June 20, 1939. N. P. CASE 2,163,234

AUTOMATIC FREQUENCY CONTROL

Filed April 3, 1936 2 Sheets-Sheet 1

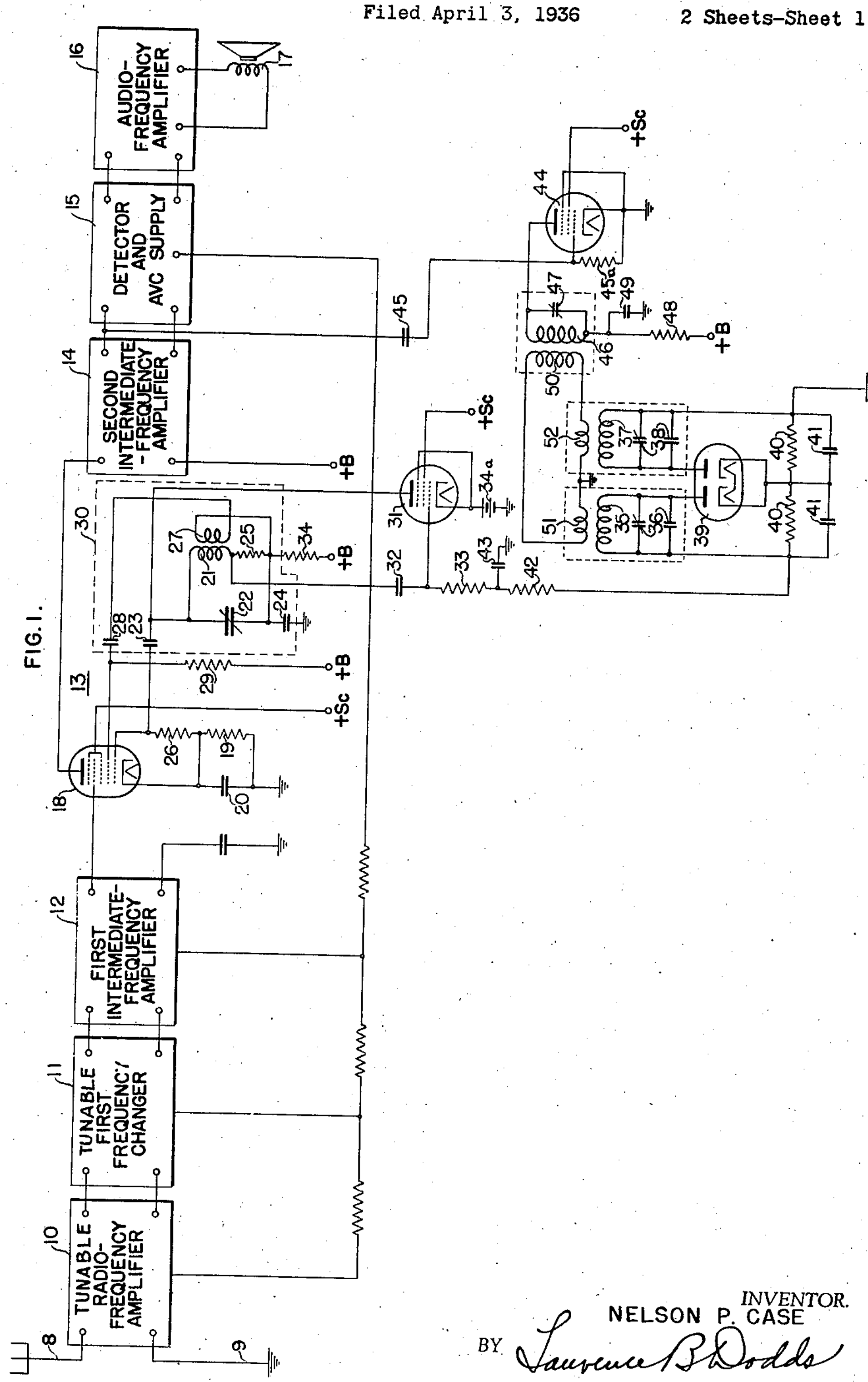

FIG. 1.

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FIG. 4.

