

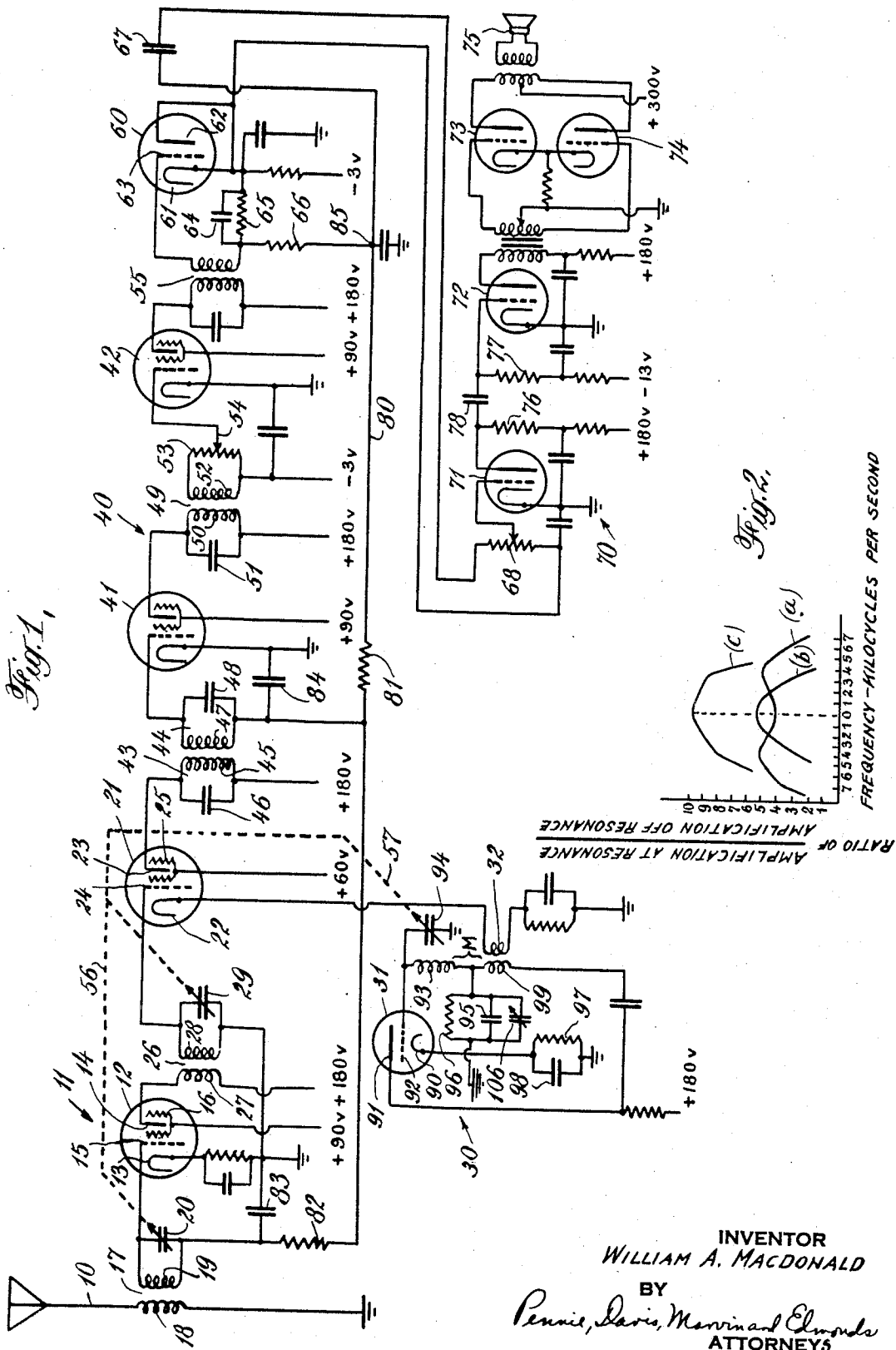
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WAVE SIGNALING SYSTEM

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WAVE SIGNALING SYSTEM

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Original application February 13, 1931, Serial No. 515,528, now Patent No. 1,881,235, dated October 4, 1932. Divided and this application March 14, 1932, Serial No. 598,641, and in Canada November 13, 1931

5 Claims. (Cl. 179—171)

This invention relates to radio signaling and more particularly to radio receivers of the superheterodyne type. This application is a division of my copending application Serial No. 515,528, filed February 13, 1931, and issued October 4, 1932 as United States Patent 1,881,235.

