This invention relates to modulated-carrier signal receivers, and more particularly to signal-selecting systems of such receivers and means for controlling the selectivity thereof to discriminate against undesired signals and to obtain optimum fidelity of reproduction consistent with signal reception conditions. While the invention is of general utility, it is particularly applicable to radio broadcast receivers of the well-known superheterodyne type.

The factors governing the optimum selectivity of the receiver are the signal-to-noise ratio of the signal being received, which ratio depends, under normal conditions, on the strength of the desired signal carrier and on the presence of strong undesired signal carriers on channels adjacent or near that of the desired signal. In general, a receiver should be effective to pass a band of desired modulation frequencies sufficiently narrow greatly to attenuate undesired signals, as, for example, those transmitted on channels adjacent that of the desired signal. Such narrowing of the selected band of frequencies, however, tends to impair the fidelity of reproduction of the desired signal since the outer frequencies of the sidebands, which in radio broadcasting correspond to the higher audio frequencies of modulation, are suppressed. Accordingly, it is desirable that the width of the selected band of frequencies be contracted only when disturbing noise or an undesired signal of sufficient amplitude to cause interference are present, and that, in their absence, the width of the selected band should be expanded sufficiently to admit and pass all of the sideband frequencies of the desired signal.

Various expedients have been proposed for obtaining the type of selectivity control described above. In certain of these arrangements adjustable impedance elements, such as vacuum tubes, have been connected in circuit with the selective circuits adjustable to damp such circuits and thereby adjust the width of their band-pass characteristics. This type of element, however, is usually inherently of high impedance which restricts its application to a parallel connection with the other elements of the associated tuned circuits. As thus connected, the inherent capacitance of such an element incidentally influences the resonant frequency of the circuit in which it is connected. This effect is undesirable, particularly in circuits, such as radio-frequency preselector circuits, which are tunable over a range of frequencies, since it tends to restrict the tuning range.

The main disadvantages of using vacuum tubes for variably damping tuned circuits are realized most severely in association with the tunable input circuit of a radio receiver. Both desired and undesired signals may be present in this circuit with substantial amplitude sufficient to cause fluctuation of the vacuum-tube shunt conductance with resulting distortion of the desired signal or cross modulation thereof by the undesired signal. The latter is a form of interference which cannot be filtered out in subsequent selective circuits. In the case of the usual input circuit comprising fixed inductance and variable capacitance for tuning, the band width thereof is affected unequally by the same shunt conductance for different tuning adjustments so that uniform increment of band width is not obtained.

In general, the use of nonlinear impedance elements, such as vacuum tubes, tends to result in undesired cross modulation effects. Accordingly, it is desirable to provide in such selector circuits an impedance element of variable resistance having for any given value of resistance a linear relation between voltage and current at high frequencies. Control is facilitated if the resistance of such a device is subject to variation in response to adjustment of a control current or voltage applied to the device.

In the case of a superheterodyne receiver, one form of proposed selectivity control is obtained by connecting impedance elements in circuit with the resonant circuits of the intermediate-frequency channel and providing control means for adjusting the resistance of these elements to expand the width of the frequency band transmitted by these circuits in accordance with the amplitude of the intermediate-frequency carrier. In providing a selectivity control arrangement for this type of receiver, it is desirable not only to provide means for adjusting the band-pass characteristic of the intermediate-frequency channel, but also to provide means for similarly adjusting the width of frequency bands passed by the radio-frequency selector circuits of the receiver, by the same amount, independent of the tuning adjustment.

It is an object of the present invention to provide an improved simple and economical arrangement which may easily be adjusted to control the sensitivity and selectivity of a modulated-carrier signal receiver so that there may be obtained uniform output with maximum fidelity of reproduction consistent with any particular condition of reception.

It is a further object of the invention to pro-
vide an arrangement for adjusting the width of the frequency band transmitted through a radio-frequency selector circuit with freedom from undesired cross modulation of the desired signal carrier by strong undesired signals on nearby frequencies.