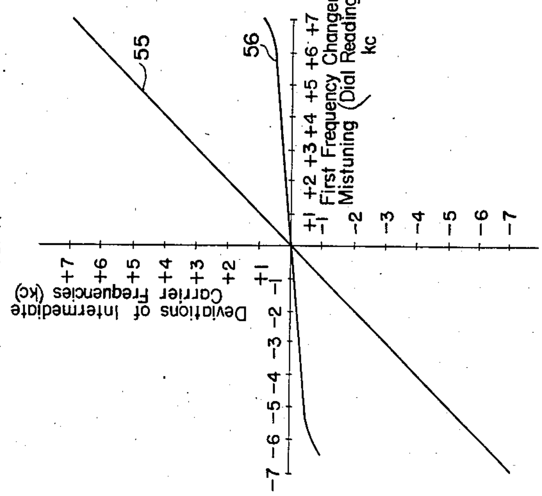


FIG. 3.

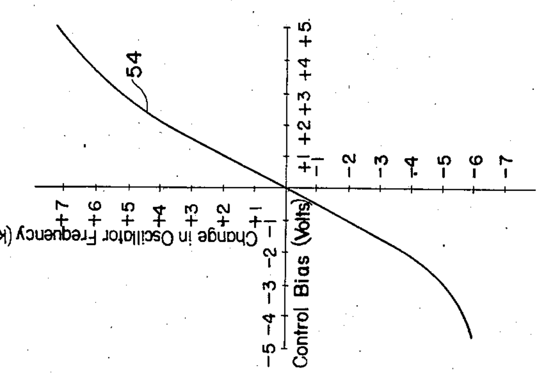
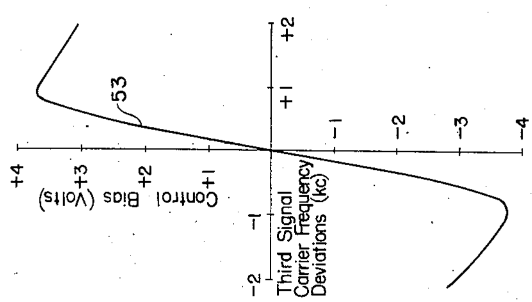


FIG. 2.



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UNITED STATES PATENT OFFICE

2,163,234

AUTOMATIC FREQUENCY CONTROL

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Application April 3, 1936, Serial No. 72,532

4 Claims. (Cl. 250—20)

This invention relates to selective modulated-carrier signaling systems of the superheterodyne type, and particularly to the automatic control of the frequency derived by the frequency-changing means of such a system.

According to conventional radio broadcasting practice, each program is transmitted on a carrier frequency having two sidebands of modulation usually extending 5 or more kilocycles on either side thereof. The various broadcasting stations are allotted different carrier frequencies which, in the present practice, are uniformly spaced throughout the broadcast frequency range, the spacing of adjacent carrier frequencies usually being 10 kilocycles.

In a conventional superheterodyne receiver, there is included a frequency changer tunable over a wide range of frequencies for deriving from any desired modulated-carrier signal within an equal related range a second modulated-carrier signal normally having a predetermined carrier frequency. An intermediate-frequency channel is coupled to the output of the frequency-changing means, designed selectively to pass this predetermined carrier frequency and its sidebands of modulation. For optimum selectivity and fidelity of reception the frequency of the modulation carrier developed by the frequency changer should be located substantially at the center frequency of the intermediate-frequency channel, that is, it should always be maintained at the said predetermined frequency. As is well understood in the art, however, any mistuning of the frequency-changing means, due to incorrect tuning adjustments by the operator, to drift in the frequency of the oscillations produced in the frequency changer, or to other causes, produces deviations in the carrier frequency of the signal developed by the frequency-changing means from its normal or predetermined frequency, that is, from the mean frequency of the intermediate-frequency channel, thereby impairing the selectivity and fidelity of reception to the extent of such deviations.