The principal objects of this invention are to obtain in a superheterodyne type of radio receiver, high sensitivity, selectivity, uniformity of amplification, freedom from cross-talk and interfering noises and whistles and negligible radiation of oscillations, over a wide range of frequency.

The usual superheterodyne receiver arrangement comprises an antenna and ground, or a loop antenna, a radio-frequency amplifier provided with signal selecting circuits, a modulator or first detector, a local oscillator for producing local oscillations which are combined with the incoming carrier signal frequency at the modulator to produce a new carrier signal wave of intermediate frequency, an intermediate frequency amplifier, a second detector for producing the modulation component of the intermediate frequency waves, an audio-frequency amplifier, and a signal translating or sound producing system.

It is to be preferred that the radio-frequency system be highly selective, by virtue of which extraneous signals are highly attenuated, so that the tendency toward undesired "beats" in the modulator is further reduced.

An important feature of the invention is the provision of an intermediate frequency amplifier which selectively and uniformly transmits the intermediate carrier frequency and the associated sidebands. The intermediate frequency amplifier comprises a plurality of vacuum tube amplifier stages coupled by an arrangement of coupling circuits which act to provide the above noted desirable transmission characteristic. One of the interstage coupling circuits comprises a plurality of syntonously tuned circuits coupled by a degree of coupling greater than optimum, whereby the transmission of that particular coupling system is characterized by resonances sufficiently spread to provide a transmission band which readily transmits all the frequencies of sidebands. Since this type of coupling system provides a somewhat decreased transmission over a range of frequencies between the resonances, other of the interstage coupling systems are proportioned to have a single resonance peak which lies between the resonance peaks of the first-mentioned coupling system, whereby the cumulative effect upon the entire intermediate-frequency

amplifier is to provide a substantially uniform transmission over the entire sideband range of frequency.

The interstage coupling systems of the intermediate-frequency amplifier which are characterized by a single resonance peak, preferably each comprise a transformer having a primary winding and a secondary winding coupled sufficiently close so that a condenser connected across one of the windings tunes the system as a whole to the intermediate frequency. It is preferable, although not essential, that the winding which is so tuned is the anode circuit, or primary winding, since the input impedance of the coupling system is thereby made relatively high and great attenuation of undesired signals is obtained. The other winding of the transformer is preferably naturally resonant below the range of radio-frequency signals to be received, that is, it is capacitively reactive to frequencies in the broadcast range.

A feature of the intermediate-frequency transformer construction is the adjustment of the voltage step-up ratio to a desired value. This involves providing the proper number of secondary turns to give the desired ratio, while at the same time maintaining the natural resonance of the winding at a desired value below the tuning range of frequency, by furnishing the necessary effective capacity. To secure this required effective capacity a proper "form factor" should be chosen for the winding which will provide a distributed winding capacity of the desired value; if necessary, the winding capacity may be supplemented by an external or added capacity.

The combination of a sharply selective radio-frequency amplifier and the intermediate-frequency amplifier having the broad, uniform, transmission characteristic is particularly advantageous, since it permits a moderate amount of "mistracking" of the received signal frequency and of the local oscillator frequency without seriously impairing the quality of transmission through the intermediate-frequency amplifier.

The above and other features will more fully appear from the following detailed description when read in conjunction with the drawings, of which:

Fig. 1 illustrates a superheterodyne radio receiver the component electrical units of which are arranged in accordance with this invention;

Fig. 2 illustrates transmission characteristics

of the intermediate-frequency amplifier and of portions thereof.

