Feb. 23, 1937 N. M. RUST 2,071,902

TUNABLE SELECTOR CIRCUITS

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Fig. 1

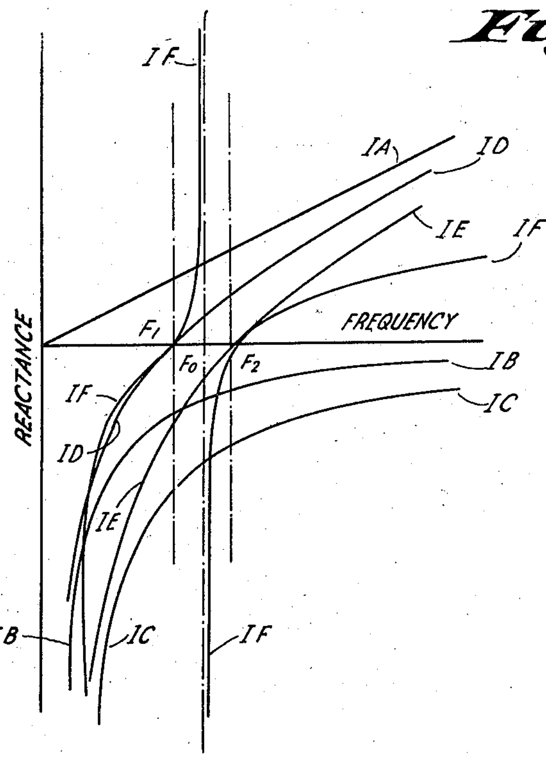

Fig. 4

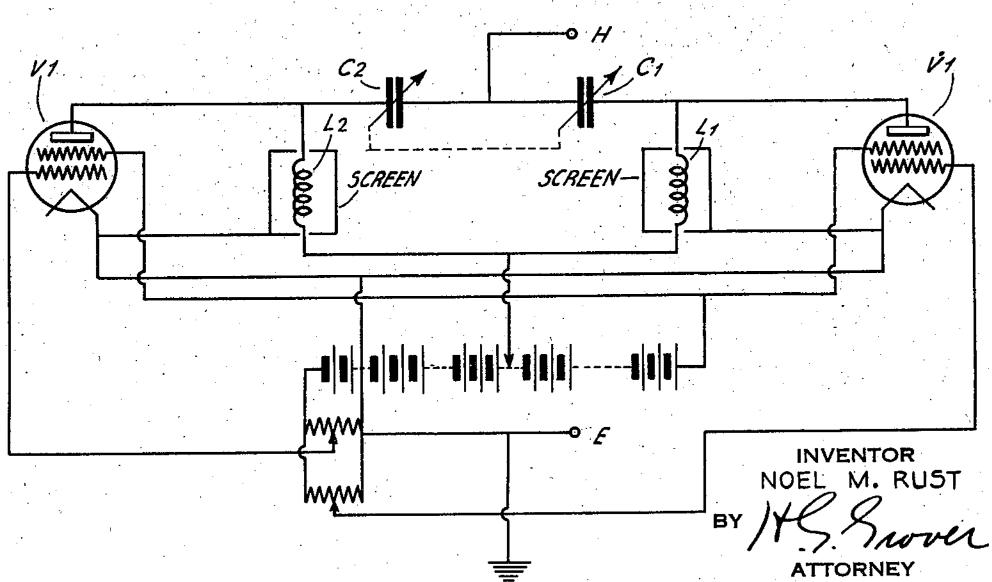

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Fig. 2

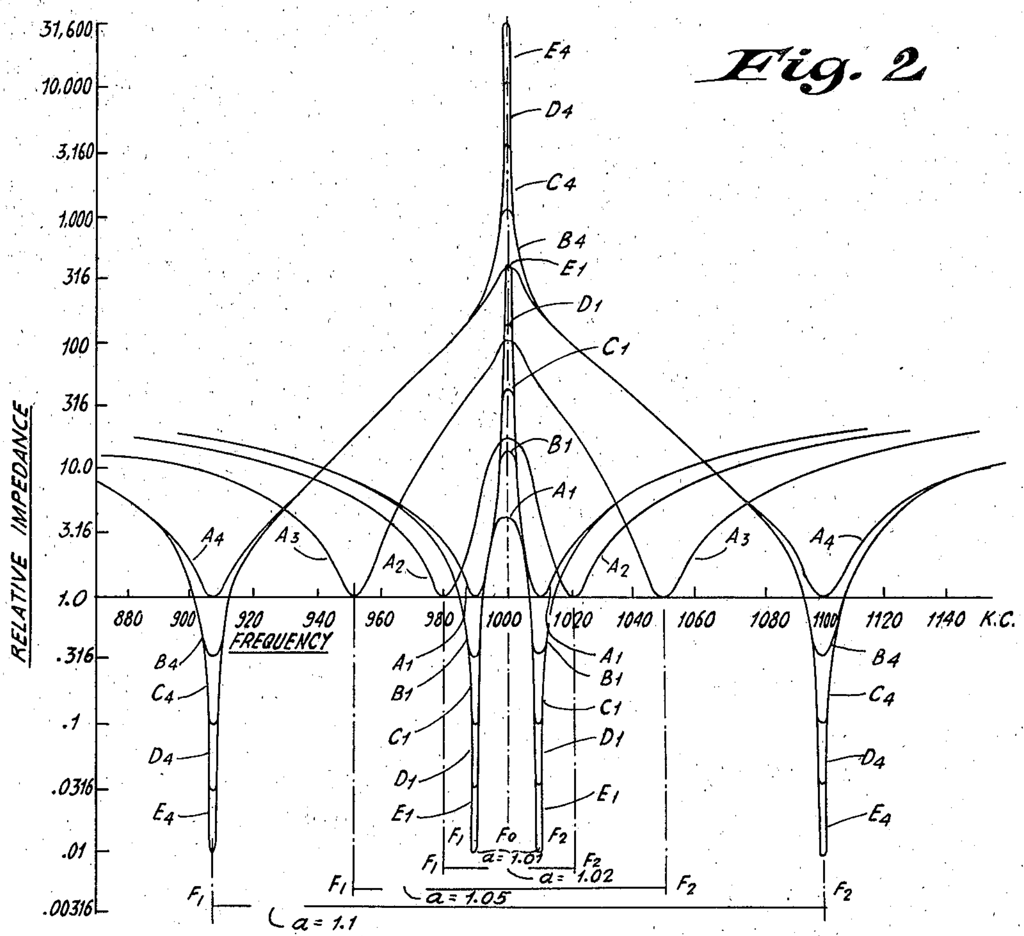

Fig. 3

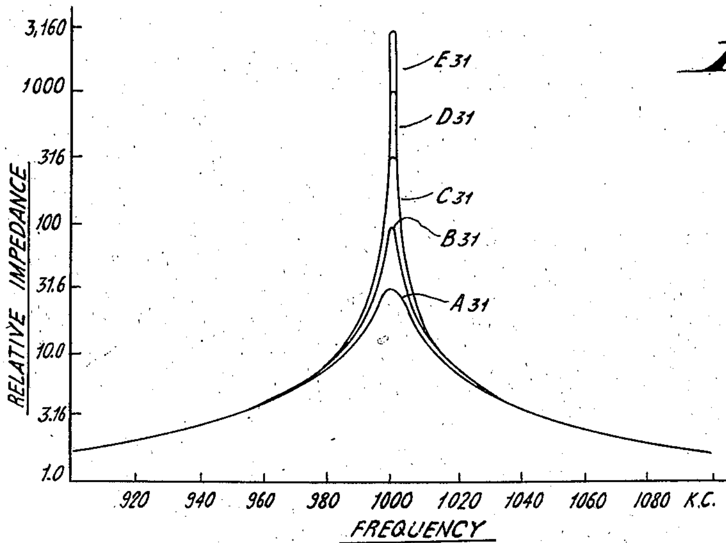

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Fig. 5

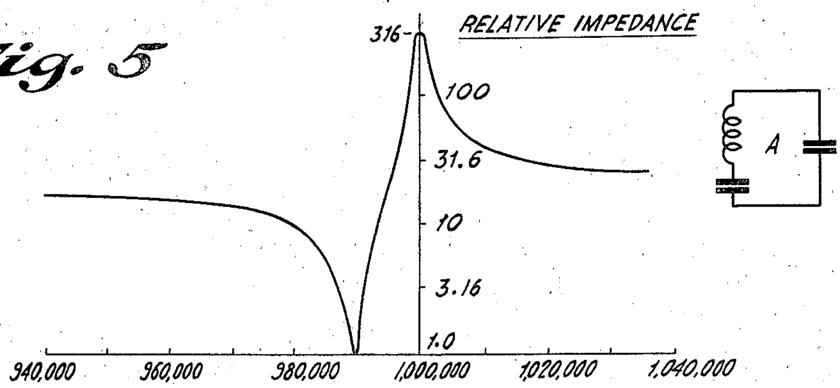

Fig. 6

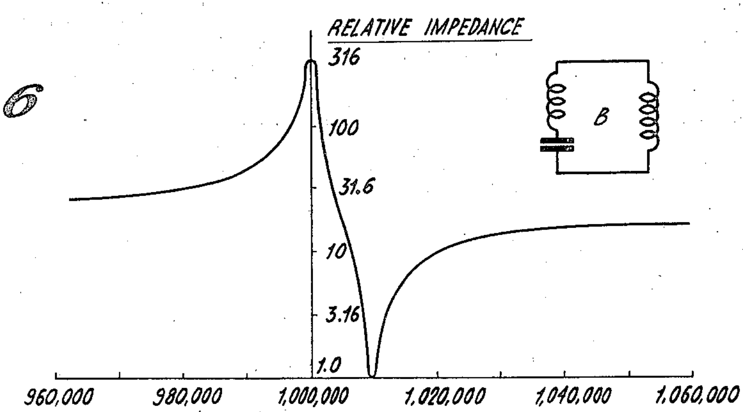

Fig. 7

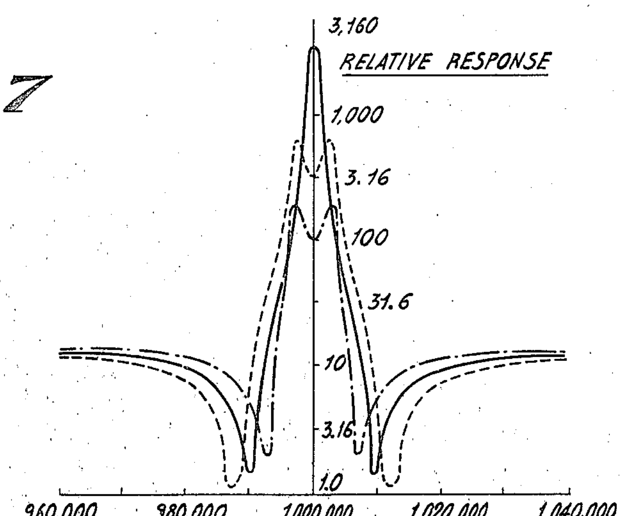

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Fig. 8

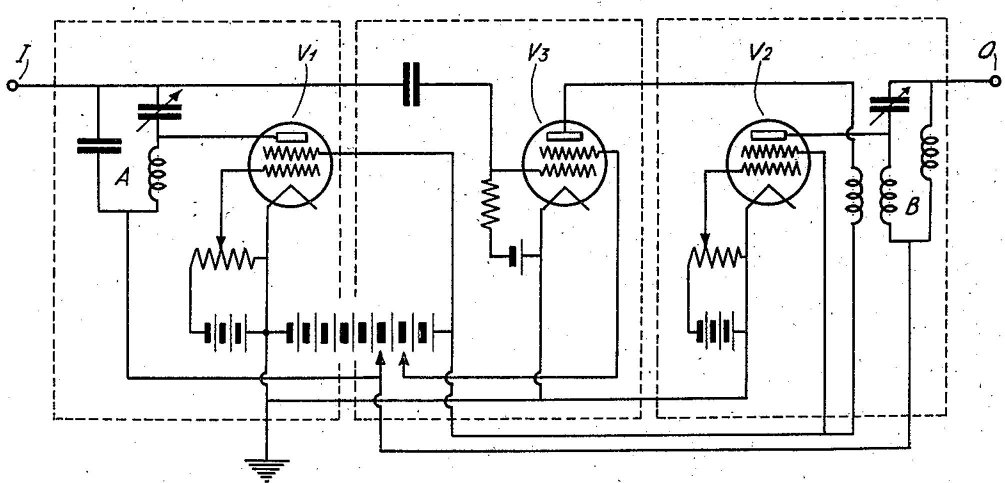

Fig. 9

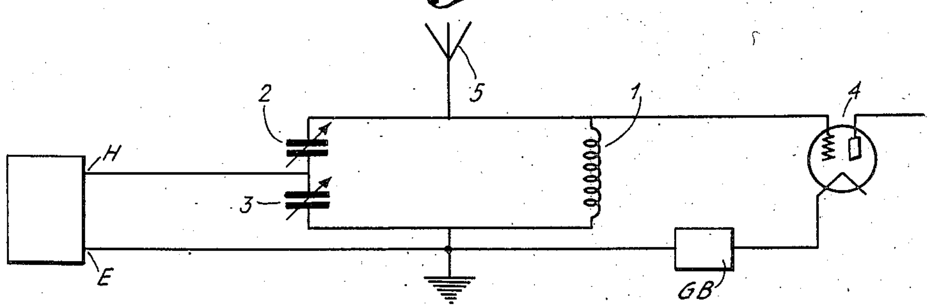

Fig. 10

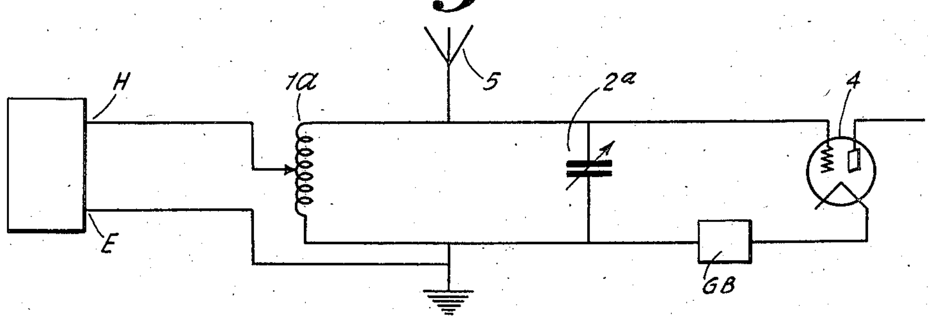

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Fig. 11

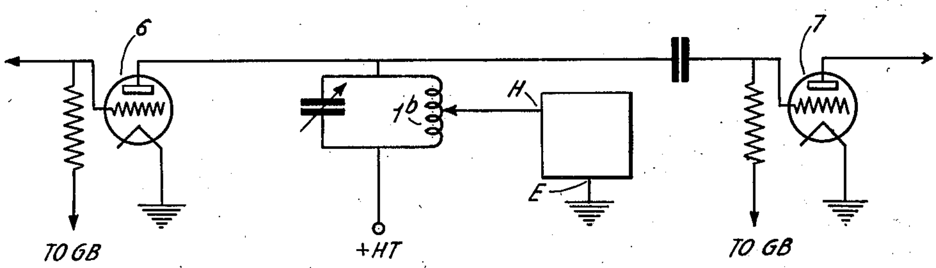

Fig. 12

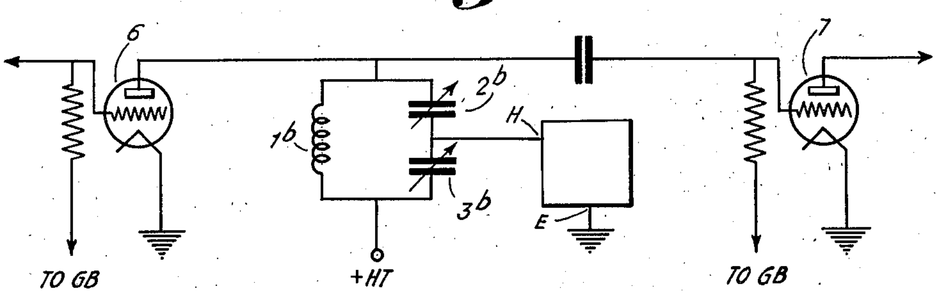

Fig. 13

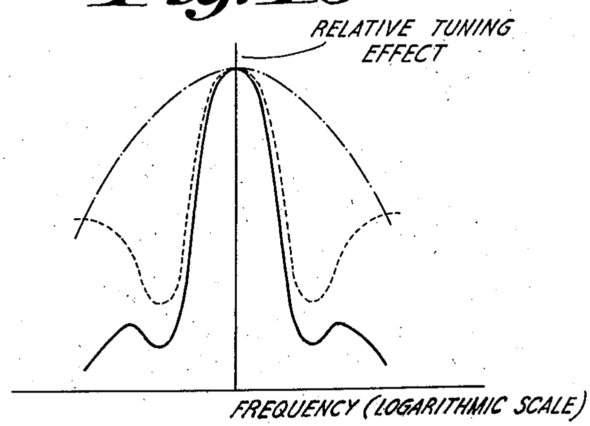

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Fig. 14

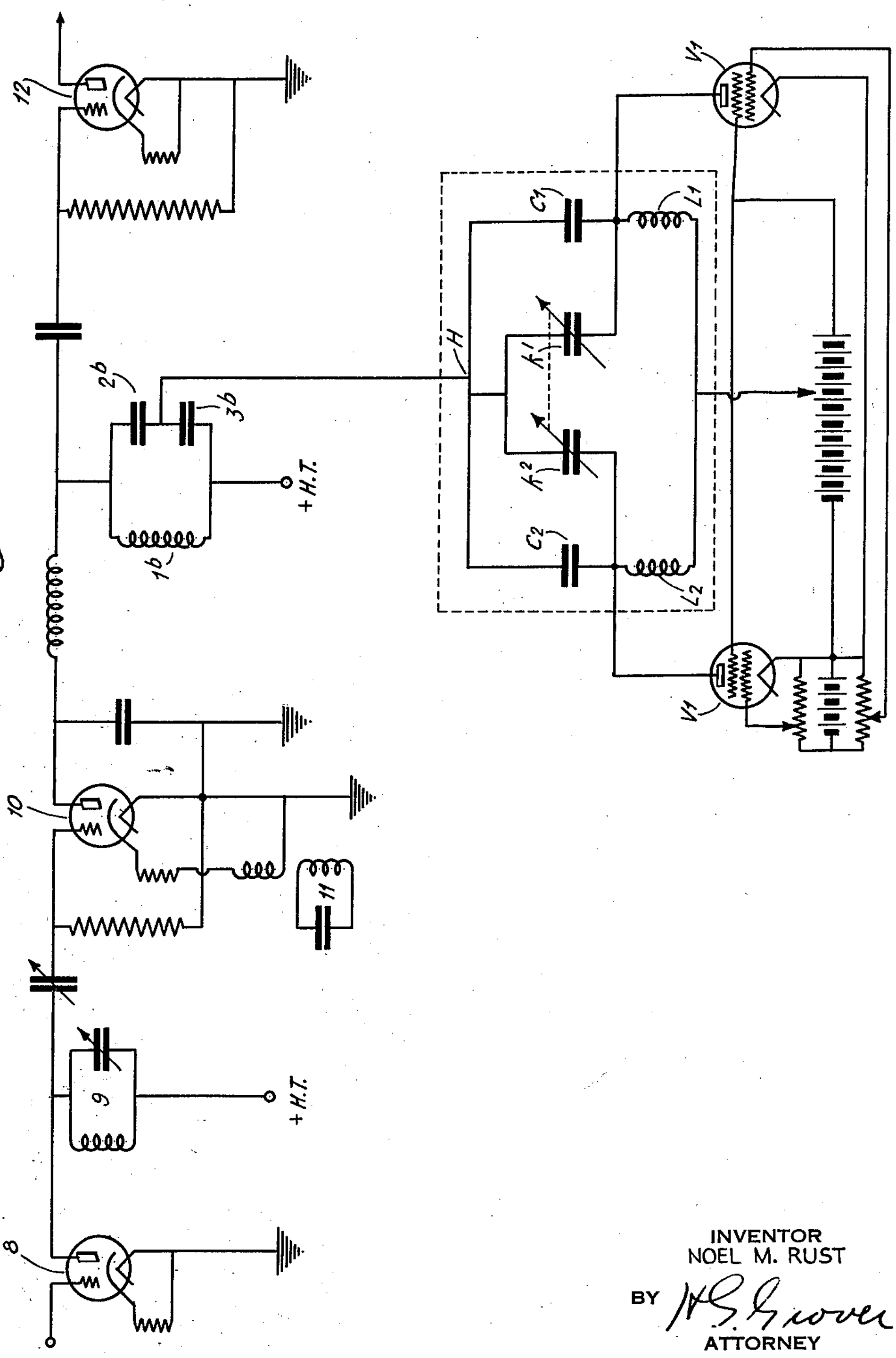

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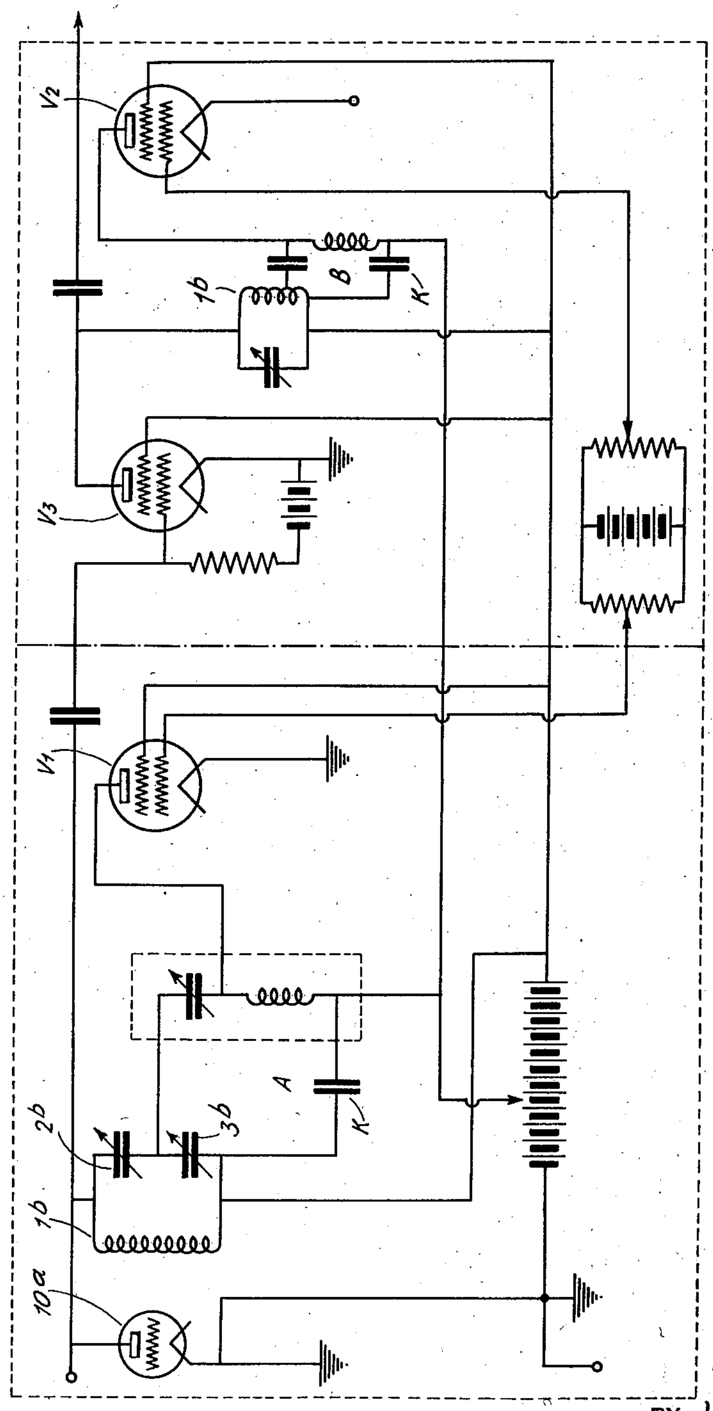
Fig. 15



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Patented Feb. 23, 1937 2,071,902

UNITED STATES PATENT OFFICE

2,071,902

TUNABLE SELECTOR CIRCUITS

Noël Meyer Rust, Chelmsford, England, assignor to Radio Corporation of America, a corporation of Delaware

Application June 26, 1933, Serial No. 677,617
In Great Britain July 14, 1932

14 Claims. (Cl. 178—44)

This invention relates to frequency selective circuit arrangements for use in radio reception, and has for its main object to provide a circuit arrangement suitable for use for receiving broadcast radio reception and whereby a high degree of selectivity may be obtained.

