July 21, 1936. H. A. WHEELER 2,048,527

SELECTIVE CIRCUITS

Filed Feb. 1, 1932 3 Sheets-Sheet 1

Fig. 1

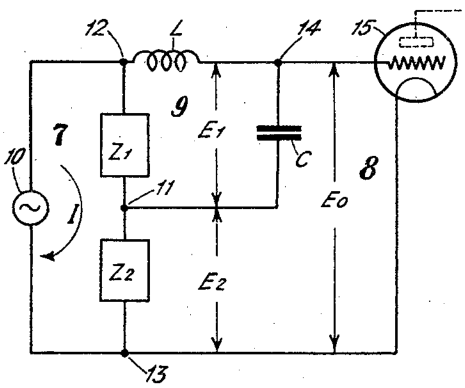

Fig. 2

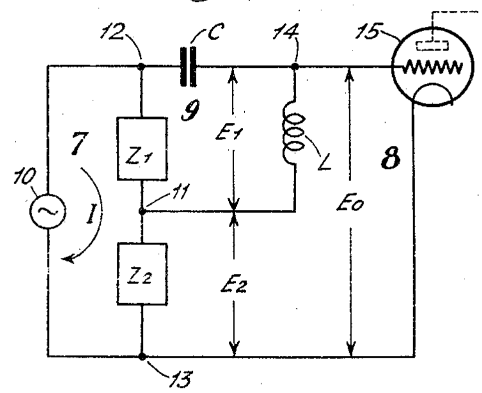

Fig. 3

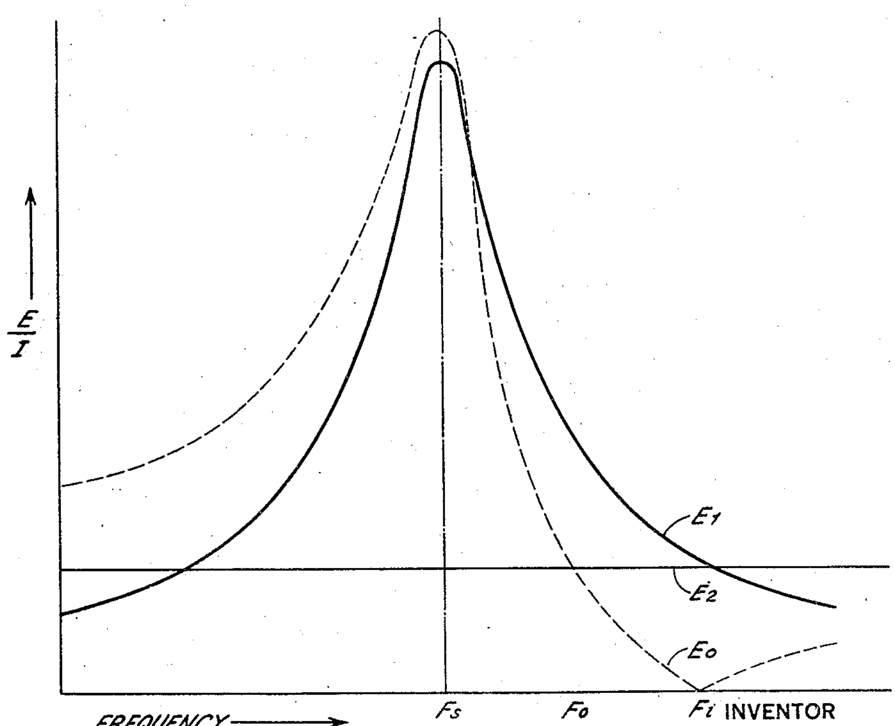

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Fig. 4

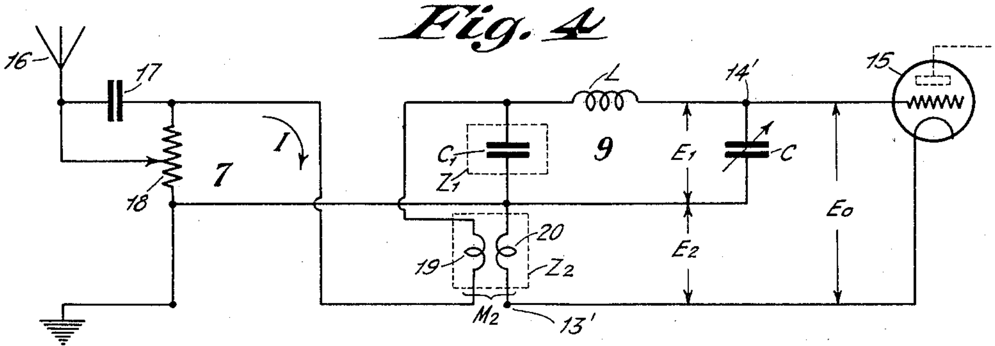

Fig. 5

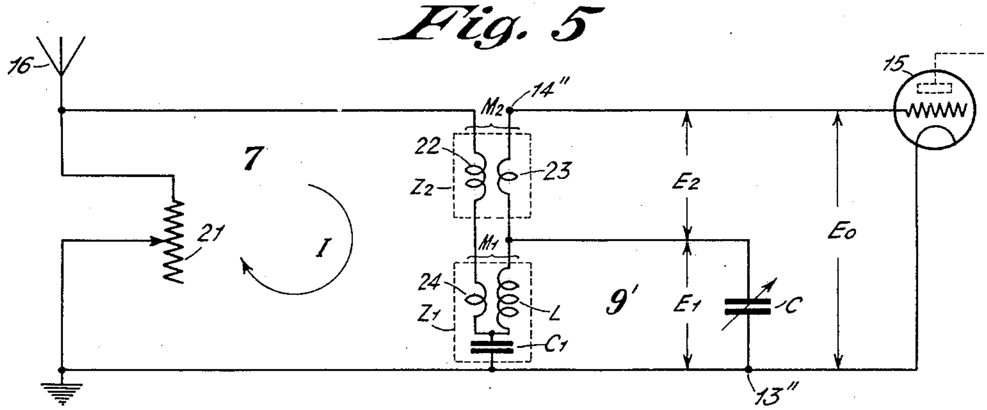

Fig. 6

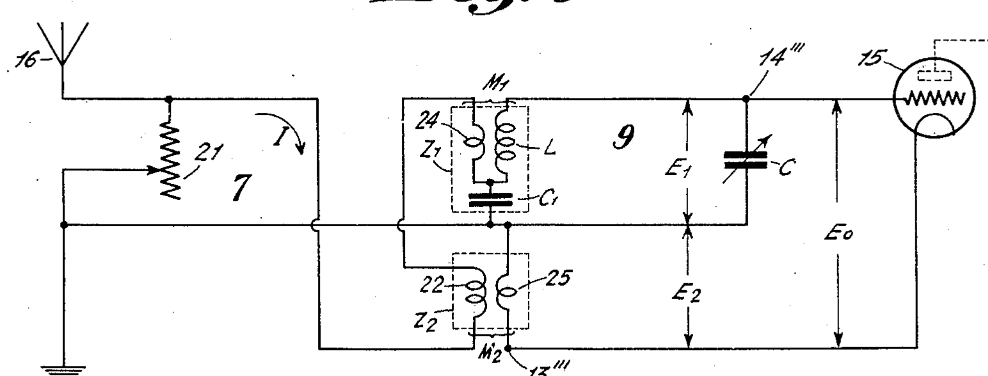

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Fig. 7

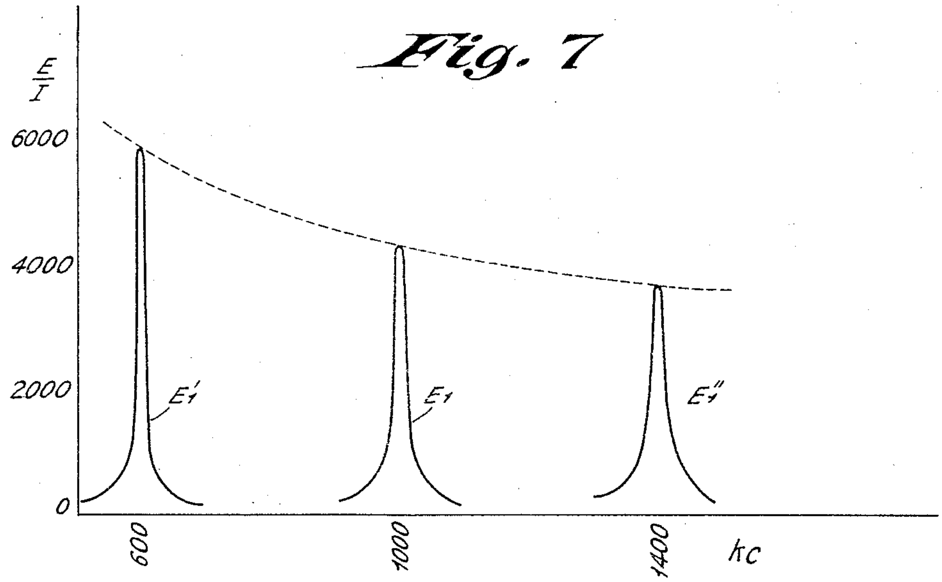
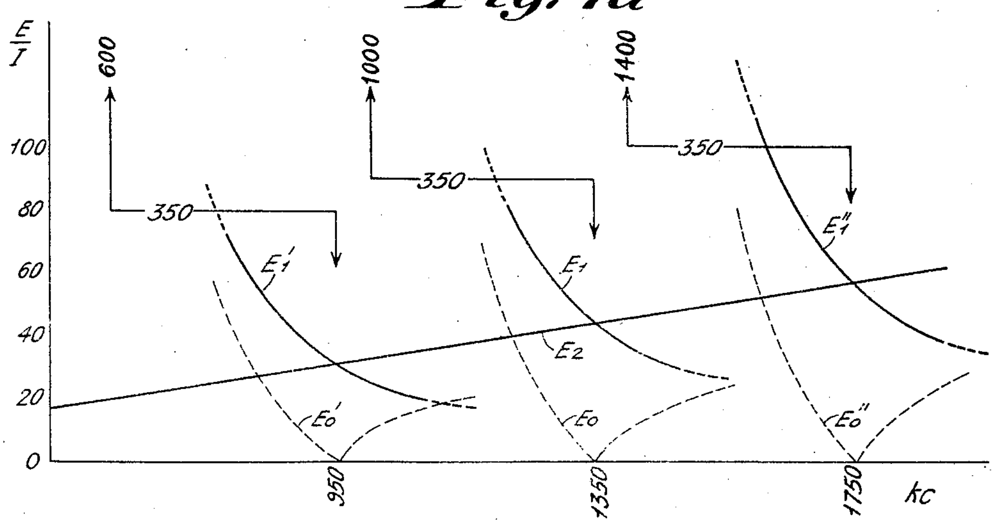


Fig. 7a



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SELECTIVE CIRCUITS

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Application February 1, 1932, Serial No. 590,173

19 Claims. (Cl. 250—20)

The present invention relates to improvements in selective electrical circuits, and more particularly to selective circuits for preventing the reception of "image frequencies" in the operation of superheterodyne radio receivers.

A superheterodyne type of radio receiver has an inherent defect in that it is responsive to signals of two frequencies each separated from the oscillator frequency by an amount which is equal to the intermediate frequency. Thus, when such a receiver is tuned to receive a desired signal, in the presence of undesired signals differing therefrom by an amount which is twice the intermediate frequency, such undesired signals are received, converted into the intermediate frequency, and interfere with the desired signal, which has also been converted into the intermediate frequency. The frequency of such interfering signals to which the superheterodyne receiver is responsive is known as the "image frequency". Tuned circuits must be relied upon to suppress signals of this frequency and to prevent their being converted into the intermediate frequency.

It is the object of the present invention to overcome the above-noted disadvantage of the superheterodyne radio receiver and provide a new and improved selective circuit for preventing the reception of signals of the image frequency.

