

Aug. 1, 1944.

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2,354,959

AMPLITUDE-AND FREQUENCY-MODULATION RADIO RECEIVER

Filed Nov. 14, 1941

2 Sheets-Sheet 1

FIG. 1.

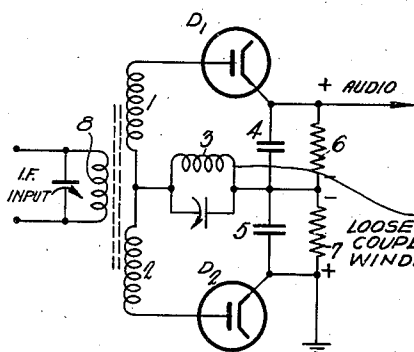


FIG. 2.

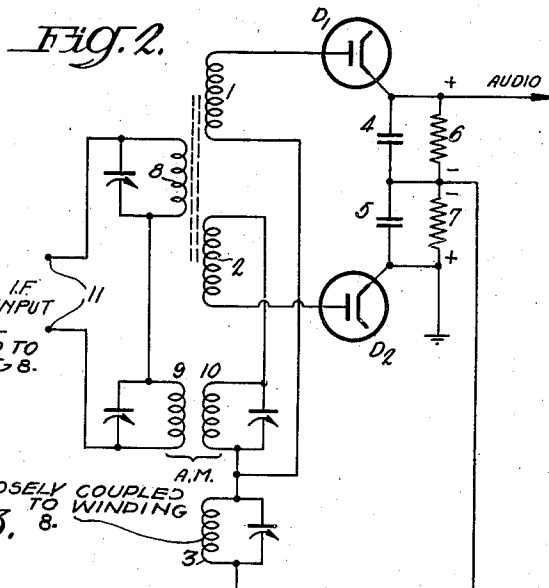


FIG. 3.

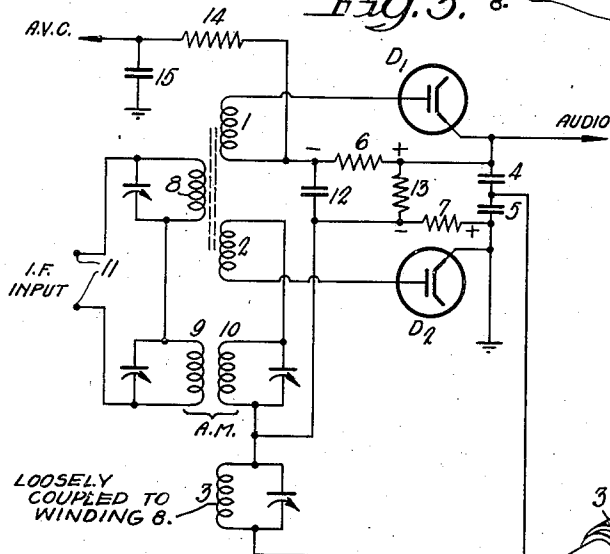


FIG. 4.

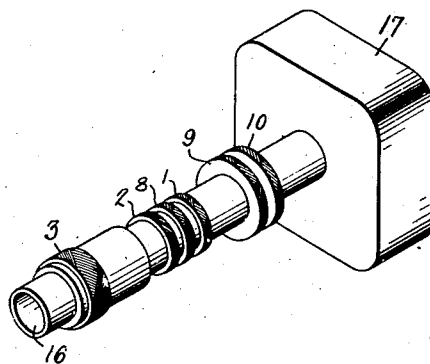
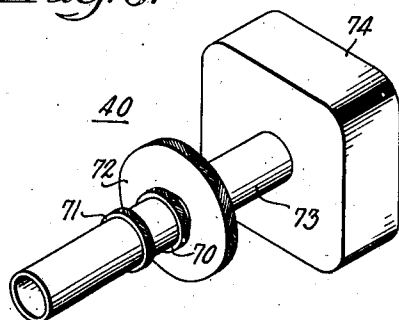


FIG. 6.



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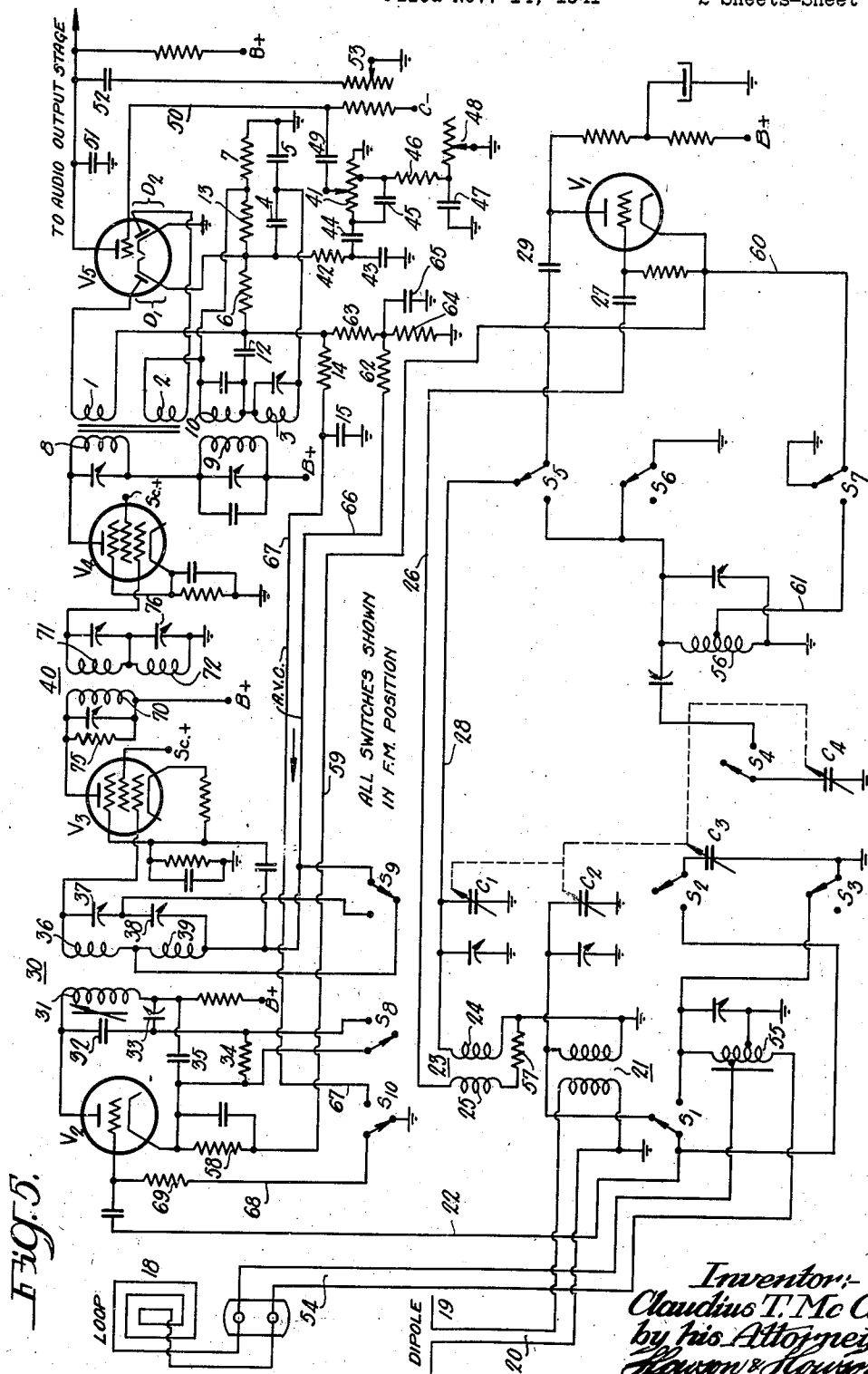
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,354,959