Certain arrangements have heretofore been devised in attempts to control the frequency of the signal derived by the frequency-changing means, thereby automatically to reduce these deviations. Satisfactory automatic frequency control for reducing the mentioned deviations, however, has various operating characteristics which, heretofore, have not been procured. Among these characteristics are the following: The intermediate carrier frequency, when under control, should be held within relatively narrow limits of deviation, for example, ±1000 cycles from the desired predetermined frequency. The automatic control action should be effective for mistuning of the frequency changer to an extent of the order of, but less than, the frequency separation of the signals in the broadcast range, and ineffective or relaxed, or preferably reversed in its action, for greater extents of mistuning, in order that the frequency changer may thereupon immediately be adjusted to receive the next adjacent signal in the range. Moreover, the frequency control action should have equal sensitivity and range throughout the range of frequencies to which the system is tunable, and such control action should be independent of the signal strength of any usable received signal, as well as independent of the ordinary variations in the operating voltages utilized for the system. Various other characteristics must be achieved in order that the system shall be satisfactory from the standpoint of stability of operation and shall be commercially feasible in its construction, as will be more apparent hereinafter.

The object of the present invention, therefore, is to provide an improved automatic frequency control for the frequency changer of a modulated-carrier signaling system embodying one or more of the desirable characteristics set forth above.

In accordance with the present invention, there is provided a selective modulated-carrier signaling system which comprises a tunable frequency-changing means, including a frequency-determining circuit, for deriving from any selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation a second modulated-carrier signal having a carrier normally of a predetermined frequency of an order of magnitude in kilocycles not greater than 100. The derived signal is subject to frequency deviations within narrow limits upon mistuning of the frequency-changing means. This tunable frequency-changing means may comprise a single tunable frequency changer or two or more frequency changers coupled in cascade only the first of which is tunable. Frequency-discriminating means are provided which are selectively responsive to predetermined frequencies displaced above and below the predetermined frequency by an amount of the order of one kilocycle and at least a major fraction of one per cent. of the derived intermediate frequency. Frequency-correcting means are coupled to the frequency-discriminating means for adjusting the frequency-determining circuit to reduce the deviations of the second signal-carrier frequency in a predetermined ratio of the order of 10:1. The reactive constants of the frequency-determining circuit, the reactive constants of the frequency-discriminating means, and the response characteristic of the frequency-correcting means are so related that deviations of the second signal-carrier frequency effected by mistuning of the frequency-changing means beyond a predetermined amount of the order of, but less than, the predetermined frequency separation effect relaxation of the frequency-correcting means.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings, Fig. 1 is a circuit diagram of a complete superheterodyne radio receiver, partly schematic, embodying the present invention, while Figs. 2, 3 and 4 are graphs representing certain operating characteristics of the receiver, to aid in the understanding of the invention.

Referring now more particularly to Fig. 1 of the drawings, there is shown schematically a superheterodyne receiver embodying the present invention in a preferred form. In general, the receiver includes a tunable radio-frequency amplifier 10 connected to an antenna 8 and ground 9. Connected in cascade with the radio-frequency amplifier 10, in the order named, are a first frequency changer 11, a first intermediate-frequency amplifier 12, a second frequency changer, indicated generally at 13, a second intermediate-frequency amplifier 14, a detector and automatic amplification control or AVC. supply 15, an audio-frequency amplifier 16, and a sound reproducer or loud-speaker 17.

The first frequency changer 11 includes a tunable oscillator and first modulator, the oscillator preferably being tuned conjointly with the tuning of the selective circuits in the radio-frequency amplifier 10 by unicontrol mechanism, in the conventional manner. The second frequency changer 13, which is shown in detail and will be hereinafter further described, is not tunable in the ordinary sense but its frequency may be adjusted within narrow limits by the frequency control provided in accordance with the present invention.

Automatic amplification control bias voltage developed at the AVC. supply 15 may be applied by way of suitable resistors, as shown, to one or more of the radio-frequency amplifier, frequency changer, and first and second intermediate-frequency amplifier, in accordance with established practice. It will be understood that the several parts of the system which are illustrated schematically in the drawings may be conventional in their construction and operation, the details of which are well-known in the art, rendering description thereof unnecessary herein.