It is a further object of this invention to provide an image rejection circuit in which the response to the desired signal will not be in any way diminished, although the tunable circuit has a very high selectivity against image interference, independent of the frequency to which the receiver is tuned.

For accomplishing the objects of the present invention, a selective network is provided for selectively transferring desired signal frequency currents of any frequency in a band of frequencies. This network is connected between the exciting circuit, or antenna, of a receiver and a responsive device, or the receiver itself. The selective network comprises a broadly resonant circuit and a selective circuit. The resonant circuit which may be the antenna circuit is broadly tuned to all frequencies within the band of frequencies for attenuating all signals of any frequency outside of said band. The selective circuit is connected between said broadly resonant circuit and said receiver, and is for suppressing all image frequency currents which are admitted by the antenna circuit and which fall within said band.

The selective circuit comprises two signal transfer means each coupled to the broadly resonant circuit and to the receiver. The first transfer means has a transfer ratio which varies greatly with frequency and has a maximum transfer at the frequency of the signal, and thus selectively transfers a signal current of any frequency within a band of frequencies. However, this transfer means incidentally transfers currents of the undesired image frequency though to a lesser degree. The second, or auxiliary transfer means, has a transfer ratio which does not vary greatly with frequency, and thus non-selectively transfers currents of the entire band of frequencies. These two transfer means are adjusted to respond equally and oppositely to signals of the image frequency. Thus, the relative intensity of the image frequency currents as first and secondly transferred is so adjusted that the currents may be balanced against each other and thereby image frequency currents falling within said band be completely suppressed. The first-mentioned transfer means builds up by resonance the selectively transferred currents and thus effects a much greater transfer at the carrier frequency of the signal than the non-selective transfer of the carrier frequency by the second transfer means. The second transfer means therefore has but little effect upon the transfer of the desired frequencies. Also the voltages transferred by these two transfer means are not in opposition at the desired signal frequency, as will be explained later.

The amount of non-selective transference is adjusted to equal the amount of image frequency selective transference throughout the band of frequencies. Thus, the circuits are so designed and proportioned that the frequency of complete suppression varies automatically and simultaneously with the adjustment of the selective transference at the resonant frequency of the tunable circuit, and the frequency of complete suppression is maintained substantially uniformly spaced from the resonant frequency of the tunable circuit. Therefore, in a superheterodyne receiver, the tunable circuit may be tuned to the carrier frequency of any signal and the corresponding image frequency interference will be automatically completely suppressed at all settings.

Whereas the response of the tunable circuit to the image frequency currents may vary throughout the tuning range of the receiver, this effect is compensated for by correspondingly varying the resonance of the entire input circuit so that the transfer of the image frequency through the untuned circuit will be correspondingly varied.

Whereas this invention has particular application in connection with image frequency suppression, as discussed above, it is to be understood that it also has considerable utility in general radio reception for selectively transferring currents of a desired signal frequency and preventing interference of signals of any frequency whatever. Furthermore, the principles of this invention may be applied to each of a number of resonant circuits in one system, and thereby secure proportionately greater selectivity.

Attention is now invited to the drawings, in which:

Fig. 1 is a schematic diagram illustrating one arrangement of the two transfer means;

Fig. 2 is a similar diagram illustrating an alternative arrangement of the two transfer means;

Fig. 3 is a diagram showing a curve illustrating the selective action of the circuits of Figs. 1 and 2;

Fig. 4 is a diagram showing a radio antenna circuit embodying the principles illustrated in Fig. 1;

Fig. 5 is a diagram showing a modification of the circuit of Fig. 4;

Fig. 6 is a circuit diagram showing a second modification of the circuit of Fig. 4;

Figs. 7 and 7A are diagrams showing a set of curves illustrating the selective action of the circuit of Fig. 6.

In Fig. 1, to which attention is now invited, there is shown a selective coupling system comprising exciting circuit 7 including a source of alternating current 10, and the two impedances Z_1 and Z_2, the latter of which form a path between the input terminals 12 and 13. There is also shown a work circuit 8 exemplified by the grid-cathode circuit of the vacuum tube 15. The exciting circuit is coupled to the responsive device by two transfer means. The first transfer means includes the circuit 9 composed of impedance Z_1, inductance L and condenser C. The second transfer means includes impedance Z_2. There is thus provided an output path including the condenser C and the impedance Z_2, connected in series between the output terminals 13 and 14.

The first transfer means 9 is sharply resonant at or near a frequency which will be called the signal frequency. This sharp resonance is effectively maintained by making Z_1 sufficiently small or by making the impedance of the source 10 sufficiently large so that the exciting circuit does not have a controlling effect upon the resonance of the first transfer means 9. For the same purpose, the impedance of the responsive device 15 is made sufficiently large. The current I from the source 10 flows through Z_1, builds up a circulating current in the first transfer means 9, and thereby produces a voltage E_1 across the condenser C.

The second transfer means Z_2 is not sharply resonant at any operating frequency, and may be aperiodic. The current I, flowing through impedance Z_2, builds up a voltage E_2 across this impedance.

The two transfer means will be collectively referred to as a coupling system whose input terminals are 12 and 13 and whose output terminals are 14 and 13. This coupling system need not have a terminal common to its input and output, although 13 is a common terminal, as the system is illustrated in Fig. 1.

The direction of transfer of the coupling system just described may be reversed, retaining some of the advantages of the system as shown in Fig. 1; that is to say, 14 and 13 may be used as input terminals and 12 and 13 used as output terminals.

The transfer of the first means 9 will be denoted by the ratio E_1/I, and that of the second means, by the ratio E_2/I, which latter is equal to Z_2. The combined resultant transfer will be denoted by E_0/I, in which the output voltage E_0 is the vector sum of E_1 and E_2.

Fig. 2 is similar to Fig. 1 except that L and C are interchanged. The effect of this change will be discussed below. In Fig. 2, like parts are designated by the same reference characters.

