Feb. 7, 1933. H. T. BUDENBOM 1,896,065

SELECTIVE CIRCUIT FOR SUPERHETERODYNE RADIORECEIVERS

Filed June 29, 1929

FIG. 1.

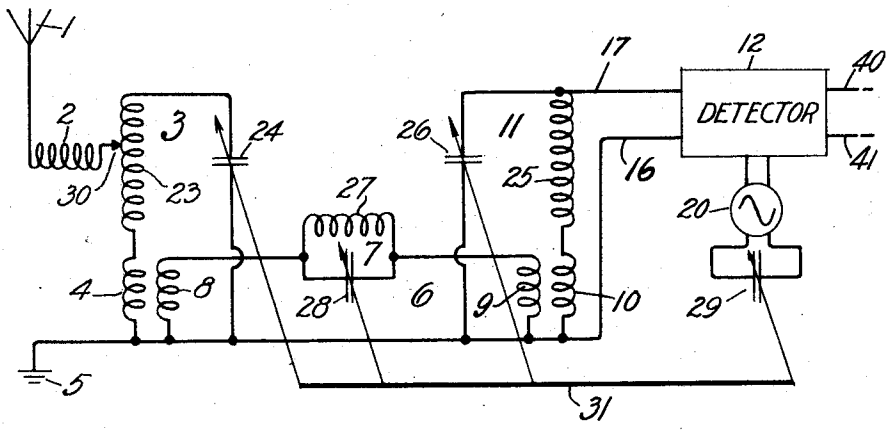
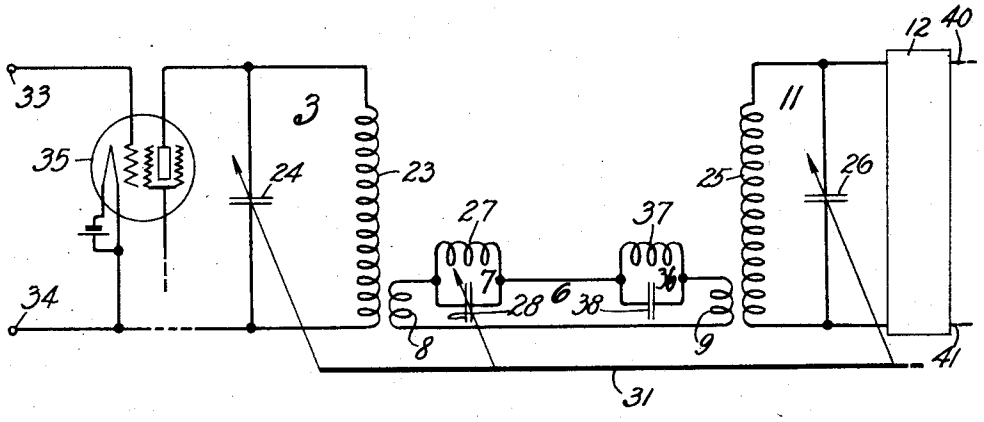


FIG. 2.



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UNITED STATES PATENT OFFICE

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SELECTIVE CIRCUIT FOR SUPERHETERODYNE RADIORECEIVERS

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This invention relates to radio receiving circuits and more particularly to receiving circuits in which a heterodyne wave is used in the detection of the signals. It has for its principal objects the elimination of undesired signals due to the interaction of the heterodyne wave with other carrier waves than that to which the receiver is tuned, and also the maintenance of a uniform degree of selectivity over the tuning range of the receiver, including, for all tuning adjustments, a selected frequency interval of sufficient width to afford improved fidelity in the reproduction of detected signals as compared with results obtainable with tuning arrangements formerly employed.

It is well known that radio receivers of the heterodyne type may respond to signals from two different stations at the same time if the carrier waves of these stations are spaced at equal frequency intervals above and below the frequency of the local heterodyne wave. Since receivers of this type are customarily arranged to operate with a beat wave of fixed frequency, the heterodyne interference arises from stations having carrier frequencies differing by a fixed amount, equal to twice the beat frequency, from that of the station it is desired to receive. This kind of interference is particularly troublesome in wave length ranges occupied by a large number of transmitting stations, as, for example, in the broadcast range, in which the transmitting wave lengths are spaced at intervals of about 10,000 cycles per second. Any attempt to eliminate the interfering signal by changing the frequency of the heterodyne wave is likely to result only in the setting up of a new interference by another station. By sharply tuning the receiving circuit to the desired station the interfering signal may be diminished, but with the ordinary forms of selective circuits it is impracticable to obtain the high degree of discrimination needed for the complete suppression of interference, without impairing the fidelity of reproduction of detected signals.