Neglecting for the moment the particular operation of the parts of the system involved in the present invention, which is hereinafter described in detail, the system above described includes all the features of a conventional triple detection superheterodyne receiver. The operation of such a superheterodyne receiver being well understood in the art, detailed explanation thereof is, therefore, deemed unnecessary. In brief, however, a desired modulated-carrier signal intercepted by the antenna is selected and amplified in the radio-frequency amplifier 10 and converted by the first frequency changer 11 to a second modulated-carrier signal at a first predetermined intermediate carrier frequency. This second signal is selected and amplified in the first intermediate-frequency amplifier 12 and is thereupon converted by the second frequency changer 13 to a third modulated-carrier signal at a second predetermined intermediate carrier frequency. The third signal is selected and amplified in the second intermediate-frequency amplifier 14 and is then converted by the detector 15 to audio frequencies of modulation which are amplified in the audio-frequency amplifier 16 and reproduced by the sound reproducer 17. Biasing potentials, developed by the AVC. supply in a well-understood manner, are supplied to control the gain of the radio-frequency amplifier, first frequency changer, and first intermediate-frequency amplifier, to maintain the amplitude of the signal output of the amplifier 14 within a relatively narrow range for a wide range of received signal amplitudes.

Referring now more particularly to the portion of the system in connection with which the present invention is employed, the frequency changer 13 comprises a pentagrid oscillator-modulator tube 18 having its signal control grid-cathode circuit coupled to the output circuit of the first intermediate-frequency amplifier 12, a suitable biasing resistor 19 and by-pass condenser 20 being included in the cathode circuit. An oscillation circuit including an inductance 21 and a condenser 22 in parallel is connected between the first or oscillator grid of the tube 18 and the cathode thereof by way of suitable coupling condensers 23 and 24. For a purpose presently to be described, a resistor 25 is included in the inductance arm of the oscillation circuit. A suitable leak resistor 26 is connected between the oscillator grid and the cathode of the tube. A feed-back inductance 27 is connected between the second grid or oscillator anode of the tube 18 and the cathode thereof by way of a coupling condenser 28 and the above-mentioned condenser 24 and is inductively coupled to the inductance 21 of the oscillation circuit. The output or anode circuit of the tube 18 is suitably connected to the input circuit of the second intermediate-frequency amplifier 14, as shown.

Proper operating voltages are supplied to the electrodes of the tube 18 from sources as indicated by +Sc for the screen supply and +B for the output and oscillator anodes, a suitable resistor 29 being included in the supply lead to the oscillator anode. A shield is preferably provided for the oscillation circuit, as indicated by the broken lines 30. The selective modulated-carrier signal receiver thus comprises a tunable frequency-changing means including a frequency-determining circuit for deriving from any selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation another modulated-carrier signal having a carrier normally of a different predetermined fequency. This predetermined frequency in accordance with the invention is of an order of magnitude not greater than 100 kilocycles. The derived carrier wave is subject to frequency deviations within narrow limits upon mistuning of the frequency-changing means.

While, in accordance with the present invention, various arrangements may be employed for adjusting the frequency of the oscillation circuit of the second frequency changer, in the present embodiment a control vacuum tube 31 is provided for this purpose. The input circuit of this tube is connected across the resistor 25 of the oscillation circuit by way of coupling condenser 32 and by-pass condenser 24. The anode circuit of the tube 31 is connected across the entire oscillation circuit. Operating voltage may be supplied to the anode of the control tube, as shown, from the source as indicated at +B, by way of resistors 34 and 25 and the inductance 21, a suitable voltage being supplied for the screen grid of the tube from the source as indicated by +Sc. The suppressor grid is connected to the cathode and the latter electrode is suitably biased, as indicated, by a battery 34a.

For developing the control bias voltage for the tube 31, a discriminating circuit arrangement is coupled to the output of the amplifier 14. The discriminating arrangement comprises a pair of resonant circuits, one including an inductance 35 tuned to a frequency adjacent to and below the second predetermined carrier frequency by condensers 36, and the other circuit including an inductance 37 tuned to a frequency adjacent to and above the second predetermined carrier frequency by condensers 38. The two discriminator circuits are individually connected to a pair of rectifiers, comprised in a double diode tube 39, provided with suitable load circuits comprising resistors 40, with by-pass condensers 41, as shown. The load circuits are connected in series, with their unidirectional voltages opposing. One terminal of the pair is grounded and the other is connected to the control grid of the tube 31 by way of series resistors 42 and 33. The resistor 42 and condenser 43 serve to filter out the modulation components which are present in the output of the diode circuits and to provide a proper time constant for the control circuit. There is thus provided for the system frequency-discriminating means selectively responsive to predetermined frequencies displaced above and below the derived predetermined intermediate frequency, in this case the second intermediate carrier frequency.