Fig. 1 illustrates a complete superheterodyne receiver embodying features of the present invention. The receiver includes an antenna circuit 10 coupled to a radio-frequency amplifier designated in general as 11. The radio-frequency amplifier 11 comprises a vacuum tube amplifier 12 of the four-electrode, or "screen-grid" type, which comprises a cathode 13, an anode 14, a control electrode 15, and a "screen-grid" 16 partially surrounding the anode. The amplifier tube 12 is coupled to the antenna through a radio-frequency transformer 17, the primary winding 18 of which is connected in the antenna circuit and the secondary winding 19 of which is connected to the grid 15 of the amplifier 12. The coupling transformer 17 is tuned to the signal frequency by means of a variable condenser 20 shunted across the secondary winding 19.

The output of amplifying tube 12 is coupled to a vacuum tube modulator tube 21, also of the four-electrode type, comprising a cathode 22, an anode 23, a control electrode, or grid, 24, and a screen-grid 25. The grid, or input circuit, of the modulator is coupled to the anode of the radio-frequency amplifier 12 by a radio-frequency transformer 26, the primary winding 27 of which is connected to the anode 14 and the secondary winding 28 of which is connected to the grid 24. The coupling transformer 26 may be similar to the antenna circuit transformer 17, and is similarly tuned by a variable condenser 29 shunted across the secondary winding 28.

The receiver is provided with a local oscillator system 30 comprising a three-electrode vacuum tube 31 and associated circuit elements which are so proportioned as to cause the tube 31 to produce oscillations of a desired frequency. The oscillator system is provided with a variable tuning condenser 94, and an output coil 32 which is connected in the input circuit of the modulator 21 by virtue of its connection between the modulator cathode 22 and ground.

The anode circuit of the modulator 21 is coupled to an amplifier designated generally as 40, which is adapted to transmit a frequency band which is lower in the frequency scale than the signal frequencies transmitted by the radio-frequency amplifier. Since the frequency band transmitted by the amplifier 40 lies between the audio-frequency range and the radio-frequency tuning range, this amplifier is called an intermediate-frequency amplifier. The intermediate-frequency amplifier comprises two screen-grid vacuum tubes 41 and 42 which are the same type as the radio-frequency amplifying tube 12. The first intermediate-frequency amplifier tube 41 is coupled to the modulator 21 through a coupling system comprising two similar tuned circuits 43 and 44. One of these tuned circuits 43 which is connected in the anode circuit of the modulator, includes an inductance 45 and a capacity 46; and the other of the tuned circuits 44, which is connected to the grid of amplifier 41, includes an inductance 47 shunted by a capacity 48. The inductances 45 and 47 are coupled magnetically.

The second intermediate-frequency amplifier tube 42 is coupled to the first intermediate-frequency tube 41 by an intermediate-frequency transformer 49, the primary coil 50 of which is tuned by a fixed condenser 51, and the secondary winding 52 of which is shunted by a resist-

ance 53. An adjustable tap 54 connects a point of the resistance to the grid of tube 42.

The output of tube 42 is coupled to the input of a detector tube 60 by means of a coupling transformer 55 which may be similar to transformer 49. As the intermediate-frequency amplifier constitutes another feature of the invention it will be dealt with in greater detail subsequently.

The second detector 60 is of the two-electrode type commonly known as a Fleming valve; although it is shown in form as a three-element tube having a cathode 61, a plate 62 and a grid 63, the cathode and plate are connected together, thereby placing the plate at the cathode potential, so that the tube is in effect a two-electrode detector having a cathode and an anode, the grid acting as an anode in this case. The input of the detector is coupled to the output of the intermediate-frequency amplifier by a connection between the high potential end of the secondary of transformer 55 and the anode (in this case the grid) of the detector and by a connection from the low potential end of the said secondary winding, through a resistance 65, to the cathode. The resistance 65 is shunted by a condenser 64 for providing a low impedance path for the intermediate frequency signals around resistance 65.