AMPLITUDE- AND FREQUENCY-MODULATION RADIO RECEIVER

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Application November 14, 1941, Serial No. 419,200

15 Claims. (Cl. 250—20)

This invention relates to radio receivers and to radio receiver circuits adapted for use in the reception of amplitude-modulated and frequency-modulated carrier waves. More particularly, the invention relates to certain novel circuit arrangements for AM/FM receivers which do not require switching when changing from AM to FM operation, or vice versa.

Radio receivers are known which include separate amplitude-modulation and frequency-modulation channels, with means for switching at will from one channel to the other. Such receivers are effectively a combination, within a common cabinet or housing, of a complete FM receiver and a complete AM receiver, having only the power supply system, the audio amplifier, and the loudspeaker in common. This construction results in an uneconomical duplication of the radio frequency, first detector, intermediate frequency, and second detector circuits and tubes, and in addition greatly complicates the manufacture of the apparatus.

The principal object of this invention is to provide an improved and economical combination AM/FM radio receiver.

Another object of this invention is greatly to simplify the construction of combination AM/FM receivers, and to utilize all or most of the tubes during both AM and FM operation, thereby effecting a substantial economy in tubes and apparatus.

Another object of the invention is to provide a combination AM/FM receiver in which the number of individual switching operations required in changing from the FM to the AM bands (or vice versa) is held to a minimum.

Still another object of the invention is to provide a balanced frequency-detector so constructed and arranged that it can also be employed as an amplitude-modulation detector without switching the detector circuits themselves.

A further object of the invention is to provide a selective intermediate frequency amplifier network capable of amplifying and transferring, without switching, or with a minimum of switching, either a frequency-modulated wave of relatively high intermediate frequency, or an amplitude-modulated wave of lower intermediate frequency.

Other objects and features of the invention will be apparent from the following description and the accompanying drawings, in which:

Fig. 1 is a schematic representation of a prior art balanced frequency-detector, which is illustrated to enable the operation and application of

the invention to be better understood and appreciated;

Fig. 2 is a schematic diagram of one embodiment of the switchless AM and FM detector of the present invention;

Fig. 3 is a schematic diagram of a preferred embodiment of the switchless AM and FM detector;

Fig. 4 is a perspective view of a detector input transformer suitable for use with the detector circuits illustrated in Figs. 2, 3 and 5;

Fig. 5 is a schematic diagram of a radio receiver embodying the switchless AM/FM detector and a switchless AM/FM intermediate frequency amplifier network; and

Fig. 6 is a perspective view of an intermediate frequency transformer adapted for use in the radio receiver of Fig. 5.

Attention is now directed to Fig. 1, wherein there is shown, by way of illustration, a balanced frequency-detector of a type to which my invention may advantageously be applied, as will be explained hereinafter in connection with Figs. 2, 3, and 5. The detector of Fig. 1 is derived from the balanced frequency-detector described and illustrated in German Patent No. 428,643 granted May 14, 1926. This detector is constructed, and operates, generally as follows. A pair of diodes D_1 and D_2 , or other suitable rectifier elements, are provided, respectively, with the untuned input windings 1 and 2, the winding 1 being connected to the anode of the diode D_1 , while the winding 2 is connected to the anode of the diode D_2 . The tuned winding 3, on the other hand, is disposed in a circuit which is common to both diodes, the winding 3 being connected between the junction of the untuned coils 1, 2, and the rectifier cathodes, the latter connection being effected by means of the radio frequency by-pass condensers 4 and 5. The diode D_1 is provided with a load resistor 6 and the diode D_2 with a load resistor 7, these load resistors being connected in shunt with the condensers 4 and 5, respectively.

