May 7, 1935. H. A. WHEELER 2,000,113

SUPERHETERODYNE RADIORECEIVER

Filed Nov. 16, 1933

Fig. 1

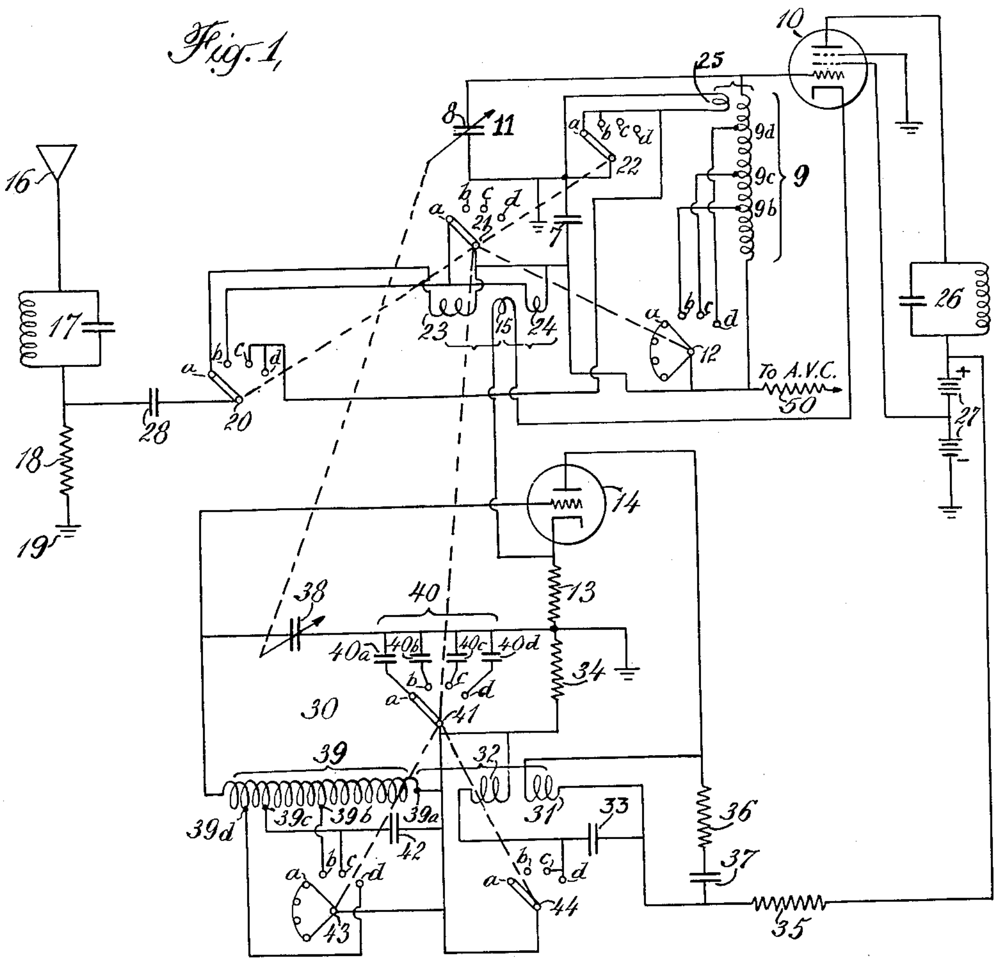
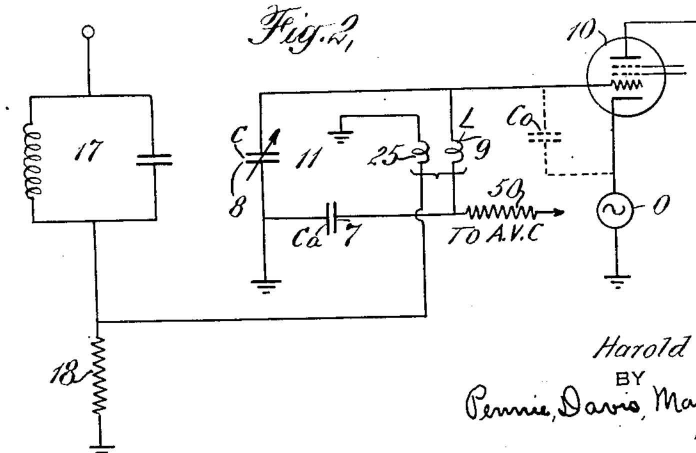