An audio-frequency amplifier, designated generally as 70 is connected to the detector circuit in the following manner: A resistance 66 is connected at one end to the point between resistance 65 and the secondary winding of transformer 55. The other end of resistance 66 is connected through a blocking condenser 67 to one end of a potentiometer, or tapped resistance 68, the other end of which is connected to the cathode 61 of the detector. The input potential for the audio amplifier is the voltage between the low potential end of resistance 68 and the tap.

The audio-frequency amplifier 70 comprises three stages of amplification. The first two stages include respectively amplifying tubes 71 and 72, resistance coupled in tandem in a conventional manner by shunt resistances 76 and 77 and blocking condenser 78. The output of tube 72 is coupled to the last audio amplifying stage, which comprises a pair of tubes 73 and 74 connected in the well-known push-pull relation. The output of the push-pull stage is coupled to a loud speaker 75.

The receiver is adapted to be tuned by a uni-control arrangement; this is effected by 130 operating variable condensers 20, 29, and 94 from a single shaft; this operation is represented by the dotted lines 56 and 57.

The sources of operating potentials such as the filament heating sources and the grid, screen-grid and anode potentials, are not shown in the drawing. These potentials may be supplied by any of the well-known methods. There are indicated in the drawing potentials which are well adapted for application to the various leads; these potentials are given with respect to ground potential.

For the purpose of automatically controlling the strength of the signal current delivered to the audio amplifier, there is provided a volume controlling system which automatically regulates the amplification of the receiver so that the detected, or audio, signals remain substantially uniform. The volume controlling arrangement is of the type described in a paper pre-

sented before the Institute of Radio Engineers by H. A. Wheeler and published in pages 30-34 of the Proceedings of the Institute of Radio Engineers, January, 1928. The system comprises a connection 80 extending from the lower end of resistance 66 to the control electrode 15 of radio-frequency amplifier 12 and to the control electrode of intermediate-frequency amplifier 41. The connection 80 is led to the control electrodes of amplifiers 12 and 41 by connections to the low-potential ends of the grid circuit windings 19 and 47, respectively, of the associated coupling systems. There are included in the connection 80 resistances 81 and 82, the function of which will be more fully explained later. For the purpose of keeping the grid potential from the cathodes, but still enabling the grid circuits to be completed, there are provided blocking condensers 83 and 84. The above-described automatic volume control system is disclosed and claimed in the copending application of Harold A. Wheeler, Serial No. 203,879, filed July 7, 1927 and in his U. S. Patent 1,879,863, issued Sept. 27, 1932.

The receiver is provided with a number of resistors, some of which furnish biasing potentials for vacuum tube grids, and others of which are inserted in the leads supplying operating potentials to the electrodes of the tubes. There are also provided by-passing condensers at advantageous points. These elements contribute toward good operation; and since they are in general use and are well-known in the art, no further details are given here.

The following is a brief description of the operation of the receiver: A radio signal received by the antenna 10 is selected in the well-known manner by the selective circuits of coupling transformers 17 and 26, which are tuned to the same frequency. The modulated carrier signal, after being amplified in the radio-frequency amplifier is impressed upon the grid circuit of the modulator 21. The oscillator 30 is tuned in conjunction with the selective circuits 17 and 26 to apply to the modulator a frequency which differs from the signal frequency by a desired amount. The oscillator frequency may be either greater than, or less than, the radio carrier frequency, but it is preferably greater than the radio frequency. By virtue of the well-known phenomenon of modulation, there is produced in the output of the modulator a new carrier frequency which is equal to the difference between the frequency of the received radio signal and the local oscillator frequency. This difference in frequency is commonly known as the intermediate carrier frequency, since it is lower than the radio-frequency of the received signal but is above the audible range. The intermediate carrier frequency has associated with it the side band frequencies with which the signal is modulated.

The selective coupling circuits of the intermediate-frequency amplifier are adjusted to freely transmit the intermediate carrier-frequency and the associated side bands and to effectively exclude all other signals. The amplified output of the intermediate frequency amplifier is impressed upon the two-element detector 60, in the output of which there appears the modulation component, that is, the audio-frequency signals. The audio-frequency signals are amplified in the audio-frequency amplifier in the well-known manner and are converted into sound by the

loud speaker 75 connected to the output of the audio amplifier.