The frequency modulated signal may be supplied to the detector circuit by way of the tuned input winding 8, which, in a superheterodyne receiver, may be the output circuit of the receiver's intermediate frequency amplifier. Preferably, the untuned windings 1 and 2 are tightly coupled to the winding 8, while the tuned winding 3 is loosely coupled thereto. The windings 1 and 2 are wound in a direction such that the voltages at the opposite ends thereof are substantially 180 degrees out of phase with each other. The tuned windings 3 and 8 are preferably tuned to the center-frequency of the fre-

quency-modulated wave supplied by the preceding I. F. amplifier (not shown), and when so tuned an unmodulated input signal of this frequency will give rise to voltages across the untuned windings 1 and 2 which differ in phase from the voltage across the tuned winding 3 by substantially 90 degrees. Consequently, the diode D₁ will be supplied with a signal voltage which is the vector sum of the voltages across the windings 1 and 3, while the diode D₂ will be supplied with a signal voltage which is the vector sum of the voltages across the windings 2 and 3. At resonance the vector sum of the voltages applied to the diode D₁ will equal the vector sum of the voltages applied to the diode D₂, and, hence, for this condition the rectified output signals appearing across the load resistors 6 and 7 will be equal, and, with the differential connection shown, opposite. As the frequency of the incoming signal varies, the phase of the voltage across the tuned winding 3 will change with respect to the voltages across the untuned windings 1 and 2, and in consequence the diodes D₁ and D₂ will be supplied with input voltages differing both in phase and magnitude. Thus, when the signal frequency is above resonance, the voltage applied to one of the diodes will be greater than that applied to the other diode, while when the signal frequency is below resonance, the converse will be true. In a detector of this type, the input circuit for the diodes, comprising windings 1, 2 and 3, is a "discriminator" type circuit because it discriminates between signal frequencies above and below the center frequency to which the winding 3 is tuned.

The differential connection of the load resistors 6 and 7 permits the derivation from the cathode of D₁, of a detected output voltage whose magnitude is proportional to the difference between the signal frequency and the resonant frequency of the tuned winding 3. As is well known, the differential connection of the load resistors 6 and 7 makes the detector highly sensitive to carrier frequency changes, but very insensitive to carrier amplitude changes, and, hence, this detector is relatively insensitive to noise.

A more detailed description of the operation of this form of detector is deemed unnecessary, since the basic theory of operation is adequately treated in the above-mentioned German patent.

In Fig. 2, there is illustrated one embodiment of the detector provided by the present invention, which utilizes the principles of the prior art detector of Fig. 1. Certain elements in Fig. 2 correspond to the elements of Fig. 1 and are correspondingly designated. The device of Fig. 2 differs from that of Fig. 1 in that the device of Fig. 2 is capable of detecting both amplitude- and frequency-modulated signals, and this dual function is accomplished, in accordance with this invention, without detector-circuit switching. As in Fig. 1 the untuned windings 1 and 2 are tightly coupled to the primary winding 8, while the tuned winding 3, which is common to the input circuits of both diodes, is loosely coupled to the winding 8. The added elements, which comprise the tuned and coupled windings 9 and 10, make it possible to utilize certain of the elements which are common to Fig. 1 for detection in both the FM and AM bands. As in Fig. 1, the windings 3 and 8 may be tuned to the intermediate frequency employed in FM reception, commonly 4.3 megacycles, while the windings 9 and 10 may be tuned to the intermediate frequency employed in AM reception, commonly 455

kilocycles. As is disclosed in detail in Fig. 5, the radio frequency and intermediate frequency stages of the preceding receiving circuits may be constructed and arranged to supply either a frequency-modulated 4.3 megacycle signal or an amplitude-modulated 455 kilocycle signal to the detector input terminal 11. Of the former signal is supplied, the signal will be applied to the diodes by way of the windings 8, 1, 2 and 3, no substantial voltage appearing across the windings 9 and 10 because they are tuned to a frequency differing substantially from that of the signal frequency. By so designing the tuned transformer 9, 10, that the impedance of the condenser across the winding 10 is negligible at 4.3 megacycles, the series insertion of this tuned circuit between the upper end of winding 2 and the lower end of winding 1 will have no appreciable effect upon the operation of the circuit as a detector of the frequency-modulated 4.3 megacycle signal, the circuit functioning substantially as described with reference to Fig. 1.

If now an amplitude-modulated 455 kilocycle signal be supplied to the terminals 11, the operation above outlined will be relatively reversed, i. e., no substantial signal will appear across the windings 8, 1, 2, or 3, but instead signal will appear across the 455 kilocycle windings 9 and 10. Moreover, at this relatively low frequency (455 k. c.), the impedance of the 4.3 megacycle windings 8, 1, 2, and 3 will be negligibly small, and, hence, these windings will exert no appreciable effect upon the operation of the circuit. The amplitude-modulated 455 kilocycle signal appearing across the tuned secondary winding 10, is applied to the diode D₂ as follows—from the lower terminal of the winding 10, through the winding 3 (having negligible impedance of 455 k. c.), and through the I. F. by-pass condenser 5, to the cathode of D₂ and chassis (ground); and from the upper terminal of the winding 10, through the winding 2 (of negligible impedance at 455 k. c.), to the anode of D₂. No appreciable 455 kilocycle signal is applied to the diode D₁, since both its anode and cathode are effectively grounded for 455 kilocycle currents, and, hence, this diode will have no substantial effect upon the 455-kilocycle operation of the circuit. The audio output voltage is, of course, developed across the load resistor 7, and may be supplied to the following audio amplifier by way of the resistor 6, as will be shown in greater detail in Fig. 5.

It should be understood that the invention herein disclosed is not limited in its application to balanced detector circuits of the type illustrated in Fig. 1, but is capable of application to balanced detector circuits generally. Other known balanced detector circuits to which the invention may be applied are, for example those disclosed in the patents to Round and to Seeley, Nos. 1,642,173 and 2,121,103, respectively. The application of the invention to these and other detectors will be obvious to those skilled in the art, and specific illustration thereof is deemed unnecessary.