By this invention an improved tuning arrangement is provided for heterodyne receivers in which the substantially complete suppression of the heterodyne interference is accomplished while at the same time a substantially uniform degree of selectivity and fidelity are maintained throughout the tuning range. In general the tuning system comprises a pair of syntonous tuned circuits loosely coupled together by a coupling circuit which functions also as a wave trap for the suppression of the heterodyne interference. The tuning elements of the syntonous circuits and those of the coupling circuit wave trap and the heterodyne wave source are coupled together mechanically in such manner as to maintain them in their proper frequency relationships at all points in the operating range. Thus the heterodyne frequency may be maintained at a fixed frequency difference above the resonance frequency of the syntonous receiving circuits and the coupling circuit suppression frequency at an equal interval above the heterodyne wave.

By including the wave trap in the coupling circuit, loosely coupled to the selective circuits, any detrimental effect that it might otherwise have upon the tuning of the selective circuit is avoided. Moreover, the trap is located in a low impedance circuit, thus improving the suppression obtainable. Also, the impedances constituting the coupling circuit and the wave trap function to maintain a substantially constant degree of selectivity and fidelity of reproduction throughout the tuning range.

The invention will be more readily understood from the following description, in connection with the accompanying drawing in which:

Fig. 1 discloses a portion of a super-heterodyne radio receiving set embodying the invention and including a special tuning arrangement connected between a receiving antenna and a detector within the radio set.

Fig. 2 shows a slightly modified tuning arrangement and the manner in which it may be connected between a pair of space discharge devices in a receiving set.

Referring to Fig. 1, the antenna 1 is connected through an antenna loading coil 2, and a tuned circuit 3 including the winding

4 to ground at 5. A coupling loop 6, containing a wave trap or suppression circuit 7, is coupled by means of the winding 8 to the winding 4, associated with the tuned circuit 3. The loop 6 also contains a winding 9 which is coupled to a winding 10 included in a second tuned circuit 11.

Tuned circuit 11 includes a fixed inductance 25 and an adjustable condenser 26 in addition to winding 10.

The suppression circuit or wave trap 7 comprises a fixed inductance 27 and an adjustable condenser 28.

The detector 12 is indicated diagrammatically by a block. The tuned circuit 11 is connected to the detector 12 by means of the conductors 16 and 17.

The detector 12 is assumed to be connected to appropriate portions of the remainder of the superheterodyne receiving set by means of the conductors 40 and 41, which are shown ending in broken lines.

Oscillations are supplied to detector 12 by a generator 20 the frequency of which is adjustable by means of a variable condenser 29.

The condensers 24 and 26 are preferably identical in construction and are designed to have a range of capacity values such as is commonly used in tuned circuits of radio receiving sets.

The inductance of the winding 4 is made small in comparison with the fixed inductance 23 and the combined inductance in tuned circuit 3 is made to be of such a value that by adjusting the condenser 24 the tuned circuit 3 may be tuned to any frequency within the range for which the receiving set is designed.

In order that the antenna circuit may have merely a negligible effect upon the tuning of circuit 3, the antenna loading coil 2 is arranged to be connected to an intermediate point of inductance 23 by means of an adjustable tap 30. In addition, the inductance of the loading coil 2 is made to be large in comparison with the inductance of the winding 4 and the portion of inductance 23 included between the tap 30 and ground 5. The inductance of the loading coil is also made sufficiently large to resonate with the antenna capacity at a frequency somewhat below the lowest tuning frequency.

The adjustable condensers 28 and 29 are similar in construction to condensers 24 and 26 but do not necessarily have the same limits or rates of capacity variation. Each condenser is so designed that when it is used with a fixed tuning inductance the resonate frequency of the combination will vary in direct proportion to the angular displacement of the rotatable portion of the condenser. The four condensers 24, 26, 28 and 29 are arranged to be adjusted simultaneously by means of a single tuning handle or shaft which is indicated symbolically by means of the bar 31.

