antenna and oscillator coils are utilized for all of the short wave broadcast bands within the "D" band. In this particular receiver it was found unnecessary to employ additional trimmer capacitors for "spotting" the 16 meter band since the regular "D" band trimmer capacitors 83 and 84 also performed this "spotting" function for the 16 meter band.

The simplicity of the receiver illustrated in Fig. 8 is emphasized by the fact that operation over three regular frequency bands and four spread bands may be achieved with a band change switch of standard type having only two "wafers." A band change switch having this number of "wafers" is not uncommonly used on many receivers which do not provide any band spreading. It will be seen that this economy is secured because, in all of the embodiments of my invention disclosed herein, grid circuit switching is performed merely by connecting one terminal of each of the selected circuit elements to a grid. Thus in the receiver shown in Fig. 8, the shoes 41 and 42 perform all of the switching operations for the signal grid 53 and oscillator grid 70, respectively.

It will now be apparent that I have provided simple and effective circuits for obtaining practically any required degree of band spread over any of the narrow short wave broadcast bands. As a further advantage, a minimum number of circuit elements are required and these need not be of special design. While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A turnable circuit having first capacity tuning means capable of being selectively adjusted to provide a plurality of different capacity values and variable capacity tuning means arranged to tune said circuit over a different selected band of frequencies for each of said values, said variable means including a pair of capacity determining elements relatively movable in a predetermined manner such that equal increments of movement produce progressively decreasing capacity variations toward one end of a range of movement, the total capacity variation over said range being sufficiently great that said circuit may be tuned over each of said selected bands by moving said elements over a fraction only of said range, the capacity values of said first means being so selected that the fraction of movement of said variable means required to cover any one of said bands provides approximately the same rate of frequency variation as for any other of said bands.

2. In a resonant circuit structure, first tuning means providing a plurality of different pre-

termined capacities, second tuning means continuously variable over a capacity range, means for selectively connecting said predetermined capacities in shunt to said second means whereby said circuit may be tuned over a plurality of different frequency bands, and movable means arranged to vary the capacity of said second means over said capacity range in such a manner that the rate of capacity variation progressively decreases as said movable means approaches a position corresponding to one end of said range, each of said predetermined capacities being so adjusted that there is a point in the range of movement of said movable means for each of said bands at which the rate of frequency variation is substantially the same in all of the bands, said points occurring nearer said end position as said bands include higher frequencies.

3. A band spread tuning system for a multi-band radio receiver comprising, in combination, tuning means providing at least two different predetermined tuning adjustments, vernier means comprising a variable capacitor having a rotor and a stator for modifying said adjustments to provide band spread tuning over at least two different short wave bands, said vernier means providing a progressively decreasing capacity variation per degree of rotation of said rotor as one of its limits of capacity variation is approached, the total capacity variation of said vernier means being sufficiently great that said receiver can be tuned over each of said bands by moving said rotor over a fraction only of its capacity range, said predetermined tuning adjustments being so selected that the fraction required to tune said receiver over the higher frequency band occurs nearer said limit than the fraction required to tune said receiver over the lower frequency band.

4. In a band spread tuning system for operation over at least two widely separated short wave broadcast bands, the combination comprising an inductance requiring a relatively wide range of capacity variation to tune it over the lower of said bands and a relatively narrow range of capacity variation to tune it over the higher of said bands, a single non-linear variable capacity in shunt to said inductance having a movable capacity varying element, said capacity requiring approximately the same amounts of movement of said movable element to traverse two portions of its total capacity range, one of said portions providing said relatively wide range and the other of said portions providing said relatively narrow range, and means for selectively pretuning said inductance so that one or the other of said portions is effective, whereby approximately the same frequency spread is secured over both said bands.

5. In a multi-band radio receiver adapted for operation over the broadcast band and also over a plurality of widely separated, narrow short wave bands, a variable gang tuning capacitor assembly having a tuning range sufficient to tune said receiver over the broadcast band, each capacitor of said assembly having a non-linear law of capacity variation approximating a straight-line frequency curve, means for utilizing said capacitor assembly to tune said receiver over the broadcast band, means for selectively substituting groups of predetermined capacities for said assembly, each of said groups being effective to tune said receiver to a frequency near one of said short wave bands, and means for connecting a capacity combination in shunt to each capacity

within any selected group for tuning said receiver over a corresponding short wave band, each of said combinations comprising one of the capacitors of said gang in series with a fixed capacitor, the values of said fixed capacitors and groups of capacities being so proportioned that said receiver may be tuned over any selected short wave band by moving said gang tuning capacitor over a fraction of its total range not less than that required to tune said receiver over any frequency range of the same width within the broadcast band.

