

June 9, 1942.

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2,285,979

IMAGE SUPPRESSION SYSTEM

Filed May 15, 1941

*Fig. 1.*

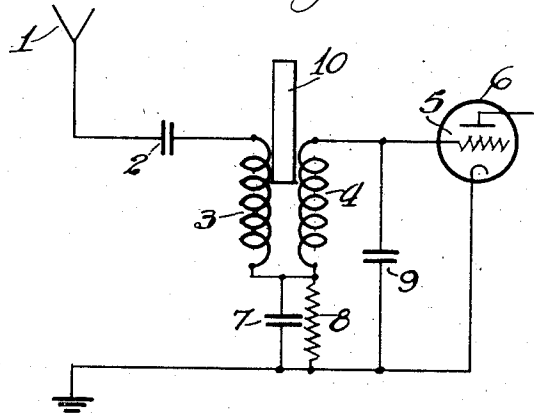
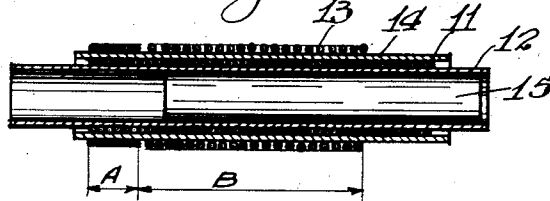


*Fig. 2*



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## UNITED STATES PATENT OFFICE

2,285,979

## IMAGE SUPPRESSION SYSTEM

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Application May 15, 1941, Serial No. 393,538

8 Claims. (Cl. 250—20)

The present invention relates particularly to receiving systems of the superheterodyne type in which the signal passes through one or more resonant circuits that are tuned to the signal frequency and is mixed with locally generated oscillations to produce a predetermined beat frequency at which it is amplified and which is generally termed the intermediate frequency. The part of the system through which the signal passes before any change in frequency occurs usually includes an antenna circuit and one or more resonant circuits with or without thermionic amplifying vacuum tubes and is generally termed the "preselector."

The adjacent-channel selectivity obtainable in a superheterodyne system is largely due to the efficiency of the intermediate-frequency amplifier which, being operated at a fixed frequency, may be designed to have a desired selectivity characteristic. The preselector of the receiving system serves to collect the desired signal, to aid in the rejection of undesired signals in adjacent channels, and to substantially reject signals of certain other frequencies to which a superheterodyne receiver tends to respond.

When a superheterodyne receiver is tuned to a desired signal some response may be obtained from a signal which differs from the frequency of the desired signal by twice the intermediate frequency of the receiver. In the usual arrangement the local oscillator is adjusted to a frequency above, rather than below, that of the signal to be received. If such a system is tuned for example, to receive a signal having a frequency of 1000 kilocycles, and if the intermediate frequency of the receiver is 460 kilocycles, the local oscillator will be adjusted to a frequency of 1460 kilocycles in order to convert the received signal to the intermediate frequency of 460 kilocycles, at which it is to be further amplified. If, at the same time, a signal of 1920 kilocycles happens to be present at the input of the receiver, this signal, together with the oscillations of the local oscillator, will likewise produce a beat frequency of 460 kilocycles which will also be amplified by the intermediate frequency portion of the receiver, and will supply an undesirable response at the output thereof. This type of interference is commonly referred to as "image response."

It is an object of the present invention to minimize or completely prevent such image response in superheterodyne receivers in a simple, inexpensive and efficient manner. More specifically it is an object of the present invention to pro-

vide a preselector system for superheterodyne receivers and the like which affords effective suppression of image frequency response over the entire tuning range of the receiver.

My invention is intended for use in connection with resonant circuits which are tuned over a range of frequencies by inductance variation. Such a system is the one disclosed by Polydoroff in United States Patent No. Re. 21,282, in which a resonant circuit having an inductance coil and capacitor is adjusted over a range of frequencies by movement of a compressed comminuted ferromagnetic core relative to the inductance coil. This method of tuning is commonly called permeability tuning. An improved form of such a system is disclosed by Schaper in United States Patent No. 2,051,012. Both Polydoroff's original system and Schaper's improved system may readily be ganged to provide multiple unit systems. Permeability tuning is especially adapted for use in the preselector of a superheterodyne radio receiver because its use permits the preselector to be designed so as to provide substantially uniform gain and selectivity throughout the frequency range, thus overcoming the chief cause of non-uniformity of performance in this type of receiver.