For coupling the discriminating circuits 35, 36 and 37, 38 to the output of the amplifier 14, there is provided an amplifier tube 44 having its grid-cathode circuit connected to the output circuit of the amplifier 14 by way of a suitable coupling condenser 45. A leak resistor 45a is connected between the control grid and cathode of the tube 44, and a high impedance, comprising an inductance 46 tuned to the second predetermined frequency by a condenser 47, is included in the anode circuit of the tube. Suitable operating voltages are supplied to the screen and anode of this tube from the sources indicated at +Sc and +B, respectively, the latter by way of a filter resistor 48, a by-pass condenser 49 also being included in the anode circuit, as shown.

For coupling the output circuit 46, 47 to the pair of discriminator circuits 35, 36 and 37, 38, there is provided a link circuit including in series a high impedance winding 50 relatively closely coupled to the winding 46 and a pair of low impedance windings 51 and 52 relatively closely coupled to the windings 35 and 37, respectively, and grounded at their junction. The tuned circuits 35, 36 and 37, 38 and their respective coupling coils are individually shielded, as indicated. The relative proportions of the various elements of the frequency-control means will be described in connection with the operation of the system.

Referring now to the operation of the system, when any signal is being received, voltage of the third signal frequency is supplied to the input circuit of the tube 44. Since the grid of this tube is returned directly to the cathode through the leak resistor 45a, and is isolated from any other direct-current path by the condenser 45, whenever any signal is applied to the grid a negative grid bias voltage is developed which increases with increasing signal input amplitude. Thus, the mutual conductance of tube 44, and hence its effective amplification, is greatest for weak signals and decreases as the signal strength increases. Since the plate circuit of the tube 44 includes the resonant circuit 46, 47, which is designed with a relatively high LC ratio and is tuned to the second predetermined frequency, thereby affording a high impedance at this and adjacent frequencies, the plate circuit overloads or operates beyond both its upper and lower cut-off limits for all usable signals applied to the grid during normal operating conditions of the system. Thus, whenever a useful signal is being received, a substantially constant voltage is obtained across the circuit 46, 47 regardless of variations in the amplitude of the signal, and this voltage is supplied by way of the link circuit 50, 51, 52 to the pair of circuits 35, 36 and 37, 38.

As will be described hereinafter, in order to obtain the desired frequency control it is necessary that the selective circuits 35, 36 and 37, 38 be tuned within 2 kilocycles of each other. In the preferred embodiment illustrated, these circuits are tuned at plus and minus 700 cycles from the second predetermined carrier frequency. With the circuits 35, 36 and 37, 38 tuned so closely to each other, therefore, in order to eliminate interaction between these circuits, it is necessary that they be substantially uncoupled with respect to each other. Hence, besides being shielded, as mentioned above, the circuit elements are so proportioned as to maintain the selective circuits substantially electrically independent from each other. More particularly, the impedance of the winding 50 is very large as compared with the impedances of the windings 51 and 52. For example, in the preferred embodiment the impedance of the winding 50 is of the order of 2500 times that of each of the windings 51 and 52. While this arrangement, of course, does not provide an efficient voltage transfer, a high step-down voltage ratio from the output circuit of the tube 44 to the input circuits of the double diode tube 39 is needed and this ratio is obtained with the arrangement described.

The unidirectional voltages developed across the resistors 40 are of opposite polarity so that their difference varies positively or negatively in accordance with deviations of the second predetermined carrier frequency toward the resonant frequency of one or the other of the circuits 35, 36 and 37, 38, and this voltage is applied to the control grid of the tube 31, as mentioned above. Since the input circuit of the tube 31 is connected across the resistor 25, which is in the inductance arm of the oscillation circuit associated with tube 18, the input voltage of the tube 31 lags the voltage across the oscillation circuit by approximately 90°. Therefore, the output current of this tube, which is supplied to the oscillation circuit 21, 22, also lags the voltage across the oscillation circuit by 90° and the tube 31, therefore, simulates a low power factor inductance.