Fig. 2



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Patented May 7, 1935

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UNITED STATES PATENT OFFICE

2,000,113

SUPERHETERODYNE RADIORECEIVER

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Application November 16, 1933, Serial No. 698,280

10 Claims. (Cl. 250—20)

The present invention relates to a radio receiver, and more particularly to a superheterodyne type of receiver for receiving signals within a plurality of frequency bands.

The receiver, in accordance with the present invention, operates with its heterodyne oscillator frequency above the signal frequency when receiving signals in the lower frequency bands and with the oscillator frequency below the signal frequency when receiving signals within the higher frequency bands. In this manner the frequency range of the oscillator is materially reduced.

The principal object of the present invention is to provide a radio receiver circuit of the superheterodyne type, which will efficiently receive and amplify signals within a plurality of frequency bands, and more particularly to provide such a circuit in which the conversion gain in the modulator or first detector circuit shall be substantially uniform throughout the entire range of the receiver.

It has heretofore been considered necessary to neutralize the grid-to-cathode capacity of the first detector tube in order to obtain uniform high frequency reception of signals covering a wide range of frequencies. It is, therefore, an additional object of this invention to overcome the necessity for neutralizing the inherent grid-to-cathode capacity between the input terminals of the modulator, particularly in the higher frequency bands.

These and further objects of the invention will become apparent from the following specification and claims taken in connection with the accompanying drawing.

For accomplishing the objects of this invention, switching means are provided for controlling the connection of certain of the fixed elements within the signal frequency tuned circuits and oscillator circuit, in such a manner that the variable condensers in these circuits may be utilized to tune the receiver over each of the several frequency bands.

The constants of the fixed elements controlled by the switches are so chosen that in the lower frequency bands the oscillator frequency will be higher than the received signal frequency and in the higher frequency bands the oscillator frequency will be lower than the signal frequency, thus minimizing the required frequency range of the oscillator. The difference frequency between the signal and oscillator frequencies in both the higher and lower frequency bands is, however, the same, and the same intermediate frequency circuits may be used for the entire range of the receiver.

Attention is now invited to the accompanying drawing, of which:

Fig. 1 is a circuit diagram of the signal input and oscillator circuits of a superheterodyne receiver constructed in accordance with the present invention;

Fig. 2 is a diagram of the same circuits connected to operate in the highest of the several frequency bands.

Reference is now made to Fig. 1, which shows the circuit of a receiver constructed in accordance with the present invention, adapted to cover four frequency bands. The following frequency bands are given as suitable for use in such a receiver when using a 450 kc. intermediate frequency:

First band	Signal frequency	550 kc. to 1500 kc. (ratio 2.73)
	Oscillator frequency	1000 kc. to 1950 kc. (ratio 1.95)
Second band	Signal frequency	1400 kc. to 3600 kc. (ratio 2.57)
	Oscillator frequency	1850 kc. to 4050 kc. (ratio 2.19)
Third band	Signal frequency	3500 kc. to 9000 kc. (ratio 2.57)
	Oscillator frequency	3050 kc. to 8550 kc. (ratio 2.80)
Fourth band	Signal frequency	8500 kc. to 20,000 kc. (ratio 2.35)
	Oscillator frequency	8050 kc. to 19,550 kc. (ratio 2.43)

The circuits of the superheterodyne radio receiver shown in Fig. 1 are connected by the several switches in the position *"a"* shown to operate in the lowest of the four frequency bands, which is in this case the broadcast band. The modulator or first detector tube 10 has a tunable selector or parallel resonant input circuit 11 and a modulating voltage source connected in series between its input terminals. The selector circuit is composed of the inductance 9, the alignment condenser 7, and the variable condenser 8 connected between its grid and cathode. The variable condenser 8 is for tuning the selector circuit to the received signal frequency in any of the bands through which the receiver may operate. A switch 12 is provided having its contacts *b*, *c* and *d* connected to taps 9*b*, 9*c* and 9*d*, respectively, of the inductance 9, for altering the input inductance, as will be explained more fully hereinafter.