In accordance with the present invention, I achieve substantial elimination of response to the image-frequency signals by employing an arrangement in which such off-resonance signals produce opposed and substantially equal voltages in the input circuit of the first vacuum tube of the receiver, while the desired signal, to which the system is resonant, produces a normal resonant voltage in that circuit. To secure this result, I employ a varying mutual inductance across which one of the opposing image-frequency voltages appears, and I arrange to automatically adjust the value of this mutual inductance, by the action of the tuning means, in such manner that the image-frequency voltage across it will be substantially equal to the image-frequency voltage generated across a second reactive element in series with the mutual inductance in the input circuit of the vacuum tube, the connections being such that these two voltages are opposed, and therefore cancel.

Although my invention may be advantageously employed in superheterodyne radio receivers having more than one variably tuned resonant circuit ahead of the first demodulator, its efficiency is such that excellent performance is realized from the use of a single variably tuned resonant circuit in this portion of the receiver, thus

providing a substantial reduction in the cost of manufacture.

The invention will be better understood by reference to the accompanying drawing, in which

Fig. 1 is a schematic diagram of a preferred form of the circuit arrangement according to the invention, and

Fig. 2 is an elevation partly in section of a simple and inexpensive embodiment of a permeability-tuned radio-frequency transformer suitable for use in the arrangement of Fig. 1.

Several systems have previously been proposed for the suppression of image-frequency response in systems tuned by inductance variation. In general, these systems include portions which are in approximate resonance with the image-frequency signals throughout the tuning range, and which are connected either to act as high-impedance traps between the antenna and the input electrode of the first vacuum tube, or as low-impedance shunts between the antenna and ground. As will be clear from what is to follow, the arrangement according to the present invention differs from these earlier systems in that it does not include any portion which is resonant, or intended to be resonant, to the image-frequency signals.

Referring to Fig. 1 of the drawing, antenna 1 is connected, optionally through a series capacitor 2, to one terminal of the primary 3 of a radio frequency transformer, the corresponding terminal of whose secondary 4 is connected to the input electrode 5 of vacuum tube 6, which may be a radio frequency amplifier tube, or, more usually in modern practice, the oscillator-modulator tube of a superheterodyne receiver. Primary 3 and secondary 4 have a common terminal connected through capacitor 7 shunted by resistor 8 to ground. Capacitor 9, which may be made adjustable for alignment purposes, is connected from input electrode 5 to ground.

Antenna 1, capacitor 2, primary 3 and capacitor 7 form what I term the signal collector circuit of my system, and secondary 4 and capacitors 7 and 9 form a resonant circuit across the input of vacuum tube 6; this latter circuit is tuned to the desired signal by means of ferromagnetic core 10 which is arranged to slidably enter secondary 4 to vary its inductance, and which may be ganged with other tuning cores, for example, one which tunes the oscillator of a superheterodyne receiver, in a uni-control arrangement.

Currents induced in antenna 1 by signals of whatever frequency flow through primary 3 and capacitor 7 to ground and produce series voltages across capacitor 7; they also induce voltages in secondary 4. The voltages induced in secondary 4 may be put in phase-opposition to the corresponding voltages across capacitor 7 by suitable connection of secondary 4. Thus, if primary 3 and secondary 4 are properly proportioned, the mutual reactance between primary 3 and secondary 4 at an image frequency corresponding to a signal to which resonant circuit 4-7-9 may be tuned may be made equal to the capacitive reactance of capacitor 7, so that equal and opposite image-frequency voltages are produced resulting in substantially zero image-frequency voltage across capacitor 9. At the frequency of the desired signal, however, the mutual reactance of the transformer 3-4 and the capacitive reactance of capacitor 7 are widely different, so that for the desired signal a considerable net voltage

is induced into circuit 4-7-9 in the usual manner.

