

Dec. 16, 1941.

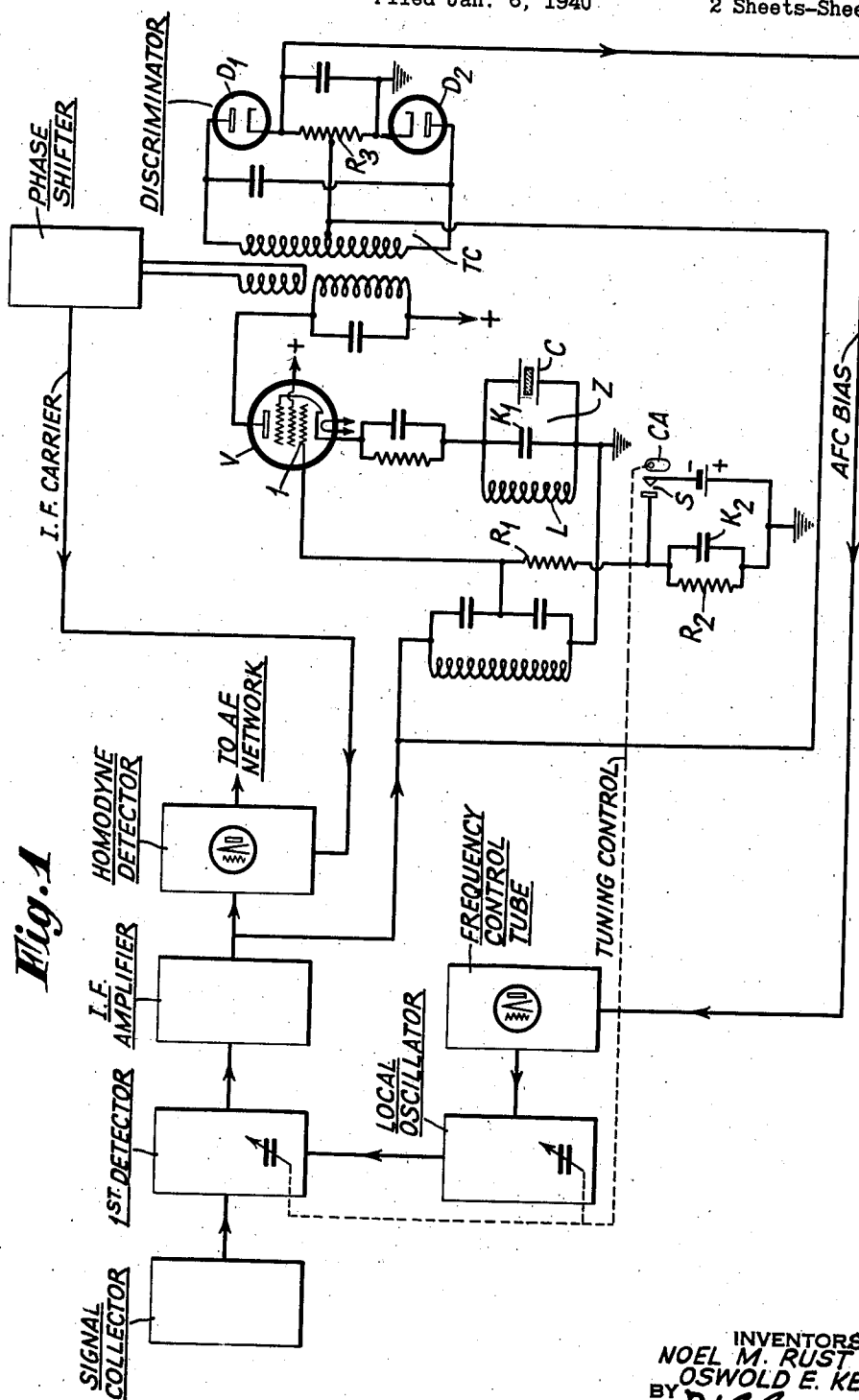
N. M. RUST ET AL

2,266,517

AUTOMATIC FREQUENCY CONTROL CIRCUIT

Filed Jan. 6, 1940

2 Sheets-Sheet 1



INVENTORS
NOEL M. RUST
OSWOLD E. KEALL
BY *H. H. Brown*
ATTORNEY

Dec. 16, 1941.