Attention is now directed to Fig. 3 wherein is illustrated a combination of the above-described switchless AM/FM detector circuit and the novel AVC circuit described and claimed in co-pending application, Serial No. 415,465, filed October 17, 1941, Patent No. 2,330,902, October 5, 1943. The circuit of Fig. 3 differs from that of Fig. 2 in the interconnection and utilization of its load resistors 6 and 7. The differential

connection between the resistors is maintained, for audio frequencies, by the connection of an audio by-pass condenser 12 between the left-hand (anode) ends of the said resistors. However, for direct currents, the resistors are connected in a relatively reversed fashion by means of a high resistance element 13. The latter element, which may be a one-megohm resistor, may be connected between the right-hand (cathode) end of the resistor 6, and the left-hand (anode) end of the resistor 7. This connection is such that, during the reception of frequency-modulated signals, the direct-current products of the rectification process are added to produce an overall direct-current output voltage which is substantially double that established across either resistor alone. This additively-combined direct-current output voltage may be filtered by means of the filter network 14, 15, and employed to control the gain of a preceding radio- or intermediate frequency amplifier stage. As is described in detail in the above-mentioned copending application, the advantages of this novel AVC connection lie not only in increased AVC voltage output, but also in the fact that the magnitude of the AVC voltage varies symmetrically with the tuning of the receiver about the proper tuning point.

During the reception of amplitude-modulated signals, under which condition only the diode D₂ is supplied with signal voltage, AVC voltage may be derived from the negative (anode) end of the load resistor 7 by way of the serially-connected resistors, 13, 6, and 14, the control voltage appearing at the junction of the resistor 14 and the condenser 15. The audio output signal may again be derived from the junction of the resistors 6 and 13 and the cathode of D₁, this point being coupled to the ungrounded end of the resistor 7 through the resistors 6 and 13, which are effectively in parallel for audio frequencies since the impedance of the condenser 12 is negligible at these frequencies.

Reference may now be had to Fig. 4, which illustrates a detector input transformer of a type suitable for use with the dual detectors of Figs. 2, 3, and 5. This transformer may comprise an insulating tube 16 fixed to an insulating support 17, the latter carrying, as is conventional, the several condensers and trimmers necessary for properly tuning the windings carried by the tube 16. The windings 1, 2, 3, 8, 9, and 10 correspond, respectively, to the like-numbered windings of Figs. 2, 3, and 5, and in one embodiment of the invention had inductances of 37, 37, 33, 39, 200, and 200 microhenries, respectively. The windings 9 and 10 are preferably shunted by large enough tuning capacities to by-pass 4.3 megacycle currents, and are preferably tightly coupled to give two resonant peaks. These windings, in the preferred embodiment, are then tuned to give one peak at 455 kilocycles (or whatever the selected I. F. happens to be), the frequency of the other peak being made high enough, by the tightness of coupling, not to affect the adjacent carrier attenuation at 455 kilocycles. This method of construction enables the 455 kilocycle transformer to be tuned by the adjacent of a single trimmer condenser, e. g. one on the primary side, as indicated in Fig. 5.

The windings 1, 2, and 8 may be grouped well together, as shown, to get the desired tightness of coupling therebetween, the untuned windings 1 and 2 being positioned symmetrically on either

side of the tuned primary winding 8. The tuned secondary winding 3 may be placed at some point on the tube 16 remote from the tuned primary winding 8 to secure the desired loose coupling between these tuned windings. The entire assembly is preferably housed in a conventional shield can to reduce the coupling between its windings and other components of the radio receiver in which the device is employed.

A very slightly modified version of the switchless AM/FM detector circuit, together with the novel switchless AM/FM intermediate frequency coupling network (not yet described) is illustrated in Fig. 5, which is a schematic diagram of a substantially complete AM/FM radio receiver of the superheterodyne type. In general, this receiver comprises a loop antenna 18 for the reception of amplitude-modulated signals, e. g., in the broadcast band, 550 to 1600 kilocycles; a dipole antenna 19 for the reception of frequency-modulated signals in the FM band, 42 to 50 megacycles; a local oscillator tube V₁, a first detector tube V₂, a pair of intermediate frequency amplifier tubes V₃ and V₄, and a detector, audio amplifier, and AVC tube V₅. A series of ganged switches, S₁ to S₁₀, may be provided for switching various of the circuits to condition the receiver for reception of signals either in the AM or in the FM band. If additional bands are desired, e. g., one or more short-wave bands, they can readily be added in accordance with the conventional practice. In Fig. 5 the switches are shown in their FM positions, switches S₁ to S₃ being connected in the antenna or R. F. circuits, S₄ to S₇ in the oscillator circuits, S₈ and S₉ in the first I. F. circuit, and S₁₀ in the grid bias circuit of the first detector tube V₂.

With the switches in the FM position, the short-wave dipole 19 is coupled to the input circuit of the first detector tube V₂ through the transmission line 20, the matching transformer 21, the switch S₁, and the conductor 22. The secondary of the transformer 21 may be tuned by one unit C₂ of a ganged tuning condenser element. Inductively coupled to the transformer 21 is the oscillator transformer 23 having a plate winding 24 tuned by the variable condenser C₁, and an untuned grid winding 25. The latter winding is connected to the grid of the oscillator tube V₁ by way of the conductor 26 and the condenser 27, while the plate winding 24 is connected to the plate electrode of V₁ by way of the conductor 28, the switch S₅, and the condenser 29.

In the FM position of the switches, the frequency-modulated I. F. signal output of the first detector V₂ is applied to the grid circuit of the first I. F. amplifier tube V₃ by way of an I. F. coupling transformer 30. With the switch S₃ in the FM position, the primary side of this transformer comprises the winding 31 tuned by the condensers 32 and 33 in series. The damping resistor 34 is effectively connected in shunt with the condenser 33, the impedance of condenser 35 being negligible at the intermediate frequency. The damping resistor serves to flatten the response characteristic of the network, and is conventional in FM receivers. With the switch S₉ in the FM position, the secondary side of transformer 30 comprises the winding 36 tuned by the condensers 37 and 38 in series, the winding 39 being short-circuited by the switch S₉.

The I. F. coupling transformer 40 is capable of transferring signals of either the AM or the FM intermediate frequencies, from the output

of the first I. F. amplifier tube V_3 to the input of the second I. F. amplifier tube V_4 . The novel construction of this coupling element will be described in some detail hereinafter.