The bias voltage applied to the grid of tube 31 from resistors 40, mentioned above, varies in accordance with the deviations of the frequency of the third signal, or second intermediate-frequency carrier, from its predetermined or normal frequency and thus controls the mutual conductance of the tube 31 and, hence, the amplitude of the lagging current supplied to the oscillation circuit by this tube. Thus, the apparent inductance and resonant frequency of the oscillation circuit are varied directly in accordance with the frequency deviations of the second intermediate carrier frequency from its normal predetermined value. Since the frequency of the third signal, which is developed by the frequency changer 13, is equal to the sum or difference of the frequency of the second signal developed by the frequency changer 11 and the oscillation frequency, adjustments of the latter frequency in the proper sense operate substantially to reduce frequency deviations of the third signal with respect to those of the second signal carrier frequency, in a predetermined ratio which is dependent upon the relative proportioning of the various elements of the frequency control arrangement. In the present embodiment of the invention, this proportioning is such that a ratio of control or reduction in frequency deviation of the order of 10:1 is procured. In other words, mistuning adjustments of the first frequency changer, which would tend to result in deviations of the third signal carrier frequency to an extent equal to such mistuning, are substantially compensated, the deviations of the third signal carrier frequency being reduced to approximately one-tenth this amount.

In order that the control sistem shall be effective to maintain the receiver accurately adjusted for reception of any desired signal only so long as the mistuning does not equal or exceed the frequency separation of adjacent signals, so that it will not be possible completely to skip over an adjacent signal, it is necessary that, while the control action shall be effective for all deviations of the second predetermined frequency within predetermined limits, for example ±700 cycles, resulting from a mistuning adjustment of the first frequency changer of approximately ±7 kilocycles, the control action shall be ineffective or relax, or preferably reverse, for deviations beyond these limits. These relations are obtained by virtue of selection of the resonant frequencies of the selective circuits 35, 36 and 37, 38 closely adjacent to and above and below the second predetermined carrier frequency; for example, they may be tuned to frequencies 700 cycles below and above the second predetermined frequency. Referring to Fig. 2, here frequency deviations of the third signal carrier from its normal predetermined frequency, in kilocycles, are indicated by the abscissae and the ordinates represent control bias voltages developed by the control means and applied to the tube 31. The curve 53 thus represents the frequency-response characteristics of the control system. It will be seen that this curve includes a relatively steep portion for frequencies close to the normal predetermined frequency and that the peaks of the curve are at frequencies corresponding to the resonant frequencies of the pair of selector circuits, the portions of the curve beyond the peaks returning toward the zero bias condition, that is, representing a reversal in the control action. Thus, when mistuning of the first frequency changer results in a deviation of the frequency of the third signal carrier to one side or the other of its predetermined frequency, the control action is effective to reduce these deviations in a large ratio as long as they are within the limits represented by the peaks of the curve. When, however, the mistuning is to such an extent, for example more than ±7 kilocycles, as to cause deviations of the third signal carrier beyond the limits indicated by the peaks of the curve, the control action, as shown by the outer portions of the curve, in effect reverses; that is, the selective circuits become increasingly less responsive. This latter condition, of course, results in a decrease in the correction of oscillation frequency, thereby causing still greater deviations in the third signal carrier frequency, and these greater deviations, of course, result in still less responsiveness of the selective circuits. Hence, a regenerative or snap action of the control means is effected by deviations beyond the predetermined limits, due to the effective reversal of the normal control action. Beyond these limits, therefore, the control system causes a readjustment of the frequency of the oscillation circuit toward its normal value. Under these conditions, the first frequency changer is adjusted for receiving the next adjacent carrier of the range to derive therefrom a first intermediate-frequency signal at approximately its normal frequency, and the second frequency changer and the control system will operate in the manner described above to derive a second intermediate frequency and to maintain it within the desired frequency limits.