The operating characteristics of Fig. 1 will now be described, attention being invited to Fig. 3. Two frequencies will be considered as being derived from the source 10. One is the desired signal frequency F_s and the other is the undesired interfering frequency F_i, which is somewhat higher or lower than F_s. The first transfer ratio E_1/I is shown in Fig. 3 by the curve E_1. This curve shows a sharp maximum at F_s, the resonant frequency of the first transfer means 9. The second transfer ratio E_2/I is shown by the line E_2 indicating that this ratio does not have sharp resonance within the operating frequency range.

The phase relationship of E_1 and E_2 will be explained. At F_s the resonant circulating current in circuit 9 is in phase with Z_1I, and therefore E_1 across C lags 90° behind Z_1I. At frequencies lower than F_s, the circulating current in circuit 9 leads nearly 90° ahead of Z_1I and E_1 is nearly in phase with Z_1I. At frequencies higher than F_s, the circulating current lags nearly 90° behind Z_1I and E_1 lags nearly 180° behind Z_1I. E_2 is always equal to Z_2I.

If Z_1 and Z_2, shown in Fig. 1, are of like character, the voltages E_1 and E_2 differ in phase by 90° at F_s and therefore their vector sum, as represented by the curve E_0 of Fig. 3 at the point F_s, is greater than E_1. At the same time, phase opposition between E_1 and E_2 results at frequencies higher than F_s. At some frequency, F_i in Fig. 3, E_1 and E_2 are equal and opposite, with the result that E_0/I is zero, as shown by curve E_0 in Fig. 3. Changing the value of Z_2, but not its character, shifts the intersection of curves E_1 and E_2 so that any value of F_i, higher than F_s, can be suppressed by using the proper value of Z_2. Increasing the value of Z_2 brings the intersection nearer to F_s. On the other hand, increasing the value of Z_i moves the intersection away from F_s.

If Z_1 and Z_2 of Fig. 1 are made reactances of opposite kinds, the curves of Fig. 3 will be reversed and the intersection of E_1 and E_2 will be brought to a frequency lower than F_s.

Interchanging L and C, as shown in Fig. 2, reverses the polarity of E_2 without substantially changing its value. Making Z_1 and Z_2 of like character, in Fig. 2, brings the intersection of curves of E_1 and E_2 below F_s; while making Z_1 and Z_2 reactances of opposite kinds, brings the intersection to a frequency higher than F_s. Thus, interchanging L and C has the same effect as changing the relationship between Z_1 and Z_2, and making both changes at once has substantially no effect upon the operation of the coupling system. Since any frequency F_i can be suppressed in either Fig. 1 or Fig. 2 with the proper choice of Z_1 and Z_2, there is no essential difference between these alternative arrangements. If C is a variable tuning condenser, it is desirable to ground the frame and moving parts. In this case, the terminal 11 of the condenser C in Fig. 1, or the terminal 12 of the condenser C in Fig. 2, may be grounded. Also, the impedances Z_1 and Z_2 may be of any character, such as mutual inductances, thus producing a coupling circuit having no common terminal 13 which is at once an input terminal and an output terminal.

When selective coupling systems such as those shown in Figs. 1 and 2 are connected between the antenna and frequency changer of a superheterodyne receiver, F_s is the signal frequency and F_i the image frequency, F_s and F_i differing by twice the intermediate frequency. It is more common to make F_i higher than F_s, as is shown in Fig. 3. The superheterodyne oscillator frequency F_0 is midway between F_s and F_i, as indicated in Fig. 3.

Fig. 4 is a circuit illustrating an adaptation of the principles of Fig. 1 to a selective network or coupling system for coupling the antenna to the first tube of a superheterodyne receiver. The coupling system is tuned to the signal frequency F_s and has a great selectivity against image interference, as will be explained hereinafter.

In this figure, the antenna 16 is connected to the contact of a volume control potentiometer 18, one part of which is shunted by condenser 17, the capacity of which is equal to the capacity of the average antennna. With this arrangement, the variation of the potentiometer tap does not materially affect the tuning of the coupling system as a whole but provides a means for varying the sensitivity of the combination. The antenna current divides in potentiometer 18, one part flowing directly to ground. The other part flows through the coil 19 and fixed condenser C_1. The first transfer means is the closed circuit 9, which is composed, in this instance, of C_1, L, C, of which C_1 corresponds to Z_1 of Fig. 1. The circuit 9 is sharply tuned to resonance with the signal frequency F_s by varying the capacity of the variable condenser C, and is connected to the grid of the tube 15. Coil 19 of the circuit 7 is coupled to the coil 20 in the cathode lead of the tube 15. The mutual inductance M_2 between coils 19 and 20, which provides a fixed inductive coupling between the antenna circuit and the receiver, corresponds to Z_2 of Fig. 1 and comprises the second transfer means. The condenser C_1 and the inductive coupling M_2 are proportioned relative to each other so as to deliver equal and opposite voltages, at the image frequency, to the responsive device or the receiver input and thus balance out image frequency signals which are within the band through which the resonant circuit is tunable. It is to be noted that the image frequency signals which are thus balanced out are always separated from the desired frequency to which the resonant circuit is tuned by a constant frequency difference.

Although many suitable circuit constants may be found for constructing a circuit in accordance with Fig. 4, it has been found that the following are satisfactory:

The antenna 16 and the condenser 17 may have a capacity of about 200 micro-microfarads each, potentiometer 18 may have a resistance of about 10,000 ohms, coil L may have an inductance of about 260 microhenrys, condenser C may have a capacity of 350 micro-microfarads (maximum setting), and condenser C_1 may have a capacity of about 3500 micro-microfarads. Thus the fixed condenser C_1 has a value of the order of ten times the maximum value of the variable condenser C. The mutual inductance of coils 19 and 20 may be about 4 microhenrys.