6. In combination, a reactance, a variable reactance resonating therewith, said variable reactance having a movable element for variation of the reactance thereof, said reactance varying in progressively increasing increments per linear unit of movement of said element from one end of its range of movement to the other, the frequency of resonance varying with movement of said element over a wide range including a number of non-contiguous narrow ranges, the change in frequency of resonance with said movement being too rapid for accurate adjustment in said narrow ranges, a plurality of additional reactances both corresponding to one of said ranges, and means selectively to connect said additional reactances in circuit with said first reactance to reduce the frequency change per unit of movement of said element, each of said additional reactances being so proportioned that said element varies the frequency of resonance over a range including one of said non-contiguous narrow bands and such that said narrow bands are traversed by movement of the element through the respective parts of its total range of movement where the rates of change of frequency of resonance per unit of movement are equal in the different non-contiguous bands.

7. The combination, in a radio receiver tunable over a broadcast band of frequencies, a shortwave band, and a plurality of spread bands lying in said short wave band, all by movement of a single main tuning reactance element, of a plurality of parallel scales, one scale for each of said bands of frequencies, an index member movable along all of said scales with movement of said main tuning element, a plurality of fixed reactances, one for said broadcast band and one for said short wave band, and means selectively to connect said fixed reactances to said main tuning reactance in accordance with the band over which tuning is desired, and a plurality of band spread reactances, one for each of said spread bands, and means selectively to connect said spread band reactances in circuit with said fixed reactance for said short wave band to reduce the tuning change produced by movement of said main tuning element, said spread band reactances being so proportioned that a unit of length of said scales corresponding to said spread bands represents a frequency change not greater than the frequency change represented by an equal unit of length of the scale for the broadcast band.

8. The combination, in a radio receiver tunable over a broadcast band of frequencies, a shortwave band, and a plurality of spread bands lying in said short wave bands, all by movement of a single main tuning reactance element, of a plurality of parallel scales, one scale for each of said bands of frequencies, an index member movable along all of said scales with movement of said main tuning element, a plurality of fixed reactances, one for said broadcast band and one

for said short wave band, and means selectively to connect said fixed reactances to said main tuning reactance in accordance with the band over which tuning is desired, said main tuning element having reactance varying at a progressively increasing rate with movement from one end to the other of its range of movement, and means to produce a plurality of band spread reactances of different value, one value for each of said spread bands, in circuit with said fixed reactance for said short wave band to reduce the tuning change produced by movement of said main tuning element, said spread band reactance values being so proportioned that the variation of tuning produced by movement of said main tuning element varies over different ranges corresponding to the respective band spread reactance value, each range including one of said spread bands, and such that said spread bands fall at a point in the range of movement of the main tuning element where a unit of movement produces equal tuning variation in all spread bands and in said broadcast band.

9. The combination, in a radio receiver tunable over a broadcast band of frequencies, a short wave band and a plurality of spread bands lying in said short wave band, all by movement of a single main tuning element, a plurality of fixed reactances respectively for said broadcast and short wave bands, and means selectively to connect said fixed reactances to said main tuning reactance in accordance with the broadcast or short wave band desired, said main tuning reactance element having reactance varying at a progressively increasing rate with movement from one end to the other of its range of movement, and a plurality of band spread reactances one for each of said spread bands and means selectively to connect said spread band reactances in circuit with said fixed reactance for short wave band to reduce the tuning change produced by movement of said main tuning element, said spread band reactances being so proportioned that variation of said main tuning element varies the tuning over different frequency ranges, each range including one of said spread bands and said spread bands falling at points in the movement of said tuning element whereby adjustment of the frequency of resonance by adjustment of the main tuning element is substantially equally critical in all spread bands and equal to that in the broadcast band.