The grid-cathode circuit of the modulator tube 10 is completed through the resistor 13 and the cathode coil 15.

The antenna circuit, which is composed of the antenna 16, the trap circuit 17, the shunt resistor 18, and ground 19, is coupled to the input circuit 11 by one of several arrangements by the switches 20, 21 and 22. As indicated by dotted lines, all switches shown are mechanically linked for simultaneous operation by one control. With the switches 20, 21 and 22 in the broadcast position, with contacts *a* closed as shown, the antenna current mainly flows through condenser 28, through the coil 23, and through inductance 9 and the condenser 8 which are common to the antenna and tuned input circuits. In the same band the unused coil 24 is short-circuited by the switch 21; and the coupling coil 25, which is disposed adjacent to the high voltage end of the input inductance 9, is short-circuited by the switch 22.

In the broadcast band, therefore, there is a capacitive coupling 7 between the antenna circuit and the tuned input circuit 11, and the coupling between the coil 23 and the cathode coil 15 provides an auxiliary untuned coupling between the antenna circuit and the input terminals of the modulator 10. The function of this auxiliary coupling is to suppress the image frequency which is the undesired frequency differing from the oscillator frequency by a difference equal to the intermediate frequency. The relationship between the coil 23 and the cathode coil 15 is so chosen that the image-frequency voltage impressed upon the input of the tube 10 through this coupling is equal and opposite to the image-frequency voltage impressed thereon by the tuned circuit 11, when the input circuit is tuned to the desired signal frequency. The image suppression so provided has been more fully described in my copending application for "Selective circuits", Serial No. 607,369, filed Apr. 25, 1932.

In the second band the coil 24, which is also inductively coupled to the cathode coil 15, is connected in place of the coil 23 when switches 20 and 21 are moved to contact *b*. At the same time switch 22 is simultaneously operated, the coupling coil 25 still remaining shorted and the lower portion of the main inductance 9 being short-circuited by the connection of tap 9*b* to contact *b* of switch 12. This permits the tuned input circuit to be tuned over the second frequency band by the condenser 8. The relationship between the image frequency coil 24 and the cathode coil 15 is so chosen that there will be image suppression similar to that in the broadcast band.

With each of the switches 20, 21, 22 and 12 in the position *c*, to permit operation in the third band, the antenna current mainly flows through switch 20 and coupling coil 25, the coils 23 and 24 then being disconnected. The signals thus induce a voltage in the tuned input circuit 11 by mutual inductance between the coupling coil 25 and the inductance 9 of the tuned input circuit. At the same time the switch 12, closing the contact *c*, short-circuits all that portion of the main tuning inductance 9 below tap 9*c*, thus permitting the circuit 11 to be tuned over the third band by the variation of condenser 8.

To receive signals in the highest frequency, or fourth band, the switches are all simultaneously operated to close contacts *d*, at which time the coupling between the antenna circuit and the tuned input circuit is the same as in the third band. Switch 12 in this position short-circuits all of that portion of the tuning inductance 9 below tap 9*d* to permit the condenser 8 to tune the circuit 11 over the highest band.

The trap circuit 17 is tuned to the intermediate frequency to prevent direct reception of signals of this frequency. Thus in a circuit having an intermediate frequency of 450 kc., which is that chosen as suitable for operation through the several frequency bands outlined above, the trap circuit 17 would be permanently tuned to 450 kc.

The output circuit of the modulator includes the intermediate frequency circuit 26, which is coupled to the remainder of the superheterodyne receiver. The nature of the latter is well known and is therefore not shown. The space current is supplied by a direct-current source 27.

The tunable heterodyne oscillator includes the tube 14 and the tuned oscillation circuit 30. The latter is tuned by a variable condenser 38. The dotted line between 38 and 8 indicates that these condensers are mechanically linked for uni-control operation.