It is a further object to provide such an arrangement for a radio-frequency circuit tunable by variable capacitance in which the adjustment of the band width is the same for all tuning adjustments.

It is a further object of the invention to provide, in a superheterodyne radio receiver, a selectivity control arrangement of the character described above which may be adjusted to vary, by the same amount, the width of the frequency band to be transmitted through one or both of the radio-frequency and the intermediate-frequency channels of the receiver.

Briefly, the above objects are attained in accordance with the present invention by providing, effectively in circuit with each of certain of the resonant frequency-sensitive circuits included in one or both of the radio- and intermediate-frequency channels of a radio receiver, a resistance element having a substantially constant resistance at high frequencies, but a substantial variation of resistance with respect to temperature, that is, a substantial temperature coefficient of resistance and controlling the temperature of these resistance elements by means of a temperature control heating current of adjustable magnitude to vary the selectivity of the several circuits.

The invention contemplates, in particular, the use of such a device in the first radio-frequency selector circuit of the receiver for increasing the band width and decreasing the selectivity of this circuit during reception of strong signals less subject to interference from strong undesired signals located on channels near that of the desired received carrier, which undesired signals would tend to produce cross modulation effects. In the preferred arrangement, the control current is varied directly in accordance with the amplitude of a desired signal carrier so that the resistance of each of the circuit damping resistance elements is increased with increasing desired signal amplitude to broaden the frequency band of the associated circuits. A tungsten filament incandescent lamp is one form of resistance element having the desired characteristic.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings.

In which Fig. 1 illustrates one form of the improved selectivity control arrangement in its application to a radio broadcast receiver of the superheterodyne type; and Fig. 2 illustrates a modification of one of the band-pass selector systems included in the receiver of Fig. 1.

Referring now more particularly to Fig. 1 of the drawing, the superheterodyne receiver there shown comprises a radio-frequency amplifier tube 18 coupled by means of a tunable band-pass input circuit 11 to an inductance 12, the terminals of which comprise the input terminals of the receiver and are adapted to be connected to an antenna 13 and ground 14. The output circuit 15 of the tube 10 is coupled to the tunable band-pass input circuit 16 of a frequency changer 17 comprising a modulator tube 18 and a local oscillator indicated schematically at 19 in the cathode circuit of the tube 18. The oscillator 19 may be of any form well known in the art and, since the details thereof form no part of the present invention they have been omitted from the drawing. The variable condensers of the resonant input circuits 11 and 16 and the local oscillator 19 are preferably ganged for unicontrol adjustment, as indicated by the dotted line U.

The frequency changer 17 is coupled to an intermediate-frequency amplifier 20 by means of a band-pass selector system, indicated generally at 21, which is adjustable to vary the width of the transmission band in a manner to be described hereinafter. The output from the intermediate-frequency amplifier 20 is coupled by means of a transformer 22 to a detector and A. V. C. rectifier, indicated generally at 23, which comprises a diode rectifier tube 24 having its electrodes connected across the secondary of the transformer 22 through a load circuit comprising series-connected resistors 24 and 25 shunted respectively by carrier-frequency by-pass condensers 26 and 27, the rectifier 24 and 25 and the condensers 26 and 27 being grounded as indicated at 29. Coupled in cascade with the detector 23 are an audio-frequency amplifier 30 and a sound reproducer 31. Suitable means of operating potentials 32, 33, 34, and 35 are provided for the tubes 18, 19, and 24.

Automatic amplification control is secured in a well-known manner by applying the rectified voltage developed across the load resistor 25 as a negative bias on the control electrodes of one or more of the tubes included in the radio-frequency and the intermediate-frequency channels of the receiver through a connection 36 and high-frequency blocking resistors 37. The audio-frequency voltage developed across the load resistor 24 is applied to the input circuit of the audio-frequency amplifier 30 for comparison with the output.