A further object of the invention is to obtain the required selectivity in such manner that the degree or kind of tone correction necessary to compensate for distortion due to the shape of the selectivity curve shall not be difficult to obtain practically.

It is well known that with the large number of broadcast transmitting stations in existence at the present time, it is a very difficult matter to obtain really selective reception in many places, and while fairly satisfactory results have been obtained, for example by employing in a receiver a number of tuned circuits in cascade, or a number of band pass tuning circuits in cascade, the degree of selectivity obtained is not as high as is desirable, and where very sharp selectivity is obtained the shape of the selectivity curve is often such as to make the subsequent tone correction necessary to compensate for side band distortion due to that shape a very difficult matter to obtain practically. Further, known arrangements capable of producing reasonably satisfactory results both as regards selectivity and quality are for the most part expensive and difficult to manufacture.

According to the first feature of this invention frequency selectivity is obtained by means of one or more branched circuits, each branch of which consists of inductance and capacity in series and negative resistance means is associated with said branched circuit for reducing the effective damping thereof. It is well known that a circuit consisting of two parallel branches each consisting of an inductance in series with a condenser possesses three critical frequencies at the two outer of which the branched circuit approximates to infinite susceptance while at a frequency between these two outer frequencies the branched circuit approximates to a condition of zero susceptance.