The detector 12 is assumed to work into an intermediate amplifying system which is selectively responsive to a single fixed band of frequencies. The tuned circuits 3 and 11 are tuned to the frequency of a wave which is to be received. The tuned circuits are coupled by means of the loop circuit 6 which has this coupling function in addition to its function as a suppression circuit or wave trap. In the latter capacity the loop circuit 6 discriminates against an interfering wave which may be present and to which the usual super-heterodyne receiving set would be sensitive. This frequency selective discriminating action of loop 6 is effected by means of a condition of anti-resonance in the wave trap or suppression circuit 7 whereby the loop 6 is effectively open-circuited so as to substantially neutralize or suppress the coupling between the tuned circuits 3 and 11.

To receive the desired incoming wave the oscillation generator 20 must be adjusted to generate a frequency which will translate or heterodyne the incoming wave, thus deriving therefrom a wave of the frequency to which the intermediate amplifier is tuned.

To effect heterodyne reception in the usual manner, the frequency generated by the oscillator 20 must be adjusted to differ from the frequency of the incoming wave by precisely the frequency to which the intermediate amplifier is tuned. In general, there are two possible settings of the oscillator which will serve, one above and one below the frequency of the incoming wave. Conversely, for a given oscillator setting, two incoming waves may generally be received. The purpose of the wave trap is to suppress the undesired incoming wave.

It will be evident, that in the system which is described above, the receiving tuned circuits 3 and 11 are required to be maintained in a syntonous condition, while at the same time the oscillator 20 and the wave trap 7 are required to be adjusted so that the oscillator frequency is always mid-way between the resonant frequencies of the receiving tuned circuits on the one hand and the wave trap on the other. To effect this result the condensers 24, 26, 28 and 29 are so proportioned that a given angular displacement of the rotatable members of all four condensers results in equal changes in resonant frequency in the respective systems with which the condensers are associated.

By proper adjustment the combined tuning device comprising the tuned circuits 3 and 11 together with the loop circuit 6 may be made selective to a relatively narrow band of frequencies sufficiently wide to include the two sidebands usually associated with a radio telephone broadcasting or communication channel.

Due to the use of two coupled circuits, the band selected by the tuning arrangement of

this invention is wider and more sharply defined than the band selected by a single tuned circuit. The sensitivity of the system within the selected band is also more nearly uniform, due to the use of the coupled circuits. All of these characteristics are conducive to improve fidelity of reproduction of the detected signals, since more of the essential component frequencies of the sidebands are preserved and all component frequencies are amplified to a substantially uniform degree, while undesired frequencies are discriminated against.

The width of the selected band of frequencies is fixed at any desired value by adjusting the amount of coupling between the tuned circuits 3 and 11. This coupling involves the loop 6. It has been found by means of computations and experiments that the width of the selected band of frequencies, expressed as a fraction or percentage of the mean selected frequency, is substantially equal to the percentage of coupling existing between circuits 3 and 11. This rule is one which holds when the degree of coupling is relatively small and, therefore, when the selected band is relatively narrow with respect to the mean selected frequency.

If, for example, it is desired that the selected band width should be one per cent of the value of the mean selected frequency in the band, the net coupling between circuits 3 and 11 should be adjusted to be substantially one per cent.

In respect to the function of the loop 6 as a wave trap, it is desirable that the frequency discriminated against should be determined solely by the anti-resonant frequency of the trap circuit 7. For this reason it is advisable that the coupling coils 8 and 9 should introduce very little additional reactance into the loop circuit 6. To this end, the coupling between coils 4 and 8 and also that between coils 9 and 10 is made as close as is practicable.

Referring to Fig. 2, the terminals 33 and 34 represent the points of application of a means for applying an incoming signal wave. This wave may sometimes be accompanied by interfering or undesired waves of any sort. Terminals 33 and 34 are connected respectively to the grid and cathode of a space discharge device 35 which is indicated as being of the four-electrode type, having a second grid or screen surrounding the plate or anode. The output terminals of the space discharge device 35 are connected to the tuned circuit 3 in any suitable manner, the details of which connection are not shown, being well known in the art. Tuned circuit 3 contains the variable condenser 24 and the fixed inductance 23, the latter being coupled directly to winding 8 of the loop circuit 6 instead of through winding 4. Winding 9 of loop 6 is coupled directly to the fixed inductance 25 in tuned circuit 11.

It has been found by experiments, that in some cases in spite of due care in designing the selective circuits associated with a superheterodyne receiving set there is a tendency for the selected band width to become somewhat greater when the system is tuned to receive the higher frequencies in the designed operating range. To improve this condition it has been found desirable in such cases to employ a fixed anti-resonant circuit 36 including inductance 37 and condenser 38. This circuit is tuned for a frequency slightly above the highest frequency in the designed operating range.