N. M. RUST ET AL

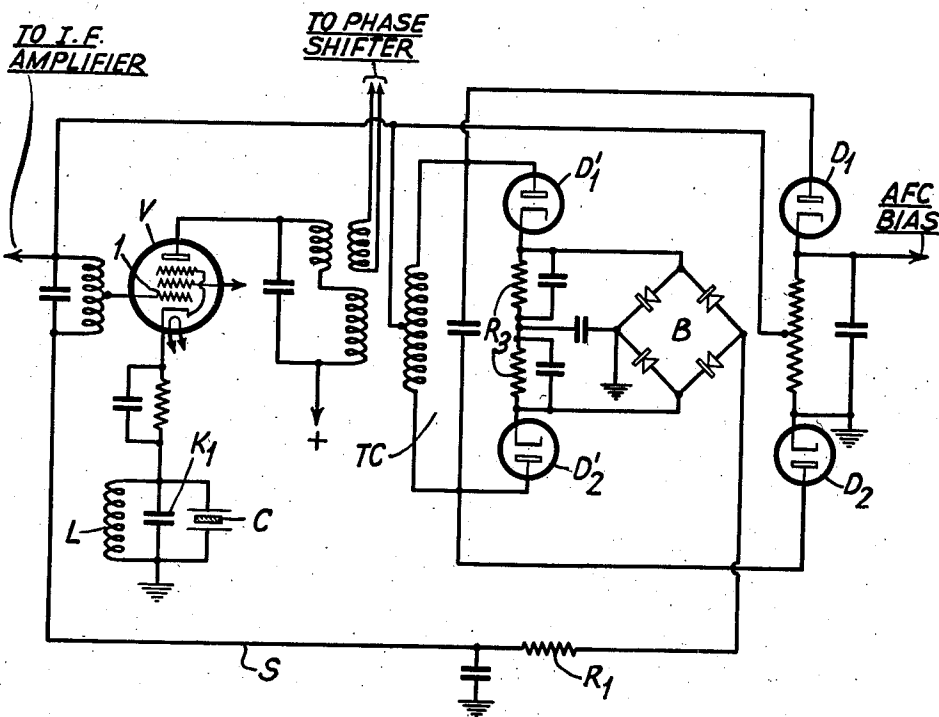
2,266,517

AUTOMATIC FREQUENCY CONTROL CIRCUIT

Filed Jan. 6, 1940

2 Sheets-Sheet 2

Fig. 2



INVENTORS
NOEL M. RUST
OSWOLD E. KEALL
BY *H.B. Snow*
ATTORNEY

UNITED STATES PATENT OFFICE

2,266,517

AUTOMATIC FREQUENCY CONTROL
CIRCUIT

Noël Meyer Rust, Chelmsford, and Oswald
Edward Keall, West Hanningfield, England, as-
signors to Radio Corporation of America, a cor-
poration of Delaware

Application January 6, 1940, Serial No. 312,664
In Great Britain January 12, 1939

11 Claims. (Cl. 250—20)

This invention relates to automatic frequency control systems suitable for use in radio, and like, receivers.

Automatic frequency control systems are now in common use in radio receivers, but such systems as are at present known fall short of requirements in certain important operating particulars. As will be appreciated a main purpose of an automatic frequency control, hereinafter termed (AFC), system is to take charge of the tuning of the receiver once it has been manually tuned to within a predetermined degree of accuracy so that the necessity for skilled tuning on the part of the operator of the receiver is reduced, or eliminated. Obviously from the point of view of the extent to which skilled manual tuning is rendered unnecessary it is desirable that the AFC system shall "take charge" when the manual tuning has been set quite a long way from the accurate tuning position. This requirement, however, is inconsistent with the maintenance of closely accurate tuning by the AFC system, and, accordingly, in known AFC systems a compromise has been sought; the "sharpness" of the system being chosen at some value which is not so great as to make the set difficult to tune by an unskilled operator, but which is nevertheless great enough to give a reasonable degree of accurate tuning. Thus "sharpness" in a known AFC system is a compromise, and, therefore, is not wholly satisfactory. It is believed that none of the known AFC systems is of sufficient "sharpness" to obtain and maintain really accurate tuning, for example tuning accurate enough for a homodyne receiver.

According to this invention a radio, or like, receiver is provided with an AFC system of variable "sharpness" so that a fairly "broad" AFC action is obtained when tuning in a station, and a "sharp" action is obtained at other times once the AFC system has "taken charge." It is thought that the expressions "broad" and "sharp" as applied to an AFC system will be found fairly self-explanatory, but it may be remarked that an AFC system may be said to be "sharp" when large tuning control output voltages are provided for short departures from correct tuning, while conversely, the system is "broad" if a large departure from correct tuning is required to provide a large control voltage. It will be appreciated that it is inherent in any AFC system that if the system is sharp the range over which it takes charge is small, whereas if it is broad the range over which it takes charge is large.