In carrying out this feature of the present invention the branched circuit is so arranged that the frequencies at which approximately infinite susceptance is obtained correspond to the limiting frequencies of a band of frequencies desired to be received, and preferably the arrangement is such that the intermediate frequency at which approximately zero susceptance is obtained is mid-way between the outer frequencies.

According to a second or modified feature of this invention there are employed what may be termed "split" or branched complex resonant circuits in cascade rather than in juxtaposition and the resonant frequencies of the separate complex circuits being arranged slightly differently i. e. "staggered" so that each separate complex circuit gives an asymmetrical response curve, the two response curves together, however, resulting in a substantially symmetrical response curve not presenting the disadvantage of a rising response on either side of a desired acceptance band.

In the drawings,

Figs. 1, 2 and 3 are sets of graphs provided for explanatory purposes,

Fig. 4 diagrammatically shows an arrangement in accordance with the invention,

Figs. 5, 6, 7 are further sets of explanatory graphs,

Fig. 8 is a diagrammatic representation of a further embodiment in accordance with the invention,

Figs. 9, 10, 11, 12, 14, 15 illustrate diagrammatically various modified arrangements incorporating the invention, while

Fig. 13 is a set of explanatory graphs.

In order that the first feature of this invention may be the better understood, the nature of the reactance and susceptance changes taking place in a branched circuit consisting of two branches in parallel each having an inductance and a condenser in series will now be described. Suppose the outermost frequencies are F_1, F_2 respectively, and the intermediate frequency is F_0 and suppose also that the intermediate frequency is the geometric mean of F_1 and F_2, a condition which involves that there shall be no mutual inductance between the inductances in the two branches of the circuit. Then

$$F_0=\sqrt{F_1F_2}.$$

Suppose the inductance and capacity in one branch are given by L_1 C_1 respectively, this branch being resonant at frequency F_1 and the inductance and capacity of the second branch which is resonant at the frequency F_2, are L_2 C_2 respectively. Ignore for the moment the effect of resistance in the branches.

The reactance occurring at different frequencies for the two branches are as shown in Fig. 1 in which the ordinates are values of reactance and the abscissae values of frequency. This said

Fig. 1 is drawn for the case in which $L_1=L_2$ and $C_1>C_2$, F_0 being equal to

$$\sqrt{F_1F_2}.$$

In Fig. 1 the curve 1A is the reactance curve of the coil L_1 which, of course, is equal to the reactance curve of the coil L_2; the curve 1B is the curve of reactance of the condenser C_1; the curve 1C is the curve of the reactance of the condenser C_2; the curve 1D the curve of total reactance of L_1 and C_1 and the curve 1E the curve of the total reactance of the combination L_2 and C_2. It will be seen that at the frequencies F_1 and F_2 one or other branch is of zero reactance. The total reactance of the whole circuit is shown by the curve 1F and as will be seen the total reactance is zero at F_1 and F_2 and infinity at F_0.