The following is a brief outline of the operation of the volume controlling circuit:

When a modulated carrier signal is impressed upon the two-electrode detector, there appears across resistances 65 and 66 a voltage having two components, one an audio-frequency component and the other a direct current component. The direct current component is proportional to the strength of the received carrier signal. An increase of the received carrier signal has the effect of increasing the voltage across resistances 65 and 66, that is, of causing the potential of point 85 to become more negative with respect to ground. Since the potential at point 85 is impressed through the connection 80 upon the grids of amplifying tubes 12 and 41, the effect is to render these grids more negative when the signal strength increases. Likewise when the signal strength decreases, the grids of amplifiers 12 and 41 become less negative. Due to the variation of the potential of the amplifier grids in this manner, attendant upon the variation of the received signal strength, the amplification increases when the signals are weak and decreases when the signals are strong, so that the net effect is to maintain the signals at the second detector substantially uniform in strength. The audio-frequency component of the detected signal is prevented from appearing at the grids of amplifiers 12 and 41 by virtue of the filtering action of resistances 81 and 82 and condensers 84 and 83.

Referring now specifically to the oscillator system, it comprises a three-electrode oscillating vacuum tube 31 having a cathode 90, an anode 91 and a control grid 92. The grid circuit includes an oscillatory circuit comprising an inductance 93 and a variable capacity 94. The inductance 93 is connected at one end to the grid 92 and at the other end through the parallel arranged capacity 95 and resistance 96 to ground. There is shunted across capacity 95, a small variable capacity 106 for enabling a proper adjustment to be obtained. The cathode is grounded through a parallel arranged resistance 97 and capacity 98. The function of the resistance 97 is to provide a biasing potential for the grid.

For the purpose of establishing the condition of oscillation, the anode 91 is connected through a coil 99 to the point between the grid circuit inductance 93 and capacity 95. The coil 99 is so situated relative to coil 93 that a substantial degree of inductive coupling exists between the two coils. By virtue of this circuit arrangement of the oscillator there exist in common with both the grid and the anode circuits of the oscillator, the capacity 95 and the mutual inductance M of coils 93 and 99. These common, or mutual impedances are made sufficiently large so that the tube 31 is set into oscillation; and the frequency of the oscillation is the frequency at which the circuit including inductance 93 and capacities 94 and 95 is resonant.

Since the voltage across the capacity 95 is at least at the highest frequencies of the range over which the oscillator is tuned, and is greatest at the lowest oscillator frequency, it follows that the effect of this capacity in producing an oscillating voltage is greater at the lower frequencies than at the higher frequencies. It fur-

the follows that the effect of the mutual impedance M in producing an oscillatory voltage is greater at high frequencies than at lower frequencies. The use of the above described oscillator in combination with a radio-frequency amplifier having an output characteristic which is complementary thereto is more fully disclosed and claimed in my aforesaid Patent 1,881,235, the application of which this is a divi-

sion. The intermediate-frequency amplifier is so designed that there is provided a fairly uniform transmission of all the frequencies of the side bands of the intermediate-carrier frequency, and furthermore, means are provided for insuring that no frequencies other than those of the desired signal are transmitted to any substantial degree.

The coupling system which couples the output of the modulator to the input of the intermediate-frequency amplifier is of the double-tuned type, that is, it comprises a pair of synchronously tuned circuits coupled electromagnetically, one of the tuned circuits 43 being situated in the modulator anode circuit and the other tuned circuit 44 in the grid circuit of the first intermediate-frequency amplifier. The degree of magnetic coupling is preferably somewhat over-optimum so that the transmission band of this coupling system is somewhat broadened by virtue of the pair of slightly spaced resonant peaks which it is well known are obtained by this arrangement. The frequency spread of the resonance peaks should preferably be about equal to or greater than the frequency range of the side bands with which the intermediate carrier-frequency is modulated.