Of special importance is the relation that this required close spacing of the peaks may be readily obtained only when the frequency control means operates at a relatively low frequency. Thus, in accordance with the preferred embodiment of the present invention, the second predetermined or normal frequency for the third signal carrier is 100 kilocycles. The approximately 1.5 kilocycle separation of the peaks referred to, therefore, represents 1.5% of the carrier frequency. That is, the displacement of the resonant frequency of each of the frequency-discriminating circuits is an amount of the order of one kilocycle and at least a major fraction of one per cent. of the second intermediate frequency. This is effected by virtue of relationships between the reactive constants of the frequency-determining circuit, whereby a very low second intermediate frequency is obtained, 100 kilocycles in the illustrated embodiment, and the reactive constants of the frequency-discriminating means which determine their detuning with respect to the second intermediate frequency, ±700 cycles in the present case. It will be here noted that if a 450 kilocycle carrier were used the same frequency separation of the peaks would be less than 0.5%. Thus, employing the lower intermediate frequency, a given percentage error in the tuning of the two selector circuits results in a substantially smaller error in the frequency separation of the resonant frequencies of these circuits with respect to the intermediate carrier frequency.

In order to obtain the desired range of control and the maximum sensitivity for a given permissible range of deviations, it is necessary that the control be responsive to all deviations within the desired limits. Hence, the maximum bias voltages applied to the control tube 31, corresponding to maximum permissible deviations of the carrier frequency of the third signal, should be maintained within the cutoff limits, that is, the limits of effective variation of the mutual conductance of this tube.

More particularly, in the system illustrated, variations in the mutual conductance of the tube 31 are effective to shift the resonant frequency of the oscillation circuit, as above explained. In Fig. 3, the curve 54 clearly shows the response of the tube 31, that is, its effect in controlling the resonant frequency of the oscillation circuit in accordance with changes in grid bias voltage applied thereto. The changes in the grid bias voltage are indicated by the abscissae of the figure and the ordinates represent the resultant changes in frequency in kilocycles of the oscillation circuit. It will be apparent from Fig. 3 that within limits of approximately ±4 volts the tube characteristic is substantially linear and well below the cutoff points of the tube. The control circuits are, therefore, so proportioned that the maximum net bias voltage supplied by the diode rectifier circuits, corresponding to maximum deviations permitted the third signal carrier from its predetermined frequency, is maintained within limits of ±4 volts, as clearly shown in Fig. 2. In other words, the control bias adjusting means is so related to the mutual conductance characteristic of the control tube that the bias voltages applied thereto, corresponding to maximum permissible deviations of the carrier frequency of the second signal, always effect operation of the control tube within both the upper and lower cutoff limits thereof.

The ultimate effects of these changes are clearly shown in Fig. 4, wherein tuning misadjustments of the first frequency changer, in kilocycles, are indicated by the abscissae, and the resultant frequency deviations of the third signal carrier frequency from the desired second predetermined frequency are indicated by the ordinates. The curve 55 shows the frequency deviations of the second signal and, if no frequency control is employed, also those of the third signal. In this same figure, curve 56 shows the results obtained when the frequency control of the present invention is employed. It will be observed that frequency deviations of the third signal carrier frequency are maintained within relatively narrow limits, that is, within less than ±1 kilocycle, for mistuning adjustments up to approximately ±7 kilocycles.

Due to the action of the tube 44, the control behaves substantially uniformly for signals of all useful intensities, that is, signals which are of sufficient amplitude to provide the standard output for the receiver, while for weaker signals the frequency control means become decreasingly effective. Moreover, by virtue of the double superheterodyne arrangement providing a relatively fixed oscillator frequency which is subjected to the frequency control, the same control action is obtained regardless of the first signal carrier frequency to which the system is tuned. Furthermore, due to the proportioning and arrangement of the various elements of the control circuits, the control action is substantially independent of ordinary variations in the operating voltages utilized.

While there has been described what is at present considered 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. A selective modulated-carrier signaling system comprising tunable frequency-changing means including a frequency-determining circuit for deriving from any selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation a second modulated-carrier signal having a carrier normally of a predetermined frequency of an order of magnitude in kilocycles not greater than 100 but subject to deviations within narrow limits upon mistuning of said frequency-changing means, frequency-discriminating means selectively responsive to predetermined frequencies displaced above and below said predetermined frequency by an amount of the order of one kilocycle and at least a major fraction of one per cent. of said intermediate frequency, frequency-correcting means coupled to said frequency-discriminating means for adjusting said frequency-determining circuit to reduce the deviations of said second signal carrier frequency in a predetermined ratio of the order of 10 to 1, the reactive constants of said frequency-determining circuit, the reactive constants of said frequency-discriminating means, and the response characteristic of said frequency-correcting means being so related that deviations of said second signal carrier frequency effected by mistuning of said frequency-changing means beyond a predetermined amount of the order of but less than said predetermined frequency separation effect relaxation of said frequency-correcting means.