The foregoing conditions ignore the effect of resistance losses, and, if it were not for such losses, it would be possible to construct a circuit which would produce sharp rejector effects for the frequencies F_1 and F_2 and a sharp acceptor effect for the frequency F_0. In practice, however, owing to resistance losses in the coils, as the frequencies F_1 and F_2 are brought very near to each other by making the condensers C_1 and C_2 more nearly equal (assuming L_1 and L_2 to be equal) the rejector effects tend to be merged into one another, and the acceptor resonance appears only as a small bump between rejector dips; for this reason, therefore, in practice the split, or branched, circuit arrangement described is not by itself very effective for the purpose in question.

Fig. 2 shows the effects of resistance. The curves of the said Fig. 2 are curves connecting relative impedances (ordinates) with frequency (abscissae) and illustrate the relative value of the impedances obtained at the three resonance frequencies F_1, F_0 and F_2 for different relative values of these resonant frequencies i. e., for different positions of adjustment. It will be seen that there are four groups of curves shown in Fig. 2, each group being drawn to show the impedance values obtained at a particular ratio

$$\frac{F_2}{F_0} \text{ or } \frac{F_0}{F_1}$$

This ratio is marked in Fig. 2 by a and as will be seen there are four groups of curves one for where $a=1.01$, one for where $a=1.02$, one for where $a=1.05$ and one for where $a=1.1$. For the sake of convenience, and in order not to have too many curves on the same figure, each group of curves for the values $a=1.02$, $a=1.05$ is represented by one curve only there being five curves in each of the two remaining groups.

The curves in the group for $a=1.01$ are indicated by the letters A1, B1, C1, D1, E1, respectively while the corresponding curves in the group for $a=1.1$ are indicated at A4, B4, C4, D4 and E4. The curve A2 is drawn for the value $a=1.02$ and the curve A3 for the value $a=1.05$. The curves in each group are drawn for different values of the reciprocal of the coil dissipation factor i. e. are drawn for different values of

$$\frac{\omega L1 \omega L2}{RR}=Q$$

where $\omega=2\pi F$ and R is the resistance. The curves A1, A2, A3 and A4 represent the case where Q=100, the curves B1, B2, B3 and B4 represent the case where Q=316, the curves C1, C2, C3 and C4 represent the case where Q=1000, the curves D1, D2, D3 and D4 represent the case where Q=3160 and the curves C1, C2, D3 and C4 represent the case where Q=10,000.

It will be apparent from Fig. 2 that for those cases where Q is of high value the resonance "peaks" and "dips" are very sharp while the general shapes of the curves between those resonant peaks are not substantially different from the shapes of the curves obtained when Q is of low value, and it will therefore be seen that the general shapes of the curves are such that the distortion due thereto will be readily easily correctible. For a normally good coil employed at present day broadcasting frequencies at one million cycles per second or thereabouts Q would have a value of about 100, and it will be obvious from Fig. 2 that the degree of selectivity obtained from a branched circuit as described and having coils with a Q value of about 100 will be quite insufficient.

In carrying out the present feature of the invention, however, the Q value is greatly increased by applying negative resistance to the coils and it will be seen that where Q is increased to the value of 3160 (curves D1, D2, D3, D4) the "peak" to "dip" ratio is over 3000. With the apparatus normally available at the present time it will probably not be convenient practically to raise the Q value much above 3000 to 4000 though, of course, it is theoretically possible to do so.

Fig. 3 is a set of curves connecting relative impedances (ordinates) with frequency (abscissae), and shows the impedance for an ordinary tuned circuit with different values of coil dissipation, this tuned circuit being tuned to 300 meters. The curve A31 is drawn for a Q value of 100, B31 for a Q value of 316, C31 for a Q value of 1000, D31 for a Q value of 3160 and E31 for a value of 10,000. Comparing the curves of Fig. 2 with those of Fig. 3 it will be seen that for a given value of Q the ratio of impedance at F_0 to that at F_1 and F_2 can be made very much greater than in the case of the ordinary circuit (illustrated by the Fig. 3 now being referred to) because of the two fold effect which enhances both "peak" and "dips" as the damping is reduced. Thus with the circuit described any given impedance ratio necessary to reduce the interference of a station whose frequency is F_1 or F_2 can be produced with a lesser degree of applied negative resistance (which results in greater circuit stability) and for the all important modulation frequencies up to 5000 cycles less tone correction is required.

In the foregoing it has been assumed throughout that the radio frequency response curves follow the impedance curves, and this is approximately true so long as the circuits employed are connected across a circuit of relatively much higher impedance, e. g. the grid circuit of a valve. The effect of connecting a circuit in accordance with this invention across a circuit of high impedance is mainly to blunt the peak occurring at F_0 without much affecting the peaks occurring at F_1 and F_2, and by connecting a circuit in accordance with this invention across a circuit of impedance of a relative value of about 10 the flattening of the peak at F_0 is such as substantially to simplify the problem of subsequent audio frequency correction without much affecting the selectivity effect and by suitably arranging shunt impedances it is therefore possible to control the sharpness of the peak at F_0 without substantially affecting the sharpness of the dips at F_1 and F_2.

Fig. 4 shows a convenient arrangement in accordance with the first feature of this invention, and, as will be seen from the said Fig. 4, the branched circuit consists of inductances L_1 and L_2 in series with condensers C_1 and C_2 the condenser C_1 being greater than the condenser C_2 and the two condensers being gang controlled. The coils L_1 and L_2 are preferably screened from one another in order to avoid mutual inductance, for the effect of mutual inductance is to upset the relation

$$F_0=\sqrt{F_1F_2};$$

bringing the value F_0 closer either to F_1 or F_2 according to the sign of the mutual inductance and thus producing an asymmetrical curve. If this effect is desired, as it may be in some cases, arrangements may be provided for controlling the mutual inductance between the coils. In the arrangement shown in Fig. 4 the required negative resistance effects are obtained by means of a pair of screened grid valves V_1, V_2 which are adjusted in manner known per se to operate on the negative resistance portions of their characteristics. The amount of negative resistance injected may be controlled by adjusting the potentials applied to the electrodes of the screened grid valves.

As shown in Fig. 4, the two cathodes of the tubes V_1 and V_2 are connected together and through a common connection the cathodes are connected to an intermediate point of the current source. The anodes of the two tubes are also connected together through by means of a circuit which includes condensers C_1 and C_2 and also by a circuit which includes the two coils L_1 and L_2. A point intermediate the coils L_1 and L_2 is connected to a point of the source which is positive with respect to the cathode connection point thus maintaining the anodes positive with respect to the associated cathodes. The outer grids of the two tubes are connected together and are maintained at a more positive potential than the anodes by connection to a point of the source which is more positive than the anode connection point. The two inner grids are preferably biased negatively and for this purpose provision is made to connect each to a separate variable potentiometer device to allow separate adjustment thereof. The potentiometer resistor in each case is shown connected across a portion of the source between the cathode connection point and a point of the source which is negative with respect to the cathode connection point.

It is not necessary that two screened grid valves be employed since obviously one valve can provide the negative resistance for both branches of the branched circuit, but the arrangement illustrated is preferred since it is symmetrical. In order that the condensers C_1C_2 may be properly ganged together they should be so-called "straight line" frequency condensers and by the use of correctly designed "straight line" frequency condensers the whole circuit can be tuned i. e. moved up and down the frequency scale while maintaining a substantially constant frequency separation between the dips and the peak (see Fig. 2) at all points.