The two succeeding intermediate-frequency transformers 49 and 55 are preferably identical, although this identity is not essential. These transformers are so constructed that there exists a close electromagnetic coupling between their primary and secondary windings, whereby the coupling system tunes as a whole at the resonant frequency of the winding which is shunted by the condenser. Each of the two transformers 49 and 55 is characterized by a single resonance, rather than a double resonance such as is obtained from the first intermediate-frequency coupling system.

There is an advantage from a commercial standpoint, as well as from a transmission standpoint, in providing one coupling system of the double-resonance type and the other coupling system of the single-resonance type. It has been found difficult to adjust the double-resonance system commercially so that the two resonance peaks are properly spaced and are of approximately the same height. Hence, it is desirable that there be only one of these double-resonance systems. The advantage from the transmission standpoint is that the single-resonance of the transformers 49 and 55 can be made to lie midway between the peaks of the double-resonance coupling system, whereby the over-all transmission provided by the intermediate frequency amplifier is substantially uniform over the side band range of frequencies.

Curve "a" of Fig. 2 illustrates the transmission-frequency characteristic of the double-resonant system. The ordinates represent the ratio of the gain at resonance to the gain near resonance and the abscissae represent frequencies in kilocycles per second. The frequency

marked "zero" represents the intermediate carrier-frequency, and the abscissae on either side of the carrier-frequency are the frequencies of the side bands.

Curve "b" of Fig. 2 represents the transmission-frequency characteristic of the transformers 49 and 55. The combination of the two types of coupling system cooperates to produce a transmission characteristic of the type illustrated in curve "c" of Fig. 2. The intermediate frequency amplifier can be readily constructed so that the over-all response at a side-band frequency of four kilocycles from the intermediate carrier-frequency is as much as 80% of the response at the carrier-frequency.

By providing a relatively flat-topped response characteristic of the type of curve "c", slight mistracking between the oscillator frequency and radio-frequency carrier frequency, that is, variations in the difference between the radio-frequency carrier and oscillator frequency, cause no serious change in the over-all sensitivity over the important side-band range.

In considering an intermediate-frequency amplifier of the type under discussion including coupling systems utilizing double tuning between the output of one tube and the input of the second tube, together with coupling systems utilizing but a single resonant circuit tuned to the intermediate frequency, it has been found preferable, although not essential, to arrange the coupling systems utilizing but a single physically resonant circuit so that the resonant circuit is connected between the cathode and anode of the preceding amplifying tube rather than between the cathode and control grid of the succeeding tube. Where the very highest order of performance is desired, it is usually desirable to connect the coupling systems of adjacent stages in this way, for such connections tend to attenuate voltages of signal frequency more rapidly than when the tuned circuit of the resonant unit transformer is connected between the cathode and control grid.

It is usually desirable to tune the primary circuit of transformer 55 rather than the secondary circuit because this transformer operates into a two-electrode type of detector, namely, detector 60. This form of detector imposes a shunt load on the transformer, so that if the secondary circuit were tuned instead of the primary circuit, the effect would be to materially impair the resonance characteristic of this transformer. By tuning the primary circuit and employing a step-down transformation ratio, the impedance of the secondary circuit may be arranged to match the impedance of the system into which it feeds, thus producing the most efficient condition of operation.

It is important in the design of the intermediate-frequency coupling transformers that the natural period of the winding which is not tuned by a physical capacity shall have such electrical constants that it will be naturally resonant at a frequency lower than the lowest broadcast frequency to be received. The factors which determine the resonant frequency of this winding are: Its natural inductance, the distributed capacity of the winding and the capacity of the devices connected across its terminals. All of these elements must be considered in the selection of the proper resonant frequency such that the winding is always capacitively reactive to frequencies in the broadcast band.

If this precaution is not followed and the untuned winding is arbitrarily chosen so that its natural period falls within the broadcast band, then it has been found that there is usually a high order of amplification to broadcast frequencies, and voltages of signal frequency which would normally be of small magnitude produce undesirable heterodyne whistles in the receiver.