The plate circuit of the oscillator tube 14 includes the two feedback coils 31 and 32 connected in series through the condenser 33 and one of the condensers 40. The plate of the oscillator tube 14 is supplied with direct current through the plate inductance 31 and the resistor 35 connected to the source 27. The inductance 31 is shunted by resistor 36 and condenser 37, for limiting the amplitude of oscillation in the fourth band.

The tuned oscillation circuit 30 includes the variable condenser 38, the inductance 39, and one of the several series condensers 40, selected by the switch 41.

In the broadcast band, the series condenser 40*a* of the oscillation circuit 30, which is much smaller than the coupling condenser 7 of the input circuit 11, properly restricts the tuning range of the circuit 30 as it is tuned by the condenser 38.

As indicated in the table of frequency bands, the ratio of oscillator frequency variation is less than that of signal frequency variation in the two lower bands, but is greater in the two higher bands. This is because the oscillator frequency is higher than the signal frequency in the lower bands, while it is lower in the higher bands. In superheterodyne receivers for the broadcast band, it is customary to use equal change of capacitance in condensers 8 and 38. The frequency ratio of the oscillator is then restricted partly by increasing the minimum capacitance, and partly by inserting a series condenser 40*a* which, in effect, decreases the maximum capacitance. Since the tuned input circuit 11 includes a series condenser 7, the oscillator series condensers 40*a* and 40*b* for the lower bands must be made considerably less than 7. Conversely, for the higher bands, the condensers 40*c* and 40*d* must be made larger than 7 to give the oscillator a greater ratio of frequency variation.

The inductance 39 is inductively coupled to feedback coils 31 and 32, the latter being operative only in the lower bands.

A small condenser 42 is connected between 39*a* and 39*c*. This condenser is effective only in the lower bands, and is otherwise shunted by switch 43. Its purpose is to increase the minimum capacitance of the oscillation circuit 30 and thereby to properly restrict the frequency ratio for the two lower bands.

The cathode circuit of the oscillator tube includes the resistor 13, which is common to the cathode circuit of the modulator 10. By this means the oscillation voltage is impressed between the input terminals of the modulator tube. The switches 41, 43 and 44 each having contacts *a*, *b*, *c* and *d* are for the purpose of controlling the frequency band in which the oscillator circuit is adapted to operate, and also the oscillator feedback. The capacity of each of the condensers **40a**, **40b**, **40c** and **40d** is chosen to give the proper alignment between the oscillation circuit **30** of the oscillator and the selector circuit **11** so that they may be simultaneously tuned by the tuning condensers **38** and **8**, by uni-control means, as indicated by the dotted line connecting these condensers. The connection of these series condensers in the circuit **30** is controlled by switch **41**, which may be operated to close contacts *a*, *b*, *c* or *d* to permit reception in the desired band.

The switch **43** short-circuits various portions of the inductance **39** for permitting the condenser **38** to tune the oscillation circuit **30** throughout the various frequency bands.

The switch **44** is for the purpose of short-circuiting the coupling coil **32** when operating in either of the high frequency bands, as it is unnecessary in these bands to provide so much feedback coupling.

The inductances of the various portions of the inductances **9** and **39** are chosen so that the oscillation frequency will be uniformly higher than the signal frequency as the tuning of the input and oscillation circuits is simultaneously controlled by the condensers **8** and **38**, throughout the two lower bands; and so that the frequency of the oscillation circuit will be lower than the frequency of the tuned input circuit when these two circuits are simultaneously tuned in the two higher frequency bands. In other words, the frequency of the selector circuit minus the frequency of the oscillator circuit is positive in the higher frequencies and negative in the lower frequencies of the band.

The lower end of the inductance **9** of the input circuit **11** is connected through a high resistor **50** to a circuit of the automatic volume control tube (not shown) by means of which the grid bias of the modulator **10** is automatically controlled in a manner, which, being well known, need not be further described. The condenser **28** is used to insulate the antenna circuit from this grid bias.