The detector circuit which is coupled to the output of the second I. F. amplifier tube V_4 is substantially identical to that illustrated in Fig. 3, and the corresponding elements have been correspondingly numbered to simplify comparison of the circuits. In Fig. 5, the audio by-pass condenser 12 is connected between the lower end of coil 10 and the left-hand (anode) end of the resistor 6, rather than between the left-hand ends of the resistors 6 and 7 as in Fig. 3. Likewise, in Fig. 5, the upper terminal of the coil 2 is connected directly to the junction of resistors 7 and 13, while in Fig. 3 the winding 10 is interposed in this connection. Since the impedance of the tuned circuit 10 is negligible at the FM intermediate frequency, it is obvious that these differences of wiring will have no substantial effect during FM operation of the receiver. During AM operation, however, the connection of Fig. 5 places the diode load resistor 7 in shunt with the tuned secondary winding 10, rather than in series therewith, as is the case in the connection of Fig. 3. Thus, in the circuit of Fig. 3, the effective Q of the tuned secondary winding will be higher than in the circuit of Fig. 5, in which latter case the tuned circuit is damped by the application thereacross of the load resistor 7.

In Fig. 5, as in Fig. 3, the audio output signal may be derived from the cathode of the diode D_1 , i. e., from the junction of the resistors 6 and 13. The signal from this point may be supplied to a suitable volume control potentiometer 41 by way of an I. F. filter network comprising the series resistor 42 and I. F. by-pass condenser 43, and the coupling condenser 44. If desired, the volume control may be provided with a conventional treble compensating condenser 45, and a variable bass compensating network 46, 47, 48. The audio signal taken from the potentiometer 41 may be applied, by way of the condenser 49 and conductor 50, to the control grid of the triode section of the vacuum tube V_5 . Additional I. F. filtering may be secured by connecting an I. F. by-pass condenser 51 in shunt with the output circuit of V_5 , as shown. Similarly, a conventional variable-high-cut tone control, comprising the condenser 52 and the variable resistance device 53, may be connected between the triode anode and ground.

In the AM operation of the radio receiver of Fig. 5, the switches S_1 to S_{10} are turned to their alternative positions, the receiver thus being conditioned to receive amplitude-modulated signals in a predetermined AM band, e. g. the broadcast band. Under these conditions, the FM dipole circuit is opened, and the loop antenna 18 is connected to the input circuit of the first detector tube V_2 by way of the conductors 54, the matching transformer 55, the switch S_1 and the conductor 22. The tuning condenser C_3 is connected in shunt with a portion of the matching transformer 55 through switches S_2 and S_1 . The broadcast oscillator winding 56 is connected to the plate and cathode electrodes of the oscillator tube V_1 through the agency of switches S_8 and S_7 , respectively. The grid of the oscillator tube is connected to the grounded end of the winding 56 by way of the condenser 27, conductor 26, winding 25, and resistor 57, the latter having a low resistance of say 10 ohms to reduce

any possible tendency toward parasitic oscillations. The impedance of the winding 25 is negligible at broadcast frequencies, and, hence, its presence in the oscillator grid return circuit can be ignored during AM operation.

Injection of the oscillator signal into the first detector circuit may be secured, during AM operation, by connecting the cathode of V_2 to an intermediate point on the oscillator tank winding 56. This connection includes the cathode bias resistor 58, the lead 59, the lead 60, the switch S_1 and the lead 61.

The I. F. coupling transformer 30, which in the FM position of the switches S_8 and S_9 (shown) is conditioned to transfer I. F. signals of the order of say 4.3 megacycles, can be conditioned to transfer signals of the intermediate frequency commonly employed in AM receivers (for example 455 kilocycles). Thus, it will be seen that in the AM position of the switches, the I. F. by-pass condenser 35 is shunted across the tuning condenser 33, thereby lowering the resonant frequency of the primary circuit which now consists essentially of the winding 31 and the fixed condenser 32. Similarly, when the switch S_9 is moved to its AM position, the short circuit around the winding 39 is removed, and applied instead to the trimmer condenser 38, thus leaving a resonant secondary circuit tuned to 455 kilocycles and comprising the windings 36 and 39 and the condenser 37. As has already been indicated, and as will be explained in greater detail hereinafter, the transformer 40 is adapted to transfer signals of either the AM or FM intermediate frequencies without switching.

Returning now to the detector and AVC circuits associated with the vacuum tube V_5 , it is pointed out that in the particular circuit of Fig. 5, there are provided two sources of AVC voltage, namely, that at the junction of the resistor 14 and condenser 15, as already described in connection with Fig. 3, and that provided at the left-hand end of the resistor 62 whose other end is connected to the junction of the AVC voltage dividing resistors 63 and 64. The latter may be of the order of two megohms each, and adapted to provide a second AVC voltage whose magnitude is say one-half of that available at the junction of resistors 14 and 63. The condenser 65 may be connected between the upper end of resistor 64 and ground to provide filtering for the second AVC source. The control voltage from this source is applied to the gain control electrode of the first I. F. amplifier V_3 by way of the resistor 62, the conductor 66 and the coils 39 and 36. It will be seen that this AVC voltage is applied to V_3 during both AM and FM operation of the receiver.

Full AVC voltage, on the other hand, is applied only to the control grid of the first detector tube V_2 , and this only during AM operation. The full AVC circuit may be traced from the junction of the elements 14 and 15, via conductor 67, switch S_{10} (AM position), conductor 68, and resistor 69 to the grid of V_2 . During FM operation, this AVC circuit is broken by the switch S_{10} and the lower end of the grid resistor 69 is connected to ground through the conductor 68, grid bias under these conditions being supplied solely by the cathode resistor 58.