2. A selective modulated-carrier signaling system comprising tunable frequency-changing means including a frequency-determining circuit for deriving from a selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation a second modulated-carrier signal having a carrier normally of a predetermined frequency of an order of magnitude in kilocycles not greater than 100 but subject to deviations within narrow limits upon mistuning of said frequency-changing means, frequency-determining means selectively responsive to predetermined frequencies displaced above and below said predetermined frequency by an amount of the order of one kilocycle and at least a major fraction of one per cent. of said intermediate frequency, frequency-correcting means coupled to said frequency-discriminating means for adjusting said frequency-determining circuit to control the extent of the deviations of said second signal carrier frequency in a predetermined ratio to the extent of said mistuning of the order of 10 to 1, the reactive constants of said frequency-determining circuit, the reactive constants of said frequency-discriminating means, and the response characteristic of said frequency-correcting means being so related that deviations of said second signal carrier frequency due to mistuning of said frequency-changing means within a predetermined amount, of the order of but less than said predetermined frequency separation, effect control of said correcting means to reduce said deviations and deviations effected

by mistuning beyond said predetermined amount effect control of said correcting means to tune said frequency-determining circuit to derive a second signal of said predetermined frequency from the next adjacent signal in said range.

3. A modulated-carrier signaling system comprising a tunable first frequency changer for deriving from any selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation a second modulated-carrier signal having a carrier normally of a first predetermined frequency, a fixed-tuned second frequency changer including a frequency-determining circuit for deriving from said second signal a third modulated-carrier signal having a carrier normally of a second predetermined frequency of an order of magnitude in kilocycles not greater than 100, said second and third signal carrier frequencies being subject to deviations within narrow limits upon mistuning of said first frequency changer, frequency-discriminating means selectively responsive to predetermined frequencies displaced above and below said second predetermined frequency by an amount of the order of one kilocycle and at least a major fraction of one per cent. of said intermediate frequency, frequency-correcting means coupled to said frequency-discriminating means for adjusting said frequency-determining circuit to reduce the deviations of said third signal carrier frequency in a predetermined ratio of the order of 10 to 1, said second predetermined frequency, the reactive constants of said frequency-determining circuit, the reactive constants of said frequency-discriminating means, and the response characteristic of said frequency-correcting means being so related that deviations of said third signal carrier frequency effected by mistuning of said first frequency changer beyond a predetermined amount of the order of but less than said predetermined frequency separation effect relaxation of said correcting means.

4. A modulated-carrier signaling system comprising a tunable first frequency changer for deriving from a selected modulated-carrier signal within a wide frequency range of such signals having a predetermined carrier-frequency separation a second modulated-carrier signal having a carrier normally of a first predetermined frequency, a fixed-tuned second frequency changer including a tunable oscillation circuit for deriving from said second signal a third modulated-carrier signal having a carrier normally of a second predetermined frequency of an order of magnitude in kilocycles not greater than 100, said second and third signal carrier frequencies being subject to deviations within narrow limits upon mistuning of said first frequency changer, frequency-discriminating means selectively responsive to predetermined frequencies displaced above and below said second predetermined frequency by an amount of the order of one kilocycle and at least a major fraction of one per cent. of said intermediate frequency, frequency-correcting means coupled to said frequency-discriminating means for adjusting the resonant frequency of said oscillation circuit in accordance with said deviations to reduce the deviations of said third signal carrier frequency with respect to the deviations of said second signal carrier frequency in a predetermined ratio of the order of 10 to 1, the reactive constants of said oscillation circuit, the reactive constants of said frequency-discriminating means, and the response characteristic of the frequency-correcting means being so related that deviations of said third signal carrier frequency effected by mistuning of said first frequency changer beyond predetermined amount of the order of but less than said predetermined frequency separation effect relaxation of said correcting means.

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