Neglecting for the present the operation of the selectivity control means, the apparatus just described constitutes, in general, a conventional superheterodyne radio receiver, the operation of which is well understood in the art. In brief, signals, in the form of modulated waves, are received on the antenna. The modulated waves are amplified by the first band-pass circuit of the receiver and are supplied to the loud-speaker 31 for reproduction.

Referring now more particularly to the features of the arrangement for controlling the selectivity and selectivity of the receiver comprising the apparatus just described, the arrangement comprises, in general, means for adjusting the width of the frequency band passed by the radio-frequency selector circuits 11 and 16, means for adjusting the width of the frequency band passed by the intermediate-frequency selector circuit 21, and control means for simultaneously controlling the two band width adjusting means. The band width adjusting means for the tunable selector circuit 11 comprises a resistor 39 connected in series with other elements of the
circuit by means of direct current blocking condensers 40 and 41. Similarly, a resistor 42 is connected in series with the other elements of the tuned audio-frequency circuit 19 in the direct current blocking condensers 43 and 44.

The width of the frequency band transmitted through the intermediate-frequency channel of the receiver is determined by the adjustment of the selector system 21. This system comprises a plurality of resonating circuits 20 through 23, an output circuit III, and an intermediate link or coupling circuit II. Each of these circuits comprises one or more inductance elements 45 and one or more tuning condensers 46.

45. By means of which the circuits are individually tuned to the intermediate frequency of the receiver. Inductance elements 45 of the circuits I and II are inductively coupled, as are the corresponding elements 45 of the circuits II and III. The couplings between the circuits I and II and between II and III are initially adjusted in accordance with well-known design principles to obtain the maximum desired transmission frequency band with maximum resistance of 47 and minimum resistance of 48. The resistor 47 is connected in series with the elements 45 and 46 of the circuit I and the resistor 48 is connected in series with the elements 45 and 46 of the link circuit II.

Preferably, each of the enumerated resistors 39, 42, 47, and 48 comprises an incandescent lamp including a filament of tungsten or like material having a large temperature coefficient of resistance such that, when it is subjected to a variable current, it manifests a substantial current coefficient of resistance. The filaments of these resistors are designed with sufficient thermal inertia that their resistances are substantially unaffected by radio-frequency or intermediate-frequency variations of current therein. As was noted previously, this form of resistor has certain desirable characteristics when used in a selector circuit as a damping means.

In order to adjust the resistance values of the resistors 39, 42, and 47 simultaneously in the same sense, these resistors are connected in series by means of high-frequency choke coils 49 and 50. These coils and the by-pass condenser 41, 44 serve to isolate the selector circuits from even the lowest audio frequencies. Similarly, the blocking condensers 40, 41, 43, 44 are effective to prevent direct current from flowing through the elements of the selector circuits 11 and 16 other than the resistors 39 and 42. Control current is supplied to these series-connected resistors by the voltage sources 34 and 35 and the amplitude of this current is controlled by a tube 51 comprising a part of the control means 38 and having its space-current path included in series with these resistors. The voltage sources 34 and 35 and the amplitude of which is controlled by a tube 52 also included in the control means 38 and having its space-current path in series with this resistor. The latter space current is varied to adjust the resistance of 48 in the opposite sense relative to that of the three resistors, as required by the selector 21.

Preferably, the control means 38 is arranged automatically to control the magnitude of current through the several resistors in accordance with the amplitude of a desired received carrier in such manner that the width of the frequency band transmitted through the selector circuit 11 and 16 and the system 21 is varied directly with the intensity of the signal carrier. To this end the control electrode of the tube 51 is connected through an audio-frequency blocking resistor 53 and the connection 37 to the positive terminal of the load resistor 24, and the control electrode of the tube 52 is connected through an audio-frequency blocking resistor 54 to the automatic volume control connection 38. The control electrodes of the tubes 51 and 52 are by-passed to ground for audio-frequency currents by condensers 55 and 56, respectively. Auxiliary manually adjustable means are provided for further controlling the effective bias applied between the input electrodes of these tubes. For the tube 51, this means comprises a voltage source 57 shunted by a voltage divider 58 having an adjustable arm 59 connected to the cathode of the tube and, for the tube 52, it comprises a voltage source 60 shunted by a voltage divider resistor 61 having an adjustable arm 62 connected to the cathode of the tube.