The tuned circuit 11 is connected to the detector 12. The oscillation generator 20 is not shown in this figure but is assumed to be connected either to the plate circuit of the detector 12 or to some other suitable portion of the receiving system. The rotatable parts of the condensers 24, 26 and 28 are arranged to be moved in unison by means of the handle or shaft 31 to which may also be joined the condenser for tuning the oscillation generator (not shown).

What is claimed is:

1. A selective circuit comprising a pair of syntonous tuned circuits having their tuning elements mechanically connected for the maintenance of syntony and impedance coupling means for said tuned circuits, said coupling means being adapted to maintain a substantially constant width band transmission characteristic throughout the tuning range, and including a variable element mechanically coupled to the tuning elements of the syntonous circuits, whereby transmission between said circuits is suppressed at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

2. A band selective circuit comprising a pair of syntonous tuned circuits having their tuning elements mechanically connected, and impedance coupling means for said tuned circuits comprising a variable element mechanically coupled to the tuning elements of the syntonous circuits and adapted to neutralize the coupling of said circuits at a frequency differing by a substantially constant amount from the resonance frequency of said circuits.

3. A receiving circuit comprising a pair of syntonous tuned circuits adapted to be tuned to receive an incoming signal, a local heterodyne wave source, variable means for controlling the frequency of said source, electrical coupling means for said tuned circuits, a variable impedance included in said coupling means whereby the coupling of said tuned circuits may be neutralized, and means for mechanically coupling the tuning elements of said syntonous circuits, the frequency controlling means of said wave

source, and the said variable coupling impedance whereby the resonance frequency of said tuned circuits and the frequency at which the coupling of said circuits is neutralized are maintained at equal intervals above and below the frequency of said wave source.

4. A receiving circuit in accordance with claim 3 in which the coupling means is adapted to maintain an effectively constant width band transmission characteristic.

5. In a heterodyne receiving system, a selective circuit comprising a pair of syntonous tuned circuits, impedance coupling means for said circuits of sufficiently close coupling effect to promote band transmission, and means included in said coupling means for the substantial suppression of heterodyne interference.

6. A selective circuit comprising a pair of syntonous tuned circuits having their tuning elements mechanically coupled for the maintenance of syntony, and impedance coupling means adapted to provide a band selective transmission characteristic and to suppress transmission between said circuits at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

7. A selective circuit comprising a pair of syntonous circuits having their tuning elements mechanically connected for the maintenance of syntony and impedance coupling means for said circuits, said coupling means including an anti-resonant circuit adapted to suppress transmission between said circuits at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

8. A selective circuit comprising a pair of syntonous circuits having their tuning elements mechanically coupled for the maintenance of syntony, and impedance coupling means for said tuning circuits, said coupling means being adapted to maintain a substantially constant width band transmission characteristic throughout the tuning range, and including an anti-resonant circuit, said anti-resonant circuit having a variable element, mechanically coupled to the tuning elements of the syntonous circuits, whereby transmission between said circuits is suppressed at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

9. A selective circuit comprising a pair of syntonous tuned circuits having their tuning elements mechanically connected for the maintenance of syntony, and impedance coupling means for said tuned circuits, said coupling means being adapted to provide a band selective transmission characteristic and including a variable element mechanically coupled to the tuning elements of the syntonous circuits, whereby transmission between said circuits is suppressed at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

10. A selective circuit comprising a pair of syntonous tuned circuits having their tuning elements mechanically coupled for the maintenance of syntony, and impedance coupling means for said tuned circuits, said coupling means being adapted to provide a band selective transmission characteristic and to suppress transmission between said circuits at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

11. A selective circuit comprising a pair of syntonous circuits having their tuning elements mechanically connected for the maintenance of syntony, and electrical coupling means for said tuned circuits, said coupling means being adapted to provide a band selective transmission characteristic, and including two anti-resonant circuits for regulating said transmission characteristic, one of said anti-resonant circuits having a variable element mechanically coupled to the tuning elements of the syntonous circuits, whereby transmission between said circuits is suppressed at a frequency differing by a substantially constant amount from the frequency of tuning of said syntonous circuits.

In witness whereof, I hereunto subscribe my name this 29th day of June, 1929.

HORACE T. BUDENBOM.