10. The combination, in a radio receiver, tunable over the broadcast band, a short wave band, and a spread band, all by movement of a single variable tuning reactance element, the reactance of which varies at a progressively increasing rate from one end to the other of its range of movement, of a plurality of fixed reactances corresponding respectively to said broadcast band and short wave band, means selectively to connect said fixed reactance in circuit with said variable reactance for tuning over the respective broadcast or short wave band, a band spread reactance, and means to connect said band spread reactance in circuit with said fixed reactance for said short wave band to narrow the range of frequencies over which tuning is varied by movement of said element, said band spread reactance having such a value that said spread band falls in said narrowed range and also falls at a point in the movement of said element where the rate of tuning variation with movement substantially equals that in the broadcast band.

11. In combination, a fixed reactance resonat-

ing with two reactances both in parallel therewith, one being fixed and the other variable, said variable reactance varying the frequency of said resonance over a plurality of frequency bands, said variable reactance having an element movable through a range to produce progressively increasing changes in said reactance, and each of said bands corresponding to different respective portions of said range of movement of said element, means to select that one of said plurality of frequency bands over which resonance is to occur solely by changing the value of said second mentioned fixed reactance, and the values of said second mentioned fixed reactance for the different frequency bands being so proportioned that equal movements of said movable element in different portions of its total range of movement produce equal changes in frequency of resonance in all of said bands by reason of the different rates of change of said variable reactance in said different portions of said total range of movement of said element.

12. In combination, a fixed reactance resonating with two reactances both in parallel therewith one fixed and one variable, said variable reactance having an element movable for variation thereof to vary the frequency of said resonance, the linear movements of said element producing non-linear variation of said variable reactance, means to vary the value of said fixed reactance thereby to cause the frequency of resonance of said reactances to vary over different frequency bands, solely by changing the value of said second fixed reactance, said different bands being traversed by movement of said element through different non-contiguous portions of its total range of movement, and the values of said second fixed reactance corresponding to said different frequency bands being so proportioned that equal increments of movement of said movable element produce equal changes in the frequency of resonance in all of said non-contiguous bands.

13. In combination, a fixed reactance, a variable reactance resonating therewith, a movable element variable to vary said variable reactance to change the frequency at which resonance occurs over a wide range, a plurality of parallel scales, an index member movable along said scales from end to end as said movable element varies through its range of movement, and one of said scales corresponding to said wide frequency range and other of said scales having portions thereof corresponding to non-contiguous minor portions of said one scale, and means selectively to connect additional fixed reactances in shunt with said first fixed reactance, one of said fixed reactances being so connected for each of said minor portions of said one scale, said fixed reactances having such values that a unit

of length of any of said portions of said other scales corresponds to substantially the same change in frequency of resonance, and to a smaller change in frequency than an equal unit of length of said one scale.

14. In combination, an inductance, a variable condenser resonating therewith and having a rotor movable to change the capacity of said condenser, said capacitance varying at a progressively increasing rate with movement of said rotor through its range of movement, an index cooperating with a plurality of parallel scales and movable through the length of all of said scales simultaneously with movement of said rotor through its range, one of said scales corresponding to a frequency range too wide for accurate adjustment of said condenser for resonance at desired frequencies therein, a plurality of fixed condensers, each corresponding to one of the other of said scales, and means selectively to connect said fixed condensers in parallel with said inductance, said condensers having such values that the resonance of said inductance, variable condenser and respective fixed condenser is varied by movement of said rotor through different respective portions of its total range of movement to an extent per increment of movement substantially equal in all of said portions of its range and each of said portions of its range having a corresponding calibration on a respective one of said other scales.

15. The combination, in a radio receiver tunable over a broadcast band of frequencies, a short wave band, and a plurality of spread bands lying in said short wave band, all by movement of a single main tuning reactance element, of a plurality of parallel scales, one scale for each of said bands of frequencies, an index member movable along all of said scales with movement of said main tuning element, a plurality of fixed reactances, one for said broadcast band and one for said short wave band, means selectively to connect said fixed reactances to said main tuning reactance in accordance with the band over which tuning is desired, means selectively providing reactance having different desired values, one value for each of said spread bands, and means selectively to connect the reactance of said last means in circuit with said fixed reactance for said short wave band to reduce the tuning change produced by movement of said main tuning element, said spread band reactance values being so proportioned that a unit of length of said scales corresponding to said spread bands represents a frequency change not greater than the frequency change represented by an equal unit of length of the scale for the broadcast band.

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