In considering the operation of the selectivity control means just described, it will be assumed that, in the absence of a received carrier and with the auxiliary control means 38 properly adjusted, the bias applied positively to the control tube 51 through the connection 37 is a minimum and the space current flowing through this tube and through the resistors 39, 42, and 47 is adjusted to its minimum value. Thus, these resistors are adjusted to their minimum resistance values, such that the damping of the respective circuits 11, 16 and 1 are minimum. As a consequence, these circuits are adjusted to pass the minimum band of frequencies. Under these conditions, the bias applied negatively to the control tube 52 is also a minimum and the space current flowing through this tube and through the resistor 48 is adjusted to its maximum value corresponding to the maximum resistance value of this resistor. Hence, the damping of circuit II is a maximum and the effective coupling between the circuits I and III is minimized for minimum transmission band of the selector 21.

With gradually increasing signal strength, the effective positive and negative bias voltages applied respectively to the control electrodes of the tubes 51 and 52 are increased simultaneously to increase the current flowing through the resistors 39, 42, and 47 and to decrease the current flowing through the resistor 48. As a result, the resistances of the resistors 39 and 42 are gradually increased to increase the width of the transmission band through the circuits 11 and 16; the resistance of the resistor 48 is gradually decreased to increase the effective coupling between the circuits I and III and thereby gradually to increase the width of the transmission band of the selector 21; and the resistance of the resistor 47 is gradually increased to increase the damping of the circuit I. The resistor 47 serves to provide proper damping in the entire selector 21 and thereby to assure a flat-top resonance curve or uniform transmission characteristic therefor. It is initially adjusted with such a maximum value as to meet these requirements when the system is adjusted to provide the maximum desired band width. By simultaneously adjusting the resistor 48, in the manner described, to increase the losses in the circuit II and the resistor 47 to decrease the losses in circuit I, a proper relation between damping and coupling in the selector 21 is maintained for all band width adjustments and the desired transition from broad band to sharp selectivity characteristics may be obtained.
Manual adjustment of the transmission band of the receiver may be procured by adjustment of the potentials of the cathode of the amplifier tubes 51 and 52 by the voltage sources 57 and 60. For minimum expansion and entirely automatic control, the potentials of the cathodes of these tubes should be adjusted respectively to maximum and minimum values, as indicated by the dotted line positions of the adjustable arms 59 and 62. Preferably, the adjustable arms 59 and 62 should be gauged for unimproved adjustment, such that one bias voltage is increased, while the other is being decreased. The maximum value of each bias is preferably of the order of the value required to cut off the space current in the corresponding tube.

Referring now more particularly to Fig. 2 of the drawing, there is illustrated a modification of the selector system 21 included in the intermediate-frequency channel of the receiver, which is adjustable to vary the width of the transmission band through this channel. The arrangement comprises an input circuit IV, an output circuit V coupled to the intermediate-frequency amplifier 20, and a tertiary or absorption circuit VI for controlling the band width of the selector as a whole. Each of the enumerated circuits comprises a parallel connected inductor 63 and condenser 64, and is permanently tuned to the intermediate frequency. The remaining portions of the receiver may be similar in all respects to that represented by Fig. 1. In order to vary the effective damping of the absorption circuit VI, a resistor 66 of the type described above is connected in series with the elements 63 and 64 of the circuit VI and a control current of adjustable magnitude is conducted through this resistor through the terminals 67 and 68.

The circuits IV and V are coupled by less than optimum coupling and the circuits V and VI have more than optimum coupling. The resistor 65 is chosen of a resistance value such that the maximum desired band width is obtained when the resistor has its minimum resistance value. The maximum resistance of 66 should be sufficient to make negligible the absorption effect of VI and thereby to secure the minimum band width.