The variation of the sharpness of the AFC

system may be effected manually, quasi-automatically, or wholly automatically. For example, for manual variation (which is not preferred in practice), there would be provided a manually operable switch which varies the sharpness of the AFC system in one or more steps, and which should be moved from a "broad" position to a "sharp" position when the manual tuning operation is completed. In a quasi-automatic system the control of the sharpness of the AFC system would be effected by a switch operated automatically from the normally provided tuning handle of the receiver so that when said tuning handle is being operated the switch is automatically set to a position giving "broad" AFC action, the switch position changing automatically to one giving "sharp" action when the manual tuning operation is completed. Switches adapted to be automatically operated by a tuning control handle are, of course, known per se for other purposes. It is preferred, however, to employ fully automatic variation of the AFC sharpness, and in a system of this nature the actual control, or output, voltage from the AFC system is employed to vary the sharpness of said system. Preferably, particularly in fully automatic systems in accordance with this invention, the arrangement is made such that the selectivity of the receiver is automatically varied at the same time as the sharpness of the AFC system so that the receiver becomes more selective as the AFC system becomes sharper.

The invention is illustrated in the accompanying drawings, wherein

Figs. 1 and 2 show two embodiments of the invention.

Figure 1 illustrates one way of carrying out this invention as applied to a homodyne receiver. A valve V to which received carrier and side band signals are applied, has in its cathode leg a feedback impedance Z of any suitable frequency selective type. Preferably, and as shown, the impedance consists of a piezo-electric crystal C, resonant at the carrier frequency in shunt with an inductance L and with a condenser K₁, the combination being adjusted to neutralize the shunt capacity of said crystal. The received carrier and side band signals are applied to the control grid I of valve V, and the said control grid is connected through two resistances R₁ R₂ in series to earth, the second resistance—that on the ground side—being shunted by a condenser K₂. The junction point of these two resistances is connected to one of a pair of contacts of a switch S, the other contact of which is connected

to a point of negative bias potential, this point being connected to ground through a suitable resistance, or as shown derived from a battery having its positive terminal earthed.

The switch is operated in any convenient manner known per se as by a cam CA on the actuating shaft of the normally provided tuning condenser gang shaft so that when the said shaft is moved in manual tuning the switch is closed. Output which may contain chiefly I. F. (intermediate frequency) carrier component is taken from the anode of the valve, and is utilized as in the usual manner in homodyne receivers. Fig. 1 shows schematically a receiver of the superheterodyne type employing a homodyne detector with the carrier output of tube V applied thereto. The anode circuit of the valve is also coupled to a double diode rectifier network, known as a "discriminator," comprising the usual tuned circuit TC connected between the anodes of two diodes D₁, D₂ whose cathodes are connected together by a capacity-shunted resistance R₃. One end of this resistance serves as the output terminal from which rectified AFC voltage is derived for application, as in the usual well known way, to control the mutual conductance of a frequency control tube connected, in the usual manner, to the local oscillator tube. The mid-point of the resistance in the diode network is, of course, connected to the mid-point of the inductance therein, and input signals consisting of I. F. carrier and side bands are applied to these two mid-points as well as to the input grid of the valve.

It will be seen that with this arrangement, in one position of the switch, the degenerative crystal feedback network is practically ineffective to produce feedback effect by reason of the high bias applied to the grid of the valve, but in the other position of the switch the feedback network is effective and a substantial amount of negative feedback is provided. Accordingly the selectivity, or sharpness, of the valve circuit is very different for the two positions of the switch, being largest for the least bias. Change over from one condition of sharpness to the other is not effected suddenly, but smoothly and gradually by reason of the fact that when the switch is opened, after having been closed, the bias on the valve does not change suddenly but only smoothly during the period in which the charge in the condenser across the second of the two resistances in the grid circuit leaks away.

It will be seen that with this arrangement not only are two widely different degrees of sharpness of AFC action obtained, one being suitable for "searching" and the other being suitable for maintaining accurate tuning once a station has been "found," but, also, in the case of homodyne reception the selectivity of the receiver itself is simultaneously varied. This action is obtained by reason of the fact that the valve which is in the AFC discriminator network, i. e. the valve V with the crystal network in its cathode leg, is also the valve which is employed to provide the carrier component for homodyne action.

Although the use of a crystal network is not an essential in carrying out this invention, its use is preferred for the homodyne case where a very high degree of selectivity and a very high degree of AFC sharpness is necessary. In many cases however, and especially in broadcast superheterodyne receivers, it may be found commercially more economical to use in place of a crystal feedback impedance in the cathode leg of the valve, a feedback impedance consisting of two

tuned circuits in series one resonant a little above the operating I. F. and the other a little below the operating I. F.

In the above described specific embodiments the change in sharpness of the AFC system is obtained by varying the mutual conductance of a valve to which frequency selective feedback is applied. This, of course, is not a necessary feature of the invention for the feedback could be varied in other ways, for example, by providing a variable resistance across the crystal network in the first described arrangement and altering the value of this resistance by the switch.