Fig. 2 is a simplified diagram showing the essential elements of the antenna and tuned input circuits of Fig. 1, as connected by the switches to operate in the highest frequency band. In this figure the various parts are designated by the same reference characters as were used to designate the corresponding circuit elements in Fig. 1. For reference in explaining the operation of this circuit, the condensers **7** and **8** are also designated as *Ca* and C, respectively, and the inductance **9** is designated as L. The modulator cathode circuit is coupled to an oscillator symbolized as an oscillation source O.

In Fig. 2, C includes all capacitance across the tuned input circuit except the direct capacitance *Co* between grid and cathode in the modulator tube **10**. The modulator is responsive in proportion to the grid-cathode voltage coupled from the oscillator. This voltage must therefore exist across *Co*, which requires oscillator frequency current through *Co*. This current must return to ground through the remainder L, C, *Ca* of the tuned input circuit.

In the lower bands, the oscillator frequency is between 82 per cent and 12 per cent higher than the signal frequency. This difference is sufficient to prevent L, C, *Ca* offering any substantial impedance to oscillator frequency current through *Co*, assuming *Co* is on the order of 6% of the minimum value of C. The ordinary method of tuning the oscillator higher than the signal is satisfactory. This has the advantage that the image frequencies nearly always lie outside the broadcast band, from which greatest interference would otherwise be experienced.

In the higher bands, the oscillator frequency differs from the signal frequency only by 13 per cent to 2.2 per cent. In accordance with this invention, for these bands the oscillator may be tuned below the signal, as will later be explained. In no case will the image frequency fall in the broadcast band, so that this consideration can be neglected for these higher bands.

Co is ordinarily about 6% as great as the minimum value of C. When L, C, *Ca*, *Co* are tuned to the signal, then L, C, *Ca* without *Co* constitute a parallel-resonant trap at a frequency about 3% above the signal frequency. With the oscillator tuned above the signal in the ordinary manner, there is a point in the highest band where L, C, *Ca* greatly impede the oscillator frequency current through *Co*, thereby causing a "dead spot" in the tuning range, where the modulator conversion gain is greatly impaired.

This problem is solved by tuning the oscillator lower than the signal and the tuned input circuit, when operating in the higher bands. L, C, *Ca* then have a resultant inductive reactance at the oscillator frequency, which somewhat increases the current through *Co* and completely avoids the "dead spot".

The approximate condition for the "dead spot" in the tuning range, where *Co* is much smaller than C, is given by the equation:

$$\frac{Co}{C}=\frac{2\times\text{intermediate frequency}}{\text{signal frequency}}$$

Under this condition the greatest advantage is secured from tuning the oscillator below the signal frequency. In ordinary cases, the greatest advantage is obtained when the signal frequency is about twenty times the intermediate frequency. Considerable advantage is ordinarily secured when this ratio is 10 to 100 times.

An added advantage of this arrangement is in reducing the entire frequency range of the oscillator, as indicated in the following table:

	Frequency range ratio
Signal (20 megacycles/550 kc.)	36.4
Oscillator below signal, all bands (19.55 megacycles/100 kc.)	195.5
Oscillator above signal, all bands (20.45 megacycles/1000 kc.)	20.45
Oscillator above signal in lower bands and below signal in upper bands (19.55 megacycles/1000 kc.)	19.55

It can be seen that with this arrangement, instead of having a greatly reduced oscillator voltage impressed on the input terminals of the modulator **10**, the oscillation voltage in the higher bands is made substantially the same as in the lower bands, and a substantially uniform conversion gain may be obtained throughout the entire operating range of the receiver.

The heater elements of the tubes **10** and **14** can be supplied with current from any appropriate source, the details of which constitute no part of the present invention. The tubes **10** and **14** may be of any appropriate type. The modulator tube **10** may, for instance, be a type **58** pentode. The oscillator tube **14** may be a type **57** pentode, with its screen and suppressor grids connected to its plate for operation as a triode.

Although this invention has been specifically described as applicable to a superheterodyne radio receiver, it is to be understood that it may be equally useful in connection with heterodyne reception or transmission, or in connection with heterodyne oscillators and modulators in general, for whatever purpose they may be designed.

It should be further understood that although radio reception has been specifically referred to, the invention is equally applicable to any system of high frequency transmission, including wire transmission.