The circuit of Fig. 4, with the above values, is intended to tune to receive a signal frequency of from 550 to 1500 kilocycles and is intended to work with a 260-kilocycle intermediate-frequency superheterodyne amplifier. The suppression frequency should always be separated by a constant difference (520 kilocycles) above the resonant frequency of the tuned circuit. Then, when the signal frequency F_s is tuned in, the image frequency F_i is automatically suppressed. When the condenser C is tuned for lower signal frequencies, the tuned circuit is much less responsive to the image frequencies, because the constant separation bears a much greater ratio to the lower signal frequency. In order to compensate for the lower responsiveness of the tuned circuit to image frequencies, the ratio of the impedance of C_1 to the impedance of M_2 is much greater at low frequencies. By this improvement, the image voltage at E_1 and E_2 very nearly counterbalance, regardless of the frequency of the signal being received.

Image transfer E_1/I increases proportionately to image frequency, because the decrease of impedance of C_1 is more than offset by the increase of image responsiveness of the tuned circuit 9. The image transfer E_2/I increases likewise, being equal to the inductive reactance of the mutual M_2. The equality of the image voltages E_1 and E_2 is secured by selecting the correct values of the mutual M_2, and phase opposition is secured by using the correct polarity of M_2. Comparing Fig. 1 with Fig. 4, Z_1 is the negative reactance of C_1, varying inversely with frequency, while Z_2 is the negative reactance of the negative mutual inductance M_2, varying directly with frequency. The ratio of Z_2 to Z_1 varies as a square of the image frequency.

When F_i exceeds F_s by a smaller constant difference, the ratio of Z_2 to Z_1 should vary less rapidly than the square of the image frequency, but more rapidly than the first power. This is accomplished by the use of the improvements as embodied in Figs. 5 and 6, which will now be described.

Fig. 5 shows an improved adaptation of the principles of Fig. 1 to a system for coupling a radio antenna to the first tube of a superheterodyne receiver. In this figure, like parts are designated by the same reference characters. The circuit of Fig. 5 differs from Fig. 4 in the following respects: First, the order of E_1 and E_2 in series between the grid and cathode of the tube 15 is interchanged in order to permit grounding of the cathode and of the frame and moving element of the tuning condenser C. Secondly, Z_1 in Fig. 1 is replaced in Fig. 5 by the mutual inductance M_1 in addition to C_1. Thirdly, the antenna or primary circuit 7 of Fig. 5 is broadly resonant within the tunable frequency range, resulting in greater voltage amplification from the antenna to the grid of the tube 15, and in somewhat better image suppression. In Fig. 5, as in Fig. 4, Z_2 is replaced by the mutual inductance M_2. In Fig. 5 the antenna is connected to one side of a volume control rheostat 21, the variable contact of which is grounded. The variable resistance or rheostat 21 serves also to produce a variable attenuation and broadens the resonance of the primary circuit to include a band of frequencies. The antenna current divides, one part flowing through 21, the other part through the coils 22 and 24 and the condenser C_1. The first transfer means is the secondary circuit 9′, which is composed of inductance L, variable condenser C and the large fixed condenser C_1, and the mutual inductance M_1 between coils 24 and L. The secondary circuit 9′ is tuned to resonance with the signal frequency F_s by variation of the capacity of condenser C. The impedance Z_1 of Fig. 1 is replaced by the mutual inductance M_1 and the capacity of condenser C_1. The large fixed condenser couples the primary and secondary circuits only to a moderate degree and causes the tuning of the secondary circuit to be substantially independent of the primary circuit. The impedance Z_2 of Fig. 1 is replaced by the mutual inductance M_2 between coils 22 and 23, which latter is connected in series with the condenser C between the grid and cathode of the tube 15.

All the various parts of the circuit shown in Fig. 5 may have widely differing characteristics. The following values have been found satisfactory, and when used in the circuit shown, cause the circuit to operate in accordance with the present invention:

The antenna 16 has a capacity of about 200 micro-microfarads, rheostat or variable resistance 21 has a resistance of about 2,000 ohms, coils 22 and 23 have an inductance of about 110 microhenrys each, the mutual coupling M_2 is about 4 microhenrys, inductance of L is about 260 microhenrys, maximum capacity of C is about 350 micro-microfarads, and C_1 has a capacity of about 3,500 micro-microfarads. The coil 24 should preferably have a very small inductance, and the mutual coupling M_1 should be much less than M_2, as will be explained more fully hereinafter.

The circuit of Fig. 5, when constructed to embody the above values, is very similar to that of Fig. 4, but is intended to work with a 175-kilocycle superheterodyne amplifier. Therefore, the image frequency F_i is 350 kilocycles higher than the signal frequency F_s, and has a range of from 900 to 1850 kilocycles.

The antenna circuit effects some improvement in image suppression by attenuating all signals outside of the frequency band over which the receiver is designed to operate, without regard to the independent means for balancing out of the voltages E_1 and E_2. The antenna circuit, including the antenna 16, coils 22 and 24, and condenser C_1 in series, is resonant to a frequency near 1,000 kilocycles, which is about the middle of the tuning range. The variable resistance 21 has a maximum value which is great enough to permit sensible resonance in the antenna primary circuit, but which is small enough to broaden the resonance of the circuit to include all of the band, and the antenna resonance has only a negligible effect on the tuning of the coupling system as a whole. The variable resistance permits varying the sensitivity of the combination. As has been mentioned, the inherent selectivity of the tuned circuit 9′ against the image frequency currents is much less at the higher frequencies. The broad resonance of the antenna circuit offers additional selectivity against the image when F_s is in the middle or higher part of the tuning range. As a result, the total inherent selectivity against the image frequency is given a higher average value and is made uniform over the entire range. The signal voltage amplification from antenna to grid is also greatly improved as compared with Fig. 4, especially in the middle of the tuning range.

Up to this point, the effect of the grid to cathode capacitance, inherent in tube 15 or in the connecting wires, has been neglected. The assumption was made that the responsive device represented by tube 15 had such high impedance as not to have an important effect upon the tuning of the circuit. This assumption is nearly met by Fig. 4, where only the direct capacitance between the grid and cathode is included between terminals 13′, 14′, and not any capacitance to ground. In Fig. 5 this effect is greater, including the capacitance to ground of coil 23 and grid wiring of tube 15. It is desirable to reduce this inherent capacitance to as low a value as possible. Then its residual effect can be compensated for by making the ratio of Z_2 to Z_1 abnormally high at the higher frequencies. This result is automatically obtained in the following "two-point" adjustment.