The voltages appearing across capacitor 7 and also those induced in secondary 4 will be proportional to the current which generates them. In addition the voltages appearing across capacitor 7 will be proportional to the reactance of capacitor 7 which varies inversely with frequency, whereas the voltages induced in secondary 4 will be proportional to the mutual reactance between primary 3 and secondary 4, which, by virtue of the action of ferromagnetic core 10, may be made to vary likewise inversely with frequency. In such an arrangement when the core is moved to tune resonant circuit 4-7-9 to lower frequencies the mutual reactance between primary 3 and secondary 4 is kept equal to the reactance of capacitor 7 for a range of frequencies a predetermined and substantially constant interval apart from the range of frequencies covered by movement of core 10 in resonant circuit 4-7-9. By proper choice of the inductances of primary 3 and secondary 4 and by proper choice of capacitor 7, this range may be made to coincide with the image frequency range of a superheterodyne receiver and thus proper image frequency suppression may be obtained over the total tuning range of a receiver. The increase in mutual reactance which occurs as the system is tuned to the lower frequencies is also advantageous for the reason that it tends to produce uniform signal voltage across vacuum tube 6 throughout the tuning range.

In order to secure the desired variation of mutual inductance in transformer 3-4, to produce mutual reactances equal at the image-frequencies to the capacitive reactances of capacitor 7, it is preferable to concentrate a large portion of the primary turns at that end of the secondary 4 which is opposite to the end where the core enters, the balance of the primary winding being substantially uniformly disposed along the length of the secondary. In this connection a ferromagnetic core should be employed whose effective permeability is great enough to produce the required tuning range without the need of fully inserting the core into the secondary coil. With such a core the lowest frequency in the required range may be reached before the core enters that portion of the secondary over which the concentrated primary turns are located, and an undesirably large increase in the mutual reactance at this end of the range is thus avoided. In order to secure phase opposition of the voltages across the mutual and capacitive reactances, the primary 3 and the secondary 4 may, for instance, be wound in opposite directions. This avoids the necessity for reversing connections which might be disadvantageous.

Fig. 2 serves to illustrate a practical construction of the radio-frequency transformer 3-4 of Fig. 1, having a core 15 of high effective permeability capable of producing resonance to the lowest frequency in the required range before its inner end enters the concentrated portion of the primary coil. In a practical transformer in accordance with Fig. 2, the secondary 11 consisted of 280 turns of No. 38 plain enamel wire wound at 204 turns per inch for a length of 1 3/4 inches on a tube 12 of .205 inch inside diameter and .221 inch outside diameter. The primary 13 was wound on a tube 14 of .235 inch inside diameter and .255 outside diameter and 1 1/2 inches long, and consisted of two sections A and B, section A being wound with its end flush with the end

of the secondary and being  $\frac{1}{4}$  inch long, and section B being  $\frac{3}{8}$  inch long. Both sections were wound with No. 38 plain enamel wire, section A having 220 turns per inch and section B having 24 turns per inch. The effective inductance of the primary 13 was 11.4 microhenries and the inductance of the secondary 11 was 66.0 microhenries, both measured at 1560 kilocycles.

When the transformer just described was employed in a circuit arrangement as shown in Fig. 1, capacitor 7 had a value of 300 micromicrofarads and capacitor 9 had a value of 315  $\mu\mu\text{f}$  and was adjustable for purposes of alignment. Resistor 8 is included merely to provide a direct current grid return path and may suitably have a value of 5 megohms.

With core 18 of Fig. 2 being of .200 inch diameter and  $1\frac{1}{4}$  inches long, and having relatively high effective permeability, resonant circuit 4-7-8 could be tuned from 535 kilocycles to 1560 kilocycles without having to insert the core into the concentrated portion of primary 13. When aligned for maximum rejection by adjustment of capacitor 7 the system produced image ratios up to 4350. By image ratio I mean the ratio of the input voltage of image frequency required to produce a given output, to the signal voltage required for the same output. In this embodiment the antenna gain varied from 2.3 to 5.8, while the mutual inductance varied from 13.35 microhenries to 53.85 microhenries.

The transformer construction shown in Fig. 2 and described in detail above is very inexpensive to manufacture, as will be readily appreciated by those skilled in the production of such components. More elaborate development of the distribution of the primary winding, and the use of more expensive conductors will produce designs having even better performance. I have chosen to show and describe this extremely simple form, however, to illustrate how, in accordance with the invention, excellent image rejection can be achieved with a minimum of additional components and circuit complication.

Since image rejection is the principal function of the preselector circuit in modern superheterodyne receivers, and since the emphasis in the industry today is upon low cost, my invention has wide and immediate application in broadcast receivers.