I claim:—

1. In a superheterodyne receiver responsive to signals within a lower and a higher frequency band, having a tunable heterodyne oscillator and a selector tunable to the signal frequency, the arrangement for minimizing the required frequency range of said oscillator, which comprises uni-control means for simultaneously tuning both selector and oscillator, and switching means for maintaining the oscillator frequency higher than the selector frequency in the lower band and lower than the selector frequency in the higher band.

2. In a superheterodyne receiver responsive to signals within a lower and a higher frequency band, having a heterodyne oscillator, the arrangement for minimizing the required frequency range of said oscillator which comprises uni-control means for simultaneously tuning said oscillator and said received signal frequency to maintain said signal frequency higher than said oscillator frequency in said higher band and lower than said oscillator frequency in said lower band.

3. In a superheterodyne receiver responsive to signals within a lower and a higher frequency band having an intermediate frequency lower than said lower frequency band, and having a heterodyne oscillator, the arrangement for minimizing the required frequency range of said oscillator which comprises circuit means for maintaining said oscillator tuned to frequencies higher than the received signal frequency in said lower frequency band and lower than said received signal frequency in said higher band as said receiver is tuned through said lower and higher frequency bands respectively.

4. In a system for converting alternating currents from a signal frequency to an intermediate frequency which is from one-hundredth to one-tenth of said signal frequency, including a modulator having input terminals with inherent capacitance therebetween, and a parallel resonant circuit and a modulating voltage source connected in series between said terminals, said circuit with said capacitance being resonant at said signal frequency; the arrangement for most effectively applying said modulating voltage to said modulator which comprises variable circuit element means for adjusting the frequency of said modulating voltage to a frequency equal to said signal frequency minus said intermediate frequency, at which frequency the resonant circuit is inductive and causes the voltage impressed across said terminals to exceed said modulating voltage.

5. An arrangement in accordance with claim 4 in which the signal frequency is any frequency in a high frequency band, in combination with uni-control means for tuning said resonant circuit over said band and simultaneously adjusting said modulation frequency to equal the resonant circuit frequency minus the intermediate frequency.

6. In a superheterodyne receiver responsive to signals covering a broad frequency band and having a tunable heterodyne oscillator and a tunable selector circuit, means for simultaneously tuning said oscillator and selector circuits and maintaining a constant difference between the frequency of said selector circuit and of said oscillator, and switching means for changing said difference from positive to negative as said receiver is tuned from reception of the higher to reception of the lower frequencies of said band.

7. In a superheterodyne receiver responsive to signals covering a broad frequency band, a tunable selector circuit tunable to any frequency within said band, a heterodyne oscillator, uni-control means for simultaneously tuning said selector circuit and said oscillator, and circuit means for maintaining the frequency of said oscillator below the frequency of said selector circuit in the higher frequencies of said band and above the frequency of said selector circuit in the lower frequencies of said band.

8. In a variable electrical control system adapted to operate over a frequency range, a first and a second variable tuning circuit adjustable by means of a unitary control, said circuits including inductance and capacity, the product of inductance and capacity of said first circuit being greater than that of said second circuit over a portion of the frequency range, and the product of inductance and capacity of said second circuit being greater than that of the first circuit over another portion of the range, whereby said first circuit is first capacitively and then inductively reactive with respect to said second circuit as the two circuits are simultaneously tuned through the entire frequency range.

9. The method of superheterodyne reception of a signal of any frequency in a broad band of frequencies, while minimizing the frequency range of required local oscillations, which comprises selecting the signal, simultaneously adjusting the frequency of selection and the frequency of oscillation, maintaining the difference of the frequency of oscillation minus the frequency of selection substantially constant while adjusting said frequencies, and causing said difference to be positive when the frequency of selection is adjusted in the lower part of said band and negative when the frequency of selection is adjusted in the upper part of said band.

10. The method of operating a superheterodyne radio receiver to minimize the frequency range of local oscillations required to receive signals of any frequencies in a broad band, which includes the step of causing the frequency of oscillations to be higher than the frequency of reception when the frequency of reception is in the lower part of said band and lower than the frequency of reception when the frequency of reception is in the higher part of said band.

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