A two-point adjustment of Fig. 5 is made possible by the condenser C_1 and the mutual inductance M_1 associated with the first transfer means 9′. By "two-point" is meant that at two points in different parts of the tuning range the frequency of maximum suppression will fall exactly at the image frequency. At other points there may still be a slight difference, so that the image does not suffer the maximum suppression, but this difference is negligible when the two-point adjustment is employed.

With reference to Fig. 5, such an adjustment is made as follows: First, condenser C_1 is made as small as permissible without too greatly restricting the tuning range of the circuit 9′. This value of C_1 has the major effect in determining the coupling between the antenna circuit 7 and the tuned circuit 9′, and therefore the degree of voltage amplification from the antenna 16 to the grid of the tube 15. A representative value of C_1 is ten times the maximum value of C, although lower ratios may often be employed to advantage. Secondly, with the mutual inductance M_1 equal to zero, the system is tuned to a frequency in the lower part of the tuning range, and M_2 is adjusted to secure the greatest suppression of the image frequency currents. Thirdly, the system is tuned to a frequency in the upper part of the tuning range, and the value and polarity of the mutual M_1 are chosen to give the greatest suppression of the image frequency currents at this portion of the tuning range. If great precision is desired, the second and third operations may be repeated until no further improvement is possible. The greatest suppression is thereby secured at two points, namely, the lower and upper frequencies tuned in during the second and third operations, respectively. After making the two-point adjustment, nearly exact image suppression is secured over the entire tuning range. It has been explained that the character of Z_2, and therefore the polarity of the mutual M_2, is determined, first, by the type of circuit employed (Fig. 1 or Fig. 2) and, secondly, by the location of the image frequency to be suppressed (above or below the signal frequency). Experience shows that M_1 has a relatively small value and that the correct value and polarity may be best determined by trial. A negative value of M_1 is indicated in Fig. 5, which is the correct polarity for aiding phase relation between the mutual coupling component and the capacitive coupling component, which couple the antenna circuit with the first transfer means or circuit 9′. This polarity and a small value of the mutual M_1 cause a ratio of the impedance Z_2 to the impedance Z_1 which varies less rapidly than the square of the frequency, but more rapidly than the first power, which is a general requisite when the image frequency remains less than double the signal frequency. Two guiding rules may be stated to govern the choice of M_1 in the cases under consideration, having image frequencies higher than the signal frequencies: First, a smaller frequency difference between image and signal requires a larger negative value of the mutual M_1. Secondly, a greater inherent direct capacitance across the terminals 13'' and 14'' requires a less negative value (or even a small positive value) of the mutual M_1. The second rule, in extreme cases, amounts to an alteration of the general requisites just stated.

Fig. 6, to which attention is now invited, shows a preferred arrangement for accomplishing the same purposes as the circuits shown in Figs. 4 and 5, and for combining their respective advantages. In this figure, corresponding parts are designated by like reference characters. Fig. 6 has the two-point adjustment and has the broadly resonant antenna circuit of Fig. 5, but has the ungrounded tube cathode of Fig. 4 in order to minimize the direct capacitance across the terminals 13''' and 14'''. The circuit elements of Fig. 6 are like the corresponding elements of Fig. 5. In Fig. 6, M_2 is the mutual inductance between the coils 22 and 25, which latter coil has an inductance of about 10 microhenrys. Fig. 6, like Fig. 5, is intended to work with a 175-kilocycle superheterodyne amplifier so that the image frequency is 350 kilocycles higher than the signal.

Experiments with Fig. 6 have shown that the two-point adjustment provides a nearly complete image suppression over the entire tuning range from 550 to 1500 kilocycles. This condition is graphically illustrated in the curves of Fig. 7 and 7A, to which attention is now invited. These curves show the transfer ratios plotted against frequency as the system is tuned to 600, 1,000 and 1,400 kilocycles, respectively. In terms of Fig. 6, I is the exciting current flowing from the antenna through coils 22 and 24 and condenser C_1 and corresponds to I in Fig. 1. In Fig. 7 the curve E_1 shows the ratio of E_1/I when a 1,000-kilocycle signal is tuned in. This curve shows the inherent selectivity of the first transfer means tuned by condenser C. The voltage E_2 across the second transfer means is nearly imperceptible on the scale of Fig. 7. In order to better show the image suppression, the right-hand slope of the curve E_1 is shown in Fig. 7A on a highly magnified scale of ordinates, but with the same frequency scale. It is seen that the ratio of E_1/I is only about one per cent as great at the image frequency of 1,350 kilocycles as at the signal frequency of 1,000 kilocycles. In this figure, curve E_2 shows the ratio of E_2/I, which is the reactance of the mutual inductance M_2, having a value of 5.2 microhenrys in this particular case. As a result of the two-point adjustment, the curves E_1 and E_2 intersect at the image frequency. Since E_1 and E_2 are of opposite polarity, the resultant voltage E_0, as indicated by the dotted line, is zero. The curve E_0 represents the ratio E_0/I. In Figs. 7 and 7A the curves E_1' and E_1'' represent the corresponding curves for the 600-kilocycle signal and 1,400-kilocycle signal, respectively. By the proper proportioning of the mutual M_2, the slope of the curve E_2, as shown in Fig. 7A, may be made so that it will intersect the curves E_1' and E_1'' at the proper point to permit the resultant curves E_0' and E_0'' to be zero.

Whereas the present invention has been described as being particularly related to superheterodyne radio receivers, it is to be understood that the principles involved are equally applicable to general problems relating to tuned oscillatory circuits. It is further to be understood that the principles involved may be employed in successive tuning circuits included in a single system and that proportionately greater selectivity may be obtained thereby.