This frequency separation will be dependent upon the difference between C_1 and C_2 and a convenient arrangement therefor is to constitute the condensers C_1C_2 by a pair of condensers having their rotors on the same shaft and perfectly in line with one another while their stators are at a predetermined angle to one another. In fact by providing an adjustment controlling the angular separation between the stators the frequency separation between F_1 and F_2 may be adjusted and a controllable selectivity effect thereby obtained. The circuit arrangement shown in Fig. 4 may be employed in a variety of different ways, for example, as shown in Fig. 9 of the accompanying drawings in the case of an ordinary receiver an ordinary tuned circuit consisting of an inductance 1 shunted by two condensers 2, 3, in series may be connected across the grid circuit of the first valve 4 of the receiver, the aerial 5 being tapped upon the inductance 1, or, as shown, connected to the top thereof, and the terminals H and E of an arrangement as shown in Fig. 4 being connected across one of the two condensers as shown the condenser 3. GB is a grid bias source. By adjusting the condenser across which the terminals H and E are connected correct impedance matching may be obtained.

In a modification illustrated in Fig. 10 of the accompanying drawings impedance matching is obtained inductively. In this modification the tuned circuit consists simply of a coil 1*a* and shunt condenser 2*a* connected across the grid circuit of the first valve 4 the aerial 5 being tapped upon this inductance 1*a*, or as shown, connected to the top end thereof and the terminal H being variably tapped also upon the inductance 1*a* the terminal E being connected to earth. Similarly the arrangement of Fig. 4 may be associated with an inter-stage coupling, for example, as shown in the accompanying Fig. 11, the terminal H may be connected to a variable tapping point upon the inductance 1*b* in a tuned circuit in the plate circuit of the first valve 6 of two valves 6 and 7 in cascade the terminal E being connected to the common cathode point (earth).

The accompanying Fig. 12 shows a slight modification of the arrangement shown in accompanying Fig. 11 the said modification consisting in replacing the simple tuned circuit in the plate circuit of valve 6 in Fig. 11 by a tuned circuit having two series condensers 2*b*, 3*b* across an inductance 1*b* and connecting the terminal H to the point between the condensers 2*b* and 3*b* instead of to a tapping point upon 1*b*. In an arrangement described wherein a selectivity device in accordance with this invention is employed in conjunction with an ordinary tuned circuit (see the accompanying Figs. 9 and 10) the tuning operation may be very simply employed in two stages the first stage consisting in tuning the ordinary tuned circuit to the station desired and the second stage consisting in switching in the selectivity circuit and adjusting it to separate out the interference.

For example, when it is desired to improve the selectivity of a normal radio receiver for stations closely spaced in frequency the frequency separation can conveniently be arranged to be 9 kilocycles each side of the carrier F_0 (this is the normal present day separation between broadcasting stations whose frequencies are adjacent one another in the frequency spectrum) and in this way, by the use of the selectivity circuit, reception of a desired station can be effected without interference from a station of adjacent frequency. In cases where a high degree of separation is not required it will in many cases not be necessary to provide any audio frequency correction circuit unless the requirements as to quality are very stringent and/or the required selectivity very high a tone correction arrangement may be provided. Any convenient tone correction arrangement known per se may be employed for example between the output terminals of the receiver and its associated loud-speaker or in the audio frequency amplifier of the receiver.

Arrangements wherein a branched circuit in accordance with the first feature of this invention is associated with and tapped upon a tuned circuit, for example arrangements as shown in Figs. 9 to 12 of the accompanying drawings, present the advantage that the combined effects of the resonant tuned circuit and the branched circuit can be made to nullify to a great extent undesired effects due to the rising up of the characteristic on the side of the "dip" frequency remote from the "peak" frequency. This type of advantageous result is illustrated graphically in the accompanying Fig. 13 in which the chain line curve is the characteristic of the tuned circuit alone, the broken line curve the characteristic of the branched circuit arrangement tapped thereon and the full line curve the combined characteristic. As will be seen although in the full line curve characteristic rises outwardly from the "dips" the amount of rise is substantially less than in the case of the broken line curve.

Arrangements as hereinbefore described are well suited for use in superheterodyne receivers and may with advantage be employed to impart to the intermediate frequency amplifier of a superheterodyne receiver a desired degree of selectivity. A superheterodyne receiver embodying apparatus as hereinbefore described is illustrated in the accompanying Fig. 14, the said figure only showing such parts of the receiver as are necessary to an understanding of the manner in which the present invention is applied thereto. Referring to Fig. 14, **8** represents a high frequency valve operating at the received frequency and having in its output circuit the customary tuned circuit **9**. The output from the valve **8** is transferred to a first detector valve **10** to whose grid circuit is also applied, as in the usual well known way, local oscillations derived from a local oscillator represented in Fig. 14 merely as a tuned circuit **11** though, of course, there will either be provided a separate oscillator valve or the first detector will be arranged to act both as a mixing valve and an oscillator in known manner. **12** is the first valve of the intermediate frequency amplifier whose output is dealt with (by apparatus not shown) in the manner usual in superheterodyne receivers.

It will be noted that the plate circuit of the first detector valve **10** includes a tuned circuit **1**_b_, **2**_b_, **3**_b_, resembling the correspondingly indicated tuned circuit of Fig. 11 and that the junction point between the condensers **2**_b_ and **3**_b_ is connected to the terminal H of a branched circuit arrangement closely resembling that shown in Fig. 4 of the drawings. This branched circuit arrangement includes negative resistance valves V_1 condensers C_1C_2 and inductances L_1L_2 all connected after the manner of the said Fig. 4. In addition, however, there are provided two small auxiliary condensers k_1 and k_2 which are mechanically coupled together so that when one is at its maximum value the other is at its minimum value.

By adjusting the condensers k_1k_2 together it is thus rendered possible to vary the frequencies at which the "dips" occur without changing the "peak" frequency in order to meet any specific requirement at any time. Assuming the intermediate frequency to be 110,000 cycles per second, it has been found possible to adjust the apparatus between extreme positions at one of which (that corresponding to extreme selectivity) the "dip" frequencies occur at 3,000 cycles above and below the "peak" frequency and at the other of which (that in which minimum selectivity is obtained) the "dip" frequencies occur at 20,000 cycles above and below the "peak" frequency. In Fig. 14 it is assumed that the fixed condenser C_2 is smaller than the fixed condenser C_1 and the maximum value of the auxiliary condenser k_1 smaller than that of the auxiliary condenser k_2.

With this arrangement greatest selectivity will be obtained when the auxiliary condenser k_2 is at maximum value and the auxiliary condenser k_1 at minimum value. Where adjustment of selectivity is not required and a fixed predetermined selectivity is all that is necessary the auxiliary condensers k_1 and k_2 may of course be omitted. Apparatus in accordance with this invention can also be employed in connection with superheterodyne receivers to provide a high frequency tuning arrangement whereby what is commonly known as "second channel" interference may be successfully eliminated. In such an application an arrangement as shown in Fig. 4 would be employed and would be so adjusted that the "dip" frequencies were remote from the "peak" frequency by an amount equal to twice the intermediate frequency.