Having thus described my invention, what I claim is:

1. Arrangement for the suppression of undesired responses in radio receivers and the like, particularly in superheterodyne receivers, including a signal collector circuit, a resonant circuit tuned to a desired frequency, a mutual inductance between said collector circuit and said resonant circuit, and a capacitance common to both said circuits and in opposing series relation to said mutual inductance with respect to voltages induced from said collector circuit to said resonant circuit, said mutual inductance and said capacitance being so proportioned that at a frequency different from the frequency to which said resonant circuit is tuned their reactances are substantially equal to one another.

2. Arrangement for the suppression of undesired responses in radio receivers and the like, particularly in superheterodyne receivers, including a signal collector circuit, a resonant circuit tuned to a desired frequency, a mutual inductance between said collector circuit and said resonant circuit, a capacitance common to both said circuits and in opposing series relation to said

mutual inductance with respect to voltages induced from said collector circuit to said resonant circuit, and means for tuning said resonant circuit over a range of frequencies and for causing said mutual inductance and said capacitance to have equal reactances at frequencies differing by a substantially constant frequency interval from the frequencies to which said resonant circuit may be tuned.

3. Arrangement for the suppression of undesired responses in radio receivers and the like, particularly in superheterodyne receivers, including a signal collector circuit, a resonant circuit tuned to a desired frequency, a mutual inductance between said collector circuit and said resonant circuit, a capacitance common to both said circuits and in opposing series relation to said mutual inductance with respect to voltages induced from said collector circuit to said resonant circuit, and a movable ferromagnetic core for tuning said resonant circuit over a range of desired frequencies and for causing said mutual inductance to have equal reactances to said capacitance at frequencies differing by a substantially constant frequency interval from the frequencies to which said resonant circuit may be tuned.

4. An arrangement for the suppression of undesired responses in radio receivers and the like, particularly in superheterodyne receivers, including a transformer comprising primary and secondary windings arranged in opposed relation and having a common low potential terminal, a capacitance connected between said terminal and ground, a resonant circuit including said secondary and said capacitance and a ferromagnetic core movable relatively to said windings to tune said circuit to any desired signal within a range of frequencies, said primary being so constructed and disposed relatively to said secondary that at any position of said core the mutual reactance of said transformer is substantially equal to the reactance of said capacitance at frequencies differing by a substantially constant frequency interval from the frequencies of said resonant circuit.

5. A preselector system for radio receivers and the like, particularly for superheterodyne receivers, including a transformer comprising coaxially disposed primary and secondary windings arranged in opposed relation and having a common terminal, said primary being disposed around said secondary, a capacitor connected between said terminal and ground, a resonant circuit including said secondary and said capacitor and a ferromagnetic core movable relatively to said windings to tune said resonant circuit to any desired signal within a range of frequencies, said primary and said secondary being so related to one another and to said core that at any position of said core the mutual reactance of said transformer is substantially equal to the reactance of said capacitor at frequencies differing by a substantially constant frequency interval from the frequencies to which said resonant circuit is tuned by said core.

6. A preselector system according to claim 5 wherein said primary is wound over the length of said secondary but has a major portion of its turns concentrated at the end opposite that at which said core enters, said core being of such permeability as to cover the tuning range required for said resonant circuit without entering that portion of the secondary which is coincident with the concentrated portion of said primary.

7. A preselector system for superheterodyne radio receivers and the like having signal collecting means and a first vacuum tube with an input electrode, including a transformer having coaxially disposed primary and secondary windings arranged in opposed relation and having a common terminal, said primary being connected to said signal collecting means and disposed around said secondary winding, a capacitor connected between said terminal and ground, a resonant circuit including said secondary and said capacitor and connected between said input electrode and ground, and a ferromagnetic core movable relatively to said windings to tune said circuit to any desired signal within a range of frequencies, said primary and secondary being so related relative to one another and to said core

that at any position of said core the mutual reactance of said transformer is substantially equal to the reactance of said capacitor at the image frequencies corresponding to the frequencies to which said resonant circuit may be tuned by said core.

8. A preselector system according to claim 7 wherein said primary winding is wound over the length of said secondary winding but has a major portion of its turns concentrated at the end opposite that at which said core enters, said core being of such permeability as to cover the tuning range required for said resonant circuit without entering that portion of said secondary winding which is coincident with the concentrated portion of said primary.

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