What is claimed is:

1. An electrical coupling system comprising two input terminals, two output terminals, a path between said input terminals, a path between said output terminals, a circuit tunable to a desired signal frequency, said circuit including reactances of opposite kinds, a first impedance including reactance common to both of said paths and said tuned circuit, and a second impedance common to both of said paths, the ratio of said second to said first impedance having a variation more rapid than the variation in frequency as the frequency of the current impressed upon said circuit is varied.

2. An electrical coupling system comprising two input terminals, two output terminals, a path between said input terminals, a path between said output terminals, a circuit tunable to a desired signal frequency, said circuit including reactances of opposite kinds, a first impedance including reactance common to both of said paths and said tuned circuit, and a second impedance common to both of said paths, the ratio of said second to said first impedance having a variation more rapid than the variation in frequency as the frequency of the current impressed upon said circuit is varied and less rapid than the square of the frequency.

3. An electrical coupling system comprising two input terminals, two output terminals, a path between, said input terminals, a path between said output terminals, a circuit tunable to a desired signal frequency, said circuit including reactances of opposite kinds, a first impedance including reactance common to both of said paths and said tuned circuit, and a second impedance common to both of said paths, the ratio of the second to the first impedance having a variation as the frequency of the current impressed upon said circuit is varied which is proportional to the square of the change in frequency.

4. An electrical coupling system comprising a pair of input terminals, a pair of output terminals, a path between said input terminals, a path between said output terminals, a circuit tunable to a desired signal frequency, said circuit including reactances of opposite kinds, a first impedance including reactance common to both of said paths and to said tuned circuit, and a second impedance common to both of said paths, the ratio of said second impedance to said first impedance having a variation more rapid than the frequency variation, and said impedances also being proportioned to produce substantially zero resultant transfer through the system at a frequency above the resonant frequency of said circuit.

5. In a superheterodyne radio receiver, an arrangement for reducing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two individual coupling means for coupling said circuits, one of said coupling means comprising a first impedance means common to said input and output circuits, the other coupling means comprising a closed circuit tunable to a desired signal frequency, said closed circuit comprising a second impedance means also included in said

input circuit, an inductive reactance element, and a capacitive reactance element, one of said reactance elements being variable to tune said closed circuit, and said impedance means being so proportioned that image frequency interference produces in said output circuit equal and opposite voltages across said first impedance means and one of said reactance elements as said closed circuit is tuned to a desired signal frequency.

6. In a superheterodyne radio receiver, an arrangement for reducing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two individual coupling means for coupling said circuits, one of said coupling means comprising mutual coupling between said input and output circuits, and the other coupling means comprising a closed circuit tunable to a desired signal frequency, said closed circuit comprising impedance means common to said input circuit, an inductive reactance element, and a capacitive reactance element variable to tune said closed circuit, said coupling and said impedance means being so proportioned that the image frequency interference produces equal and opposite voltages across the mutual coupling and a portion of the capacitive reactance of said tuned circuit as the closed circuit is tuned, whereby image frequency voltages in said output circuit are substantially eliminated.

7. In a superheterodyne radio receiver, an arrangement for reducing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two individual coupling means for coupling said circuits, one of said coupling means comprising mutual inductance between said input and output circuits, and the other of said coupling means comprising a closed circuit tunable to a desired signal frequency, said closed circuit comprising a fixed capacitive reactance element common to said input circuit, an inductive reactance element, and a capacitive reactance element variable to tune said tuned circuit, said mutual inductance and said fixed capacitive reactance element being so proportioned that the image frequency interference produces equal and opposite voltages across the inductance in said output circuit and the variable capacitive reactance element of said closed circuit, whereby image frequency voltages in said output circuit are substantially eliminated.

8. In a superheterodyne radio receiver, an arrangement for reducing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two coupling means coupling said circuits, one of said coupling means comprising mutual inductance between said input and output circuits, the other of said coupling means comprising a closed circuit tunable to a desired signal frequency, said closed circuit comprising an inductance element inductively related to said input circuit, a fixed capacitance element also included in said input circuit, and a capacitance element variable to tune said closed circuit, said first-mentioned mutual inductance between said input and output circuits, the mutual inductance between said input and closed circuits and said capacitance element between said input and closed circuits being so proportioned that image frequency interference produces equal and opposite voltages across the inductance in said output circuit external to said closed circuit and the variable capacitance element of said closed circuit regardless of the frequency to which said closed circuit is tuned to respond, whereby image frequency voltages in said output circuit are substantially eliminated.

9. In a superheterodyne radio receiver, means for preventing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two coupling means between said input and output circuits, one of said coupling means comprising a mutual inductance between said input and output circuits and including an inductance one end of which is at ground potential, and the other coupling means comprising a circuit tunable to a desired signal frequency, said tunable circuit comprising an inductance inductively related to said input circuit, a fixed capacity also included in said input circuit, and a capacity variable to tune said circuit, the mutual inductance between said input and output circuits being so proportioned that the image frequency voltage developed across the inductance in said output circuit will be equal and opposite to that developed across the variable condenser common to said tuned and output circuits regardless of the tuning of said tuned circuit, whereby image frequency voltages in said output circuit are substantially eliminated.

10. In a superheterodyne radio receiver, means for reducing image frequency interference, which comprises a coupling system including an input circuit, an output circuit, and two individual coupling means for coupling said input and output circuits, one of said coupling means comprising a first impedance common to said input and output circuits, the other coupling means comprising a closed circuit tunable to a desired signal frequency; said closed circuit including a second impedance also included in said input circuit, an inductance, and a capacitance variable to tune the closed circuit; and said impedances being so proportioned that image frequency interference produces in the output circuit a voltage across the first impedance and a voltage across said capacitance, which voltages are substantially equal and opposite when the closed circuit is tuned to the desired signal frequency.