The following values have been found satisfactory in the design of an intermediate-frequency coupling transformer, although all of the values may be modified within wide limits and still be within the scope of the present invention:

Intermediate frequency=175 kilocycles per second

Inductance of primary winding=8.99 millihenries

Inductance of secondary winding=5.16 millihenries

Coupling coefficient between primary and secondary windings=37%

Capacity across primary winding=100 micro-microfarads approx.

The above inductance values are obtainable by winding on a one-half inch core in bobbins one-quarter inch wide, a primary coil of 800 turns of No. 38 double silk-covered copper wire and a secondary winding of 600 turns of No. 38 double silk covered copper wire. The bobbins containing the primary and secondary coils are coaxially placed side by side and are enclosed by a shielding can of 1 $\frac{3}{8}$ -inch diameter.

When the transformer is constructed in accordance with the above specification the resonant period of the secondary winding is about 350 kilocycles per second. This value of the resonant frequency is not necessarily the best value for all receivers; the best value for the resonant frequency will depend somewhat upon the particular design of the receiver. If it be desired to make the resonant period higher than the value of about 350 kilocycles per second, the number of turns on the secondary winding should be somewhat less than the value given in the above table; or, on the other hand, if it be desired to reduce the number of secondary turns and still maintain the resonant frequency at about 350 kilocycles per second, the coil should be constructed to have a higher distributed capacity.

It has been found that greater sensitivity is required in certain localities than in other localities. To enable the receiver to meet any of the required conditions of sensitivity, one of the intermediate-frequency transformers is provided with an impedance shunted across its secondary winding so that the sensitivity may be adjusted to any definite value. This is the resistance 53 of Fig. 1 having the adjustable tap 54. It is preferable to provide two or more definite taps having a switch for selecting any one of them, rather than to employ a potentiometer of the slide-wire type.

I claim:

1. In a carrier current amplifier, a plurality of vacuum tubes and a plurality of coupling systems for coupling said tubes in tandem, one of said coupling systems being doubly resonant

within the transmitting band of frequencies and another of said systems being singly resonant within said transmitting band, said single resonance being located at a frequency between said double resonances.

2. In a carrier current amplifier for amplifying a carrier signal and its associated sidebands, a plurality of vacuum tubes and a plurality of coupling systems for coupling said tubes in tandem; one of said coupling systems being resonant at two frequencies which are approximately the extreme frequencies of the side bands which are to be amplified, and another of said coupling systems being resonant approximately at the frequency of said carrier signal, whereby the over-all response of said amplifier is substantially uniform over the sideband range of frequency.

3. The combination in a modulated carrier current amplifier having a plurality of vacuum tubes and a plurality of coupling systems for coupling said tubes in tandem, of a first of said coupling systems comprising a pair of syntonously tuned circuits coupled by a coupling impedance which is sufficiently over-optimum to cause said system to be resonant at two frequencies which are separated sufficiently to cause said system to transmit the band of frequencies between and including said resonances, with a second of said coupling systems comprising a transformer having primary and a secondary winding relatively closely coupled, one of said windings being shunted by a condenser which tunes and second coupling systems to a frequency between the two resonant frequencies of said first coupling system.

4. In an intermediate carrier-frequency amplifier, in combination, a first coupling system comprising a pair of coupled circuits syntonously tuned to the same frequency, the degree of coupling being slightly over-optimum, whereby said first coupling system is characterized by two resonances situated in the frequency range approximately equi-distant from and on either side of said carrier frequency, and a second coupling system comprising a pair of coupled circuits having a relatively high degree of coupling therebetween, said second coupling system being tuned as a unit at said carrier frequency.

5. In an intermediate carrier-frequency amplifier, in combination, a first coupling system comprising a primary and a secondary winding coupled together magnetically, each of said windings being shunted by capacity of proper value to cause each of said windings to be naturally resonant at the same frequency, the degree of the magnetic coupling being slightly over-optimum whereby said first coupling system is characterized by two resonances situated in the frequency range approximately equi-distant from and on either side of said carrier frequency, and a second coupling system comprising a primary and a secondary winding relatively closely coupled magnetically and a capacity in shunt with one of the windings of said second coupling system, of proper value to tune the entire second coupling system at said carrier frequency.

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