Reference is now made to the novel intermediate frequency coupling network 40 shown schematically in Fig. 5 and illustrated in Fig. 6. This transformer comprises three windings 70, 71, and 72, spaced along a tubular form 73, or

other suitable support. The windings 70, 71, and 72 may be of the universal type, and in one embodiment of the invention had inductances of 55, 48, and 1000 microhenries, respectively. As is customary, the form 73 may be fixed to an insulating support 74, the latter carrying the various trimmer condensers employed in tuning the several windings. The coils 70 and 71 are tuned, by means of trimmer condensers connected thereacross, to resonate at the intermediate frequency employed for FM reception, commonly 4.3 megacycles. These coils are preferably over-coupled and damped sufficiently to provide a relatively flat response over the deviation range of the intermediate frequency. In the embodiment of Fig. 5, only the primary coil 70 is damped, this being done by the connection thereacross of a suitable damping resistor 75 of say 50,000 ohms. The winding 72, as will be explained hereinafter, is shunted by a relatively high capacity 76 which, at 4.3 megacycles (or in general, at the FM intermediate frequency), by-passes the lower end of coil 72 to ground. Thus, at 4.3 megacycles, the transformer 40 may be regarded as a damped double-tuned transformer comprising only two windings, the primary winding 70 and the secondary winding 71.

The winding 72 is tuned to resonate at the intermediate frequency employed in AM reception, for example, 455 kilocycles. The constants of the resonant circuit 72, 76, should be so selected that in addition to providing resonance at 455 kilocycles, the capacity 76 will be large enough to act as a by-pass to currents having frequencies of the order of 4.3 megacycles. During 455 kc. operation, the winding 70 functions as an untuned primary. Preferably, the windings 70 and 72 are tightly coupled. Since the impedance of the high frequency winding 71 is negligible as compared to the impedance of the resonant circuit 72, 76, at 455 kilocycles, i. e., at the AM I. F., the transformer 40 may be regarded during AM operation as comprising only an untuned primary winding 70 and a tuned secondary winding 72 tightly coupled thereto.

From the foregoing, it will be seen that the transformer 40 provides a switchless, 4-terminal network capable of functioning either as a wide-band double-tuned transformer at a relatively high intermediate frequency, or as a narrow-band single-tuned transformer at a relatively low intermediate frequency.

It is preferred, in accordance with one of the features of this invention, that the receiver be provided with a plurality of stages of intermediate frequency amplification, at least one stage of which is operative, without switching, at either the AM or FM intermediate frequencies, and at least one other stage of which is highly selective as between the FM and the AM intermediate frequency and requires switching from one to the other. The radio receiver shown in Fig. 5 is illustrative of this preferred arrangement. Thus the transformer 40, as has already been explained in detail, is capable of transferring efficiently and effectively signals of either the AM or the FM intermediate frequencies (e. g. 455 kc. or 4.3 mc. respectively), without it being necessary to switch any of its circuits to so adapt it. On the other hand the transformer 30 is responsive only to the intermediate frequency to which it is adjusted and can be adapted to respond in a desired manner to the other intermediate frequency only by switching certain of its circuits,

as for example by means of the switches S_3 and S_2 already described.

Obviously if all intermediate frequency transformers were of the order of the unswitched variety shown at 40 in Fig. 5, the switching operations of the receiver could be still further simplified. However it has been found that it is highly desirable to have some selection, in the intermediate frequency portion of the receiver, as between the several intermediate frequencies to which the detector circuit is responsive. This is because in practice it is difficult, and usually impractical, to design a radio frequency and first detector circuit which will not, under certain conditions, contain in the output thereof signals of both the AM and FM intermediate frequencies. Assume, for example, that the receiver is adjusted to receive an FM signal having a nominal frequency of 49.5 mc. With the local oscillator V_1 adjusted to provide a heterodyne signal of 45.2 mc. the desired intermediate frequency (difference frequency) can be obtained from the first detector V_2 , in this case 4.3 mc. However if a strong FM signal from a nearby station having a nominal frequency of 45.7 mc. should succeed in arriving at the input of the first detector tube V_2 there would appear, in the output of first detector V_2 , a spurious "intermediate frequency" signal having a frequency of 45.7-45.2 mc. or 500 kc. Since this spurious signal is frequency modulated to an extent equal to that of the undesired 45.7 mc. signal this spurious signal will spring between limits of 400 and 600 kc., and hence will contain components in the 455 kc. intermediate frequency band. Hence unless means are provided in the intermediate frequency amplifier to discriminate against the undesired 455 kc. components during FM reception distorted detection will occur in the second detector V_3 . This is because in addition to the desired FM signal being applied in balanced manner to the diodes D_1 and D_2 there will also be applied an unbalanced 455 kc. signal to the diode D_2 . In addition to the application of the undesired or spurious signal to D_2 which is in itself undesirable, the balanced operation of the diodes at 43 mc. will be interfered with, and the overall operation of the system will be correspondingly impaired.

Likewise, without due regard to the precautions observed in the receiver of Fig. 5, difficulties may be experienced when tuning stations in the broadcast band. These difficulties may be caused by a harmonic of the oscillator falling in the FM intermediate frequency band and applying a spurious signal to the diodes D_1 and D_2 . Assume, for example, that the receiver be adjusted to receive an AM signal having a frequency of 980 kc. This signal will be mixed, in the first detector V_2 , with an oscillator signal of 1435 kc. to produce the desired intermediate frequency of 455 kc. Now the third harmonic of the oscillator will be 4305 mc., and this signal lies well within the band-pass characteristic of the 4.3 mc. FM intermediate frequency system. Consequently if means are not provided to reject or to discriminate against this signal both diodes D_1 and D_2 will be subjected to a strong unwanted 4.305 mc. signal during reception of the desired 980 kc. AM signal.

In accordance with the invention the above-described spurious signal difficulties may be avoided by employing at least one switched selective circuit (in combination with the switchless circuits) between the first and second detectors. Such a switched selective circuit is exemplified by the first I. F. transformer 30 whose operation and circuit details have already been described. When

the receiver is conditioned for the reception of frequency modulated signals this transformer serves to reject the undesired spurious signals in the 455 kc. band, and when the receiver is conditioned to receive amplitude modulated signals the transformer functions to reject spurious signals in the 4.3 mc. band.