11. In a superheterodyne receiver operative to select a signal of any desired frequency in a band of frequencies and subject to interference from another signal of an undesired frequency differing from the desired frequency by a constant frequency difference, an arrangement for selectively coupling the antenna to succeeding circuits of said receiver and for reducing said interference comprising a primary circuit adapted to include said antenna, a secondary circuit coupled to said succeeding circuits and including a closed circuit tunable over said band, said closed circuit including reactances of opposite kinds, and two individual coupling means for coupling said primary and secondary circuits, one of said coupling means comprising a first impedance means common to said primary and secondary circuits, and the other of said coupling means comprising a second impedance means including reactance common to said primary circuit and said closed circuit, the ratio of the impedance of said second to said first impedance means varying more rapidly than frequency as the frequency of the current impressed on said primary circuit by said antenna is varied.

12. In a superheterodyne receiver operative to select a signal of any desired frequency in a band

of frequencies and subject to interference from another signal of an undesired frequency differing from the desired frequency by a constant frequency difference, an arrangement for selectively coupling the antenna to succeeding circuits of said receiver and for reducing said interference comprising a primary circuit adapted to include said antenna, a secondary circuit coupled to said succeeding circuits, and two individual coupling means for coupling said circuits, one of said means comprising a first impedance means common to said circuits, the other of said means comprising a closed circuit tunable over said band, said closed circuit including a second impedance means also included in said input circuit and additional reactance means, said impedances being so proportioned that image frequency interference produces in said secondary circuit equal and opposite voltages across said first impedance means and one of said additional reactance means when said closed circuit is tuned to a desired signal frequency, whereby image frequency voltages in said secondary circuit are substantially eliminated.

13. In combination with a superheterodyne radio receiver adapted to receive signals throughout a band of frequencies, including a large number of signal channels, an antenna circuit broadly tuned to said band of frequencies whereby all signals having frequencies outside of said band are attenuated, and a selective circuit coupled between said antenna circuit and said receiver, said selective circuit comprising a resonant circuit coupled to said antenna circuit and to said receiver and sharply tunable selectively to transmit to said receiver any desired signal within said band of frequencies, and an auxiliary transfer means likewise coupled to said antenna circuit and to said receiver and operative to non-selectively transfer signal voltages throughout said band of frequencies, the coupling of said resonant circuit and said auxiliary transfer means to said receiver being so proportioned that they will deliver equal and opposite voltages to said receiver at any image frequency within said band and differing from the frequency to which said resonant circuit is tuned by a substantially uniform frequency difference, whereby said selective coupling circuit suppresses all image frequency signals within said band.

14. In a superheterodyne radio receiver, the method of selectively transferring any desired signal current within a band of frequencies including a large number of signal channels, in the presence of image frequency undesired signals, which comprises predetermining attenuation of all signals outside of said band, adjustably selectively transferring currents of the desired signal frequency and incidentally transferring currents of the corresponding undesired image frequency, non-selectively transferring currents of all image frequencies within said band corresponding to desired signal frequencies also within said band, and preadjusting the relative values and polarity of the first and secondly transferred currents of said corresponding image frequency, to balance out the corresponding undesired signal simultaneously with the adjustment to selectively transfer the desired signal.

15. In combination with a superheterodyne receiver tunable to signals of any frequency in a broad band including a large number of signal channels, an input circuit, and highly selective means and non-selective means each individually coupling said input circuit to the input terminals of said receiver, said selective means comprising a resonant circuit tunable over said band, said non-selective means comprising fixed reactance adjusted to balance out image frequency signals incidentally coupled to said receiver by said selective means, and said input circuit including resistance and fixed reactance adjusted to broadly tune said input circuit within said band and thereby attenuate undesired signals of frequencies outside said band coupled to said receiver by said non-selective means.

16. In combination with a superheterodyne receiver tunable to signals of any frequency in a broad band including a large number of signal channels, an antenna circuit, and highly selective means and non-selective means each individually coupling said antenna circuit to the first vacum tube of said receiver, said selective means comprising a resonant circuit tunable over said band, said non-selective means comprising fixed reactance adjusted to balance out image frequency signals incidentally coupled to said receiver by said selective means, and said antenna circuit including resistance and fixed reactance adjusted to broadly tune the antenna circuit within said band and thereby attenuate undesired signals of frequencies outside said band coupled to said receiver by said non-selective means.

17. In combination with a superheterodyne receiver having a permanently tuned intermediate-frequency amplifier, said receiver being tunable to any frequency in a band greater in width than twice the intermediate frequency; an input circuit permanently tuned within said band for attenuating undesired signals of frequencies outside said band, a resistance connected in said input circuit for broadening its resonance to include all of said band, and highly selective means and non-selective means each individually coupling said input circuit to the input terminals of said receiver, said selective means comprising a resonant circuit tunable over said band, said non-selective means comprising fixed reactance independent of said resistance, adjusted to balance out image frequency signals within said band incidentally coupled to said receiver by said selective means, said image frequency differing by twice the intermediate frequency from the resonant frequency of said tunable circuit.

18. In combination with a superheterodyne receiver having a permanently tuned intermediate-frequency amplifier, said receiver being tunable to any frequency in a band greater in width than twice the intermediate frequency; an antenna circuit permanently tuned within said band for attenuating undesired signals of frequencies outside said band, a resistance connected in said antenna circuit for broadening its resonance to include all of said band, and highly selective means and non-selective means each individually coupling said antenna circuit to the first vacuum tube of said receiver, said selective means comprising a resonant circuit tunable over said band, said non-selective means comprising fixed reactance independent of said resistance, adjusted to balance out image frequency signals within said band incidentally coupled to said receiver by said selective means, said image frequency differing by twice the intermediate frequency from the resonant frequency of said tunable circuit.

19. A selective coupling network which comprises; a primary circuit including connected in series a capacitive antenna, a fixed inductance and a fixed condenser; a secondary circuit in-

cluding connected in series an adjustable condenser, another fixed inductance and said fixed condenser; and a third inductance inductively coupled to said first inductance connected in series with the output of said secondary circuit, said primary circuit being permanently broadly tuned to a band of frequencies including a large number of signal channels, said secondary circuit being sharply tunable by said adjustable condenser to any frequency in said band, said first two inductances being of the same order of magnitude, and said fixed condenser having a capacitance on the order of ten times the maximum capacitance of said adjustable condenser.

HAROLD A. WHEELER.