In the operation of the system of Fig. 2, to control the band width of transmission through the intermediate-frequency channel of the receiver, an increase in the resistance of the resistor 66, in response to an increase in the magnitude of the control current applied thereto through the terminals 67 and 68, increases the damping of the circuit VI to decrease the width of the frequency band passed by the system 21. Conversely, a decrease in the resistance of the resistor 66, to decrease the damping of the circuit, increases the width of the frequency band. The latter operation has the effect of lowering only the center part of the resonance curve to increase the effective band width. It is desired to have heating current in 55 which decreases with increasing carrier amplitude of the desired signal, as in the resistor 48 of Fig. 1. This may be obtained by the substitution of the selector 21 of Fig. 2 for that of Fig. 1, so that circuits IV, V, VI replace circuits I, III, II, respectively, the terminal 67 is connected to the positive terminal of the voltage source 35, and the A. V. C. lead is connected to the connection 36.

Particular reference is made to the series connection of the temperature controlled resistors 38 and 42 in the tunable radio-frequency circuits 11 and 16 in Fig. 1. These circuits have fixed inductance and variable capacitance for tuning. It is a property of such a circuit that a given increment of series resistance increases the band width of the circuit by an amount which does not vary with tuning. The band width of the intermediate-frequency selector 21 also does not vary with the tuning of the receiver. Therefore, it is possible to secure approximately equal band widths of the tunable selectors 11, 18 and the tuned selector 21, and to maintain this relation with variation of the controlled resistors during expansion of the band width.

The essential property of the temperature controlled resistors 38, 42, 47, 48, 65 is thermal inertia sufficient to prevent appreciable resistance fluctuation at high frequencies and, preferably, also at audio frequencies. The variation of temperature may be secured by heating current in the controlled resistor, or in a heating element close to the resistor. The latter effects indirect heating which is advantageous where large thermal inertia is desired, or where the heating circuit must be isolated from that of the resistor. The present embodiment contemplates the use of either direct or indirect heating of the resistor by the control current.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In a superheterodyne radio receiver including at least one resonant circuit tunable over a range of frequencies to select a desired signal carrier, a tunable frequency changer and at least one resonant circuit permanently tuned to the intermediate frequency, an electric circuit arrangement for controlling the frequency transmission band width of said circuits comprising an element connected in each of said resonant circuits having resistance variable with temperature to vary the width of the frequency band passed by the associated circuit, the means for adjusting the temperature of said elements, said resistance elements of said tunable and tuned circuits being proportioned and the resistances thereof being adjusted by said adjusting means to cause approximately equal variation of the effective band width of the individual tunable and tuned circuits.

2. In a superheterodyne radio receiver including at least one resonant circuit tunable over a range of frequencies to select a desired signal carrier, a tunable frequency changer and at least one resonant circuit permanently tuned to the intermediate frequency, an electric circuit arrangement for controlling the frequency transmission width of said circuits comprising an element connected in series with the other elements of each of said resonant circuits having resistance variable with temperature to vary the width of the frequency band passed by the associated circuit and means for adjusting the temperature of said elements, said resistance elements of said tunable and tuned circuits being proportioned and the resistances thereof being adjusted by said adjusting means to cause approximately equal variation of the effective band width of the individual tunable and tuned circuits.

3. In a superheterodyne radio receiver includ-
ing at least one resonant circuit comprising fixed inductance and capacitance variable to tune said circuit over a range of frequencies to select a desired signal carrier, a tunable frequency changer and at least one resonant circuit permanently tuned to the intermediate frequency, an electric circuit arrangement for controlling the frequency transmission band width of said circuits comprising an element connected in series with the other elements of each of said resonant circuits having resistance variable with temperature to vary the width of the frequency band passed by the associated circuit and means for adjusting the temperature of said elements, said resistance elements of said tunable and tuned circuits being proportioned and the resistances thereof being adjusted by said adjusting means to cause approximately equal variation of the effective band width of the individual tunable and tuned circuits.

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