Arrangements in accordance with the first feature of this invention possess a characteristic which may, in some cases, be undesirable in practice. For example when a circuit as illustrated in Fig. 4 is employed in a radio receiver whose other selective circuits are relatively flatly tuned, it will be found that owing to the fact that the response curve rises outwardly of the rejector dips, a condition may arise when a comparatively strong signal emitted at a frequency relatively remote from that intended to be received may cause interference. For example, the radio broadcast stations known as "London Regional" and "Muhlacker" operate at the present time on closely adjacent frequencies (only about 9 kilocycles apart) and if a circuit arrangement as illustrated in Fig. 4 were adjusted to cut out the London Regional station, and receive relatively weak signals from Muhlacker (the radio receiver being assumed to be much nearer to the London Regional station than to Muhlacker) then, owing to the rising response above referred to and to the low selectivity of the circuits of the receiver following the said circuit as illustrated in Fig. 4, a comparatively strong signal from a station such as the Midland Regional station relatively remote in frequency from that of Muhlacker may cause interference.

The second feature of this invention, which obviates this difficulty, will be better understood upon reference to the diagrammatic and explanatory graphical illustrations shown in Figs. 5, 6, 7. Consider the case of a complex split or branched circuit arrangement consisting of a capacity shunted by an inductance and a capacity in series and suppose the acceptor circuit constituted by the inductance and capacity in series has a natural frequency of 990,000 cycles per second, the whole loop circuit having a natural frequency of 1,000,000 cycles per second.

Suppose the Q value of this circuit to be 1,000. Then the curve connecting the relative impedance of the whole circuit with frequency will be as shown in Fig. 5. Since in this circuit arrangement the rejector path will behave as an inductance at 1,000,000 cycles per second, it must be tuned with a condenser to obtain an over-all acceptor effect and the condenser in shunt with the series inductance and capacity of course constitutes this tuning condenser. Similarly consider the case of an inductance shunted by an inductance and a capacity in series, the series connected inductance and capacity being tuned to 1,010,000 cycles per second and the whole loop circuit being tuned to 1,000,000 cycles per second, Q being, as before, 1,000.

Now the curve connecting relative impedance with frequency will be as shown in Fig. 6 in which the rejector or dip effect is obtained at 1,010,000 cycles per second, an inductance is required to attain an over-all acceptor effect. If in accordance with the present feature of the invention the two complex split or branched circuits just described be employed in cascaded association the total resultant response effect will be of the general form shown by the series of curves of Fig. 7. This series of curves consists, as will be seen, of three curves shown respectively in full broken and chain lines. The full line curve is drawn for the case where the capacity tuned circuit rejects 990,000 cycles per second and accepts 1,000,000 cycles per second the inductance tuned circuit accepting the same frequency, namely 1,000,000 cycles per second but rejecting 1,010,000 cycles per second.

The broken line curve is drawn for the case in which the condenser tuned circuit rejects 987,500 cycles per second and accepts 997,500 cycles per second the inductance tuned circuit accepting 1,002,500 cycles per second and rejecting 1,012,500 cycles per second. The remaining chain line curve is drawn for the case where the capacity tuned circuit rejects 992,500 cycles per second and accepts 1,002,500 cycles per second the inductance tuned circuit accepting 997,500 cycles per second and rejecting 1,007,500 cycles per second.

It will be apparent from a consideration of Fig. 7 and a comparison of this figure with the graphs of Fig. 3 that the result of cascading the circuits and "staggering" the tuning as above set forth, is to provide a band pass effect with very steep sides to the response curve, the response remaining low on either side of the "dips" between which the band pass response is obtained.

Fig. 8 of the drawings shows one cascade circuit arrangement in accordance with the present feature of the invention. As will be seen upon reference to Fig. 8 of the drawings, two split or branched complex tuned circuit arrangements are employed one, marked "A", being a capacity tuned circuit and the other, marked "B", being an inductance tuned circuit. These two circuits are ganged together at a constant frequency separation for simultaneous control and thermionic valves constituted by screened grid valves adjusted to present negative resistance are associated with the two branched circuits for reducing the damping. One of these negative resistance valves is indicated at V_1 and the other at V_2. Input is applied between terminal I and earth (cathode point) and output taken off between terminal O and earth (cathode point). It will be noted that the two branched or split circuits are in effect cascaded via what may be termed an isolating valve which is the valve V_3 of Fig. 8, this valve being also represented as a screened grid valve.

This arrangement is provided because it is important that the two cascaded circuits upon which the arrangement depends for its selectivity should be adequately screened from one another, and in carrying the circuit arrangement of the said Fig. 8 into practice, care should be taken to provide adequate screening and to isolate the various energy supplies for the valves. Such isolation may be effected in any manner known per se e. g. as indicated by the screens represented in the said Fig. 8 by broken lines. It will be appreciated by those skilled in the art that gang control is possible, for, if all the condensers of circuits A and B be ganged together and with the mutual inductance, their individual laws of variation being correctly chosen any of the curves of Fig. 7 could be reproduced at any wave length within the range. In practice, however, such an arrangement would probably be unduly clumsy and a compromise sufficient for most practical purposes is to be preferred. Such a compromise consists in leaving the "acceptor" condenser in circuit A and the parallel inductance in circuit B fixed and making the two "rejector" condensers (i. d. those in series with the inductance elements) of such individual laws that they could be ganged to produce a constant band-width in kilocycles at all frequencies within the range.

It would be a relatively simple matter to reproduce these laws from standard "straight line frequency" condensers ganged on one shaft. However, if correct adjustments of the parallel condenser in A and parallel inductance in B were made so as to produce a curve entirely symmetrical in the middle of the tuning range then, at one end of the range, although the correct band width at the top of the curve would be maintained, one side would be steepened and the other made less steep. At the other end of the range the effect would be inverted, i. e. again the width at the top would be correct, but the side which was the sharpest at the other extreme end of the range would not be the least sharp, and vice versa.

In other words, the compromise arrangement, would suffer from the defect that the response curve would only be exactly symmetrical in the center of the tuning range. This, however, would not be a too serious objection in many practical cases.

Although the present invention is of general application it may, with considerable advantage, be employed as a fixed tuned arrangement in the intermediate frequency tuning stage of a superheterodyne receiver. A portion of an amplifier embodying what may be regarded as a development of the arrangement illustrated in Fig. 8 is illustrated in the accompanying Fig. 15. Referring to Fig. 15 the valve **10a** which may for example be a high frequency valve in a radio receiver or intermediate frequency valve in a superheterodyne receiver, includes in its output circuit a tuned circuit **1b**, **2b** and **3b** corresponding to the similarly designated tuned circuit shown in the accompanying Fig. 11. The condenser **3b** forms part of a branched circuit arrangement similar to that shown at A in Fig. 8, there being provided a reaction valve V_1 as in the said Fig. 8. In the accompanying Fig. 15, V_3 is an isolating valve corresponding to the similarly designated valve of the Fig. 8, this isolating valve containing in its output circuit a simple tuned circuit including an inductance **1b** part of which constitutes the inductive branch of a circuit arrangement B corresponding to the similarly designated circuit arrangement of Fig. 8, there being provided a further negative resistance valve V_2 as in the said Fig. 8. The principal differences between the accompanying Fig. 15 and Fig. 8, are that in the said Fig. 15 the circuits A and B are in effect tapped upon tuned circuits; that parts of the reactances of the tuned circuits also constitute parts of the reactances of the circuits A and B; and that the said circuits A and B contain blocking condensers K of large value and which may, so far as the working frequencies are concerned, be regarded as though they were short circuited.