Preferably the switched selective system is inserted in an early stage of the I. F. amplifier system, and in the preferred embodiment it forms the coupling means between the first detector V₂ and the first I. F. amplifier tube V₃ as illustrated in Fig. 5 of the drawings. This arrangement has been found most satisfactory since it is desirable to reject the spurious signals at a relatively low level, rather than after they have been amplified.

Referring to the invention generally, there is provided a radio receiver having a minimum of tubes and parts, which is capable of receiving either amplitude- or frequency-modulated waves with little or no more circuit switching than would normally be necessary in switching from one AM band to another. There is provided an intermediate frequency transformer and a second detector input transformer operable on either of two widely different intermediate frequencies without any switching whatever, and, likewise, there is provided a detector and AVC system operable without switching on either AM or FM transmissions. Similarly, the I. F. filter, volume control, tone control, and detector output circuits are operable without change on either kind of signal, and these desirable features have been achieved without it being necessary to increase the number of tubes in the receiver over what would be required either in a simple AM receiver or a simple FM receiver.

Although the invention has been described with particular reference to radio receivers of the superheterodyne type and to the embodiments illustrated in the drawings, it will be understood that the invention is capable of general application and adapted to other forms of physical expression, and is, therefore, not to be limited to the specific disclosure, but only to the scope of the appended claims.

I claim:

1. In a radio receiver of the class described, a frequency detector of the balanced variety including a pair of vacuum tube devices, a pair of load impedances connected to said devices, means including a split frequency-discriminating network for supplying a received frequency-modulated signal to said tubes, an input circuit adapted to provide a received amplitude-modulated signal across its output terminals, fixed means for connecting said terminals in series with a part of said frequency discriminating network and a predetermined one only of said vacuum tube devices, an audio frequency amplifier, fixed connections for supplying detected signals from both of said load impedances to said amplifier during the reception of frequency-modulated signals, and fixed connections for supplying detected signals from said predetermined one of said load impedances to said amplifier during the reception of amplitude-modulated signals.

2. In a radio receiver of the superheterodyne type having a frequency-converter and an intermediate frequency amplifier, selective means responsive to an amplitude-modulated signal in one frequency band for establishing an amplitude-modulated intermediate frequency signal of predetermined frequency, selective means responsive to a frequency-modulated signal in another fre-

quency band for establishing a frequency-modulated intermediate frequency signal of substantially different frequency, a pair of detector elements, a discriminator-type coupling circuit operative at said different frequency and connected between the output terminals of said intermediate frequency amplifier and said detector elements, a second coupling circuit operative at said predetermined frequency and connected between the output circuit of said intermediate frequency amplifier and a predetermined one only of said detector elements, the impedance-versus-frequency characteristic of each of said coupling circuits being such that they have substantially no effect on the detection process for frequencies other than at the said intermediate frequencies at which they are operative, and an audio frequency output circuit having fixed connections to said detector elements for deriving an audio frequency output from both detector elements during the reception of frequency-modulated signals, but only from said predetermined detector element during the reception of amplitude-modulated signals.

3. In a radio receiver of the superheterodyne type, a frequency converter system, radio frequency circuits for supplying either amplitude-modulated or frequency-modulated signals to said converter system, said converter system including a plurality of selectable circuits for conditioning said converter to supply a first intermediate frequency signal in response to frequency-modulated signals, and to supply a different intermediate frequency signal in response to amplitude-modulated signals, a detector circuit including a pair of detector elements, means including at least one circuit tuned to said first intermediate frequency for supplying said frequency-modulated intermediate frequency signal to both of said detector elements in substantially balanced relation, means comprising a circuit tuned to said different intermediate frequency and operatively connected to only one of said detector elements for applying said amplitude-modulated intermediate frequency signal thereto, and an output circuit having fixed connections to said detector elements for deriving a detected signal from both elements during the reception of frequency-modulated signals and for deriving a detected signal from said one element during the reception of amplitude-modulated signals.

4. In a combination amplitude- and frequency-modulation radio receiver, a switchless detector circuit, comprising a pair of detector elements, an intermediate frequency transformer operative at one frequency and having one tuned secondary winding and two untuned secondary windings, a connection between one of said untuned windings and one of said detector elements, a connection between the other of said untuned windings and the other of said detector elements, means for connecting said tuned winding in a circuit which is common to both of said detector elements, a second intermediate frequency transformer operative at a substantially different frequency and having a tuned secondary winding, said last-mentioned tuned winding being connected in a circuit which is common to only one of said detector elements and its associated untuned winding, all of the aforesaid connections being fixed and being free of any associated switching means, and means for supplying an amplitude-modulated signal to said last-mentioned transformer and for alternatively supply-

ing a frequency-modulated signal to said first-mentioned transformer.

5. In a radio receiver of the superheterodyne type, a frequency converter system, radio frequency circuits for supplying either amplitude-modulated or frequency-modulated signals to said converter system, said converter system including a plurality of selectable circuits for conditioning said converter to supply one intermediate frequency signal of a nominal center frequency in response to frequency-modulated signals, and to supply a different intermediate frequency signal of a substantially different frequency in response to amplitude-modulated signals, a switchless fixed-circuit intermediate frequency transformer having a plurality of windings tuned to said different frequencies for transferring frequency-modulated signals at said one intermediate frequency and amplitude-modulated signals at said different intermediate frequency, and a switchless fixed-circuit detector operative at said one intermediate frequency to detect frequency-modulated signals and operative at said different intermediate frequency to detect amplitude-modulated signals.

6. In a radio receiver of the superheterodyne type, a frequency converter system, radio frequency circuits for supplying either amplitude-modulated or frequency-modulated signals to said converter system, said converter system including a plurality of selectable circuits for conditioning said converter to supply a first intermediate frequency signal in response to frequency-modulated signals, and to supply a substantially different intermediate frequency signal in response to amplitude-modulated signals, a switchless fixed-circuit intermediate frequency transformer having a plurality of windings tuned to different frequencies for transferring frequency-modulated signals at said first intermediate frequency and amplitude-modulated signals at said different intermediate frequency, and a switchless fixed-circuit detector comprising a plurality of windings tuned to different frequencies corresponding to said intermediate frequencies, a pair of diodes and a load circuit therefor, said diodes being connected to said windings to provide balanced detection of frequency-modulated signals and single-diode detection of amplitude-modulated signals.