The simplified tapped circuit arrangement embodied in Fig. 15 is such as to render it possible to dispense with the isolating valve V_3 by suitably adjusting or selecting the tappings.

What I claim is:

1. In combination with a resonant circuit tuned to a desired carrier frequency of a modulated carrier wave, a frequency selective network of the band pass type comprising at least two branch circuits, each including an inductor and a capacity element, one of said branch circuits being tuned slightly below the desired frequency and the other thereof being tuned slightly above the desired frequency, and a negative resistance means connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit, said frequency selective network being connected across a portion of said resonant circuit.

2. In combination with a resonant circuit tuned to a desired carrier frequency, a frequency selective network of the band pass type, comprising at least two branch circuits, each including an inductor and a capacity element, one of said branch circuits being tuned slightly below the desired frequency and the other branch circuit being tuned slightly above the desired frequency, a negative resistance means connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit, the inductor and pacity element in each branch circuit being in series and said resistance means including at least one screen grid tube connected to operate in dynatron fashion.

3. In combination with a resonant circuit tuned to a desired carrier frequency of a modulated carrier wave, a frequency selective network of the band pass type comprising at least two branch circuits, each including an inductor and a capacity element, one of said branch circuits being tuned slightly below the desired frequency and the other branch circuit being tuned slightly above the desired frequency, a negative resistance means connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit, each capacity element being variable, said resonant circuit including at least two reactances of opposite sign, one of the reactances being connected to at least one of said branch circuits.

4. In combination with a tunable resonant circuit, a frequency selective network of the band pass type comprising at least two branch circuits, each including an inductor and a capacity element, one of said branch circuits being tuned to a frequency which is slightly below the frequency to which the tunable resonant circuit is tuned and the other branch circuit being tuned to a frequency which is slightly above the frequency to which the tunable resonant circuit is tuned, and negative resistance means comprising a pair of screen grid tubes connected to operate as dynatrons, said negative resistance means being connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit.

5. In combination with a resonant circuit tuned to a desired carrier frequency of a modulated carrier wave, an amplifier tube connected to a resonant circuit, a frequency selective network of the band pass type comprising at least two branch circuits, each including an inductor and a capacity element, one of said branch circuits being tuned slightly below the desired frequency and the other thereof being tuned slightly above the desired carrier frequency, and a negative resistance means connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit, said selective network including an adjustable capacity element across each of the branch circuit capacity elements.

6. In a receiver of the superheterodyne type including a frequency changer tube and a following intermediate frequency amplifier tube, a tuned circuit including an inductance and at least one condenser connected between the two tubes, a frequency selective network coupled to said tuned circuit, said network comprising a pair of coupled tuned branch circuits, one of said branch circuits being tuned to a frequency which is slightly below the frequency to which the tuned circuit is tuned and the other thereof being tuned to a frequency which is slightly above the frequency to which the tuned circuit is tuned and negative resistance means connected to said branch circuits.

7. In a receiver of the superheterodyne type including a frequency changer tube and a following intermediate frequency amplifier tube, a tuned circuit including an inductance and at least one condenser connected between the tubes, a frequency selective network coupled to said tuned circuit, said network comprising a pair of coupled tuned branch circuits each of said branch circuits comprising inductance and capacity in series, one of said branch circuits being tuned to a frequency which is slightly below the frequency to which the tuned circuit is tuned and the other branch circuit being tuned to a frequency which is slightly above the frequency to which the tuned circuit is tuned, an adjustable condenser connected across at least one of the capacities and negative resistance means connected to said branch circuits.

8. In a receiver of the superheterodyne type including a frequency changer tube and a following intermediate frequency amplifier tube, a tuned circuit including an inductance and at least one condenser connected between the tubes, a frequency selective network coupled to said tuned circuit, said network comprising a pair of coupled tuned branch circuits, one of said branch circuits being tuned to a frequency which is slightly below the frequency to which the tuned circuit is tuned and the other branch circuit being tuned to a frequency which is slightly above the frequency to which the tuned circuit is tuned, and negative resistance means comprising a pair of dynatron tube circuits, said last named means being connected to said branch circuits.

9. In a receiver of the superheterodyne type including a frequency changer tube and a following intermediate frequency amplifier tube, a tuned circuit including an inductance and at least one condenser connected between the two tubes, an auxiliary condenser in series with said condenser, a frequency selective network coupled

to said tuned circuit, said network comprising a pair of coupled tuned branch circuits, one of said branch circuits being tuned to a frequency which is slightly below the frequency to which the tuned circuit is tuned and the other branch circuit being tuned to a frequency which is slightly above the frequency to which the tuned circuit is tuned, said selective network being connected across the auxiliary condenser and negative resistance means connected to said branch circuits.

10. In combination with a pair of cascaded amplifier tubes, a tunable circuit connected to the output electrodes of the first tube, the circuit including a coil and a variable tuning condenser, a frequency selective network coupled to said tunable circuit and including a branch circuit consisting of means comprising an inductance and capacity in series for tuning the branch circuit to a frequency which is just outside the frequency to which the tunable circuit is tuned, said branch circuit being connected to one of said reactive elements of the tunable circuit, and negative resistance means connected to said network to reduce the damping thereof.

11. A frequency selective network comprising a pair of branch circuits, each circuit including a coil and variable condenser in series, said branch circuits being tuned to slightly different frequencies and a negative resistance element connected in shunt with each branch circuit, a pair of screen grid tubes, a source of direct voltage for the tubes, a common connection from a point on said source to one side of each of the coils, the anode of each tube being connected to the opposite side of one coil and means for connecting the screen grids of said tubes to a point on said source which is positive with respect to the voltage of the anodes.

12. A frequency selective network comprising a pair of branch circuits, each circuit including a coil and a variable condenser in series, said branch circuits being tuned to slightly different frequencies, a condenser connected in shunt with one branch circuit, a coil connected across the other branch circuit, a pair of screen grid tubes, a source of direct voltage for the tubes, a common connection from a point on said source to one side of each of the coils, the anode of each tube being connected to an opposite side of one coil, and means for connecting the screen grids of said tubes to a point on said source which is positive with respect to the voltage of the anodes.

13. In combination with a resonant circuit tuned to a desired carrier frequency of a modulated carrier wave, a frequency selective network of the band pass type comprising at least two branch circuits each including an inductor and a capacity element, one of said branch circuits being tuned slightly below the desired frequency and the other thereof being tuned slightly above the desired frequency, and a negative resistance means connected to said branch circuits for reducing the damping of the selective network whereby a predetermined selectivity characteristic is imparted to the resonant circuit, said resonant circuit comprising an inductance device and a pair of tuning condensers in series shunted across the inductance device, said frequency selective network being connected across one of said last named condensers.

14. In a superheterodyne receiver an amplifier tube provided with an input circuit and an output circuit, a source of signalling energy of predetermined frequency, means for coupling said source to said input circuit, a utilizing circuit and means for coupling the utilizing circuit to said output circuit, said means for coupling the source to the input circuit comprising a tunable circuit tuned to a frequency which is slightly different than the frequency of the energy to be amplified, said means for coupling the output circuit to the utilizing circuit comprising a tunable circuit tuned to a frequency which is slightly different than the frequency of the energy to be amplified but in an opposite direction than the frequency to which said first named means is tuned and means connected with the coupling means for providing high attenuation in said circuits at the frequencies to which the coupling means are tuned.

NOËL MEYER RUST.