7. In a combination amplitude- and frequency-modulation radio receiver, a detector system including a transformer unit, said unit comprising a plurality of coils arranged in two groups and having a common support means, one of said groups comprising a pair of coils tuned to a predetermined intermediate frequency adapted for the transmission of amplitude-modulated signals, a second group of coils adapted for the transmission of frequency-modulated signals comprising a coil tuned to a higher intermediate frequency and a pair of untuned coils coupled tightly and positioned symmetrically thereto, another coil tuned to said higher intermediate frequency and positioned at a substantial distance from the first mentioned coil of said second group to insure loose coupling therebetween, and a connection between said untuned windings including one of the coils of said first group.

8. In a combination amplitude- and frequency-modulation radio receiver of the superheterodyne type, an intermediate frequency transformer unit adapted to function without switching at either of two substantially different intermediate frequencies, comprising a single primary winding of

relatively low inductance tuned to a relatively high intermediate frequency adapted for the transmission of frequency-modulated signals, a first secondary winding of relatively low inductance tuned to said relatively high intermediate frequency, a second secondary winding of relatively high inductance positioned closely adjacent to said primary winding, said second secondary winding being tuned to a relatively low intermediate frequency adapted for the transmission of amplitude-modulated signals, a pair of output terminals, and means for connecting said tuned secondary windings in series therebetween.

9. In a combination amplitude- and frequency-modulation radio receiver of the superheterodyne type, an intermediate frequency transformer unit adapted to function without switching at either of two substantially different intermediate frequencies, comprising a single primary winding of relatively low inductance tuned to a relatively high intermediate frequency adapted for the transmission of frequency-modulated signals, a first secondary winding of relatively low inductance tuned to said relatively high intermediate frequency and overcoupled to said primary winding to afford wide-band transfer of said frequency-modulated signals, a second secondary winding of relatively high inductance tuned to a relatively low intermediate frequency adapted for the transmission of amplitude-modulated signals, said last-mentioned winding being tightly coupled to said primary winding, said primary winding functioning substantially as an untuned winding at said lower intermediate frequency thereby to afford relatively narrow-band transfer of said amplitude-modulated signals, a pair of output terminals, and means for connecting said tuned secondary windings in series therebetween.

10. A radio receiver as claimed in claim 9, wherein said intermediate frequency transformer is characterized in the provision of means for damping at least one of the low inductance windings.

11. A radio receiver as claimed in claim 8, wherein said intermediate frequency transformer is characterized in that the tuning capacity associated with the said high-inductance secondary winding is relatively large, thereby effectively to by-pass said winding for currents of said relatively high frequency.

12. In a radioreceiver, a detector circuit adapted to operate selectively and without switching upon signals of predetermined and substantially different characteristics, comprising a pair of diodes, a pair of load impedances therefor, a signal input circuit, a discriminator-type input circuit, means for supplying an amplitude-modulated signal of predetermined carrier frequency to said signal input circuit, means for supplying a frequency-modulated signal of substantially different carrier frequency to said discriminator-type input circuit, fixed connections for operatively interconnecting said discriminator-type input circuit, said diodes and said load impedances to function as a frequency detector circuit during the reception of frequency-modulated signals, and fixed connections operatively interconnecting said signal input circuit, a predetermined one of said diodes and a predetermined one of said load impedances to function as an amplitude-modulation detector circuit during the reception of amplitude-modulated signals.

13. In a radio receiver of the class described, a combination switchless frequency- and ampli-

tude-modulation detector circuit, comprising a pair of space discharge devices, frequency-discriminating means operative during the reception of frequency-modulated waves for applying frequency-modulated signals having a predetermined center-frequency to both of said devices, fixed circuit means operative during the reception of amplitude-modulated waves for applying amplitude-modulated signals of substantially different frequency to only one of said devices, a first load impedance having fixed connections to said one device, a second load impedance having fixed connections to the other of said devices, said load impedances, said space discharge devices and said frequency-discriminating means being interconnected to provide balanced detection of frequency-modulated signals, means for deriving a signal from both of said load impedances during the reception of frequency-modulated signals, and means for deriving a signal from said first load impedance during the reception of amplitude-modulated signals.

14. A detector operative to convert both frequency-modulated carrier waves and amplitude-modulated carrier waves into audio-frequency waves, said detector comprising two rectifiers, a first transformer means for transmitting frequency-modulated waves to said rectifiers differentially, said first transformer means including a primary and two secondary windings, said secondary windings being connected in series and to said rectifiers individually, phase-shifting means operative in response to frequency variations of the frequency-modulated wave for correspondingly unbalancing the voltage applied to

said rectifiers, and a second transformer for transmitting amplitude-modulated waves into a rectifying circuit including at least one of said rectifiers, said second transformer being tuned to the frequency of the amplitude-modulated wave and including a secondary winding interposed conductively between said first-mentioned secondary windings and in series therewith, said last mentioned secondary being characterized by low impedance to the frequency-modulated waves.

15. A detector operative to convert both frequency-modulated carrier waves and amplitude-modulated carrier waves into audio-frequency waves, said detector comprising two rectifiers, a first transformer means for transmitting frequency-modulated waves to said rectifiers differentially, said first transformer means including a primary and two secondary windings, said secondary windings being connected in series and to said rectifiers individually, phase-shifting means operative in response to frequency variations of the frequency-modulated wave for correspondingly unbalancing the voltage applied to said rectifiers, and a second transformer for transmitting amplitude-modulated waves into a rectifying circuit including at least one of said rectifiers, said second transformer being tuned to the frequency of the amplitude-modulated wave and including a secondary winding in parallel with a tuning condenser, said last-mentioned secondary winding being interposed conductively between said first-mentioned secondary windings and in series therewith.

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