Again, as already stated, the variation of sharpness of the AFC system and, if desired, the simultaneous variation of selectivity of the receiver may be accomplished entirely automatically. In broad principle this may be effected by deriving from the AFC system a potential which is dependent upon the magnitude of departures from correct tuning but independent of the sense of such departures and utilizing the said voltage to control the sharpness.

Thus, in the first embodiment herein described the switch and associated circuit elements could be dispensed with and instead there could be employed a rectifier bridge B as shown in Fig. 2, having the opposite ends of one diagonal connected between the cathodes of the diodes D'₁—D'₂ in the AFC rectifier network. One end of the other diagonal is connected through a resistance to the low potential end of the signal input circuit of the valve V and the other end of said diagonal is connected to ground. With this arrangement, of course, the grid bias on the valve, and therefore the effectiveness of the frequency selective impedance in the cathode leg of the valve for feedback, would be made directly dependent upon the magnitude of the rectified output voltage obtained from the AFC network but independent of the polarity of that voltage. Thus a change in the magnitude of the derived AFC output voltage produces a change in the bias of the valve V in the discriminator network, and, therefore, a change in the AFC sharpness. In this case, as in the previous embodiments, if the valve in the AFC discriminator network were also a valve in the signal channel simultaneous variation of AFC sharpness and of selectivity would be obtained. The diodes D₁—D₂ function as the rectifiers for producing AFC bias, as in the case of Fig. 1. The bias delivered over line S increases in proportion to the departure from correct tuning in either direction, thus lessening the selectivity and giving a broader AFC control. As the signal is brought into tune the bias over S decreases and selectivity increases so that the AFC action is sharper and holds the tuning very close.

The invention is, of course, not limited to the use of variable negative frequency selective feedback in order to obtain variation in sharpness, for variable positive feedback circuits, of any suitable form known per se, could be employed.

What is claimed is:

1. In combination with a source of modulated carrier energy, a transmission path for said energy coupled to the source, said path being selective to energy of said carrier frequency, a frequency discriminator network comprising an input circuit coupled to said path, said network having an output circuit constructed and arranged to develop a direct current voltage from applied carrier energy whose magnitude and polarity is a function of the extent and sense of

carrier frequency change, and means connected to said discriminator input circuit responsive to a departure of said carrier frequency from a predetermined frequency value for controlling the selectivity of said transmission path.

2. In combination with a source of modulated carrier energy, a transmission path for said energy coupled to the source, said path being selective to energy of said carrier frequency, a frequency discriminator network comprising an input circuit coupled to said path, said network having an output circuit constructed and arranged to develop a direct current voltage from applied carrier energy whose magnitude and polarity is a function of the extent and sense of carrier frequency change, and means responsive to a departure of said carrier frequency from a predetermined frequency value for controlling the selectivity of said transmission path, said last means comprising a rectifier network whose input circuit is the said discriminator input circuit.

3. In combination with a source of modulated carrier energy, a transmission path for said energy coupled to the source, said path being selective to energy of said carrier frequency, a frequency discriminator network comprising an input circuit coupled to said path, said network having an output circuit constructed and arranged to develop a direct current voltage from applied carrier energy whose magnitude and polarity is a function of the extent and sense of carrier frequency change, and means responsive to a departure of said carrier frequency from a predetermined frequency value for controlling the selectivity of said transmission path, said discriminator comprising a pair of rectifiers, and said last means comprising a pair of rectifiers having a common input circuit coupled to said path.

4. In an automatic frequency control system for a super-heterodyne receiver of the type comprising a first detector, a local oscillator, an intermediate frequency network coupled to the first detector, means coupled to said intermediate frequency network, responsive to a frequency difference between the intermediate frequency signals and a predetermined frequency value, for adjusting the local oscillator frequency in a sense to correct for said difference; the improvement which is characterized by said intermediate frequency network being selective for said intermediate signals, and means coupled to the same point of said intermediate network as said first means, and responsive to said intermediate signals, for decreasing the selectivity of said intermediate network during periods of said frequency difference.

5. In an automatic frequency control system for a super-heterodyne receiver of the type comprising a first detector, a local oscillator, means for tuning the detector and oscillator over a range of signal frequencies, an intermediate frequency network coupled to the first detector and means, responsive to a frequency difference between the intermediate frequency signals and a predetermined frequency value, for adjusting the local oscillator frequency in a sense to correct for said difference; the improvement which is characterized by said intermediate frequency network being selective for said intermediate signals, and means concurrently operative with the tuning means for decreasing the selectivity of said intermediate network during periods of said frequency difference, said intermediate network comprising a tube having signal input and output

circuits, means common to said output and input circuits for providing degenerative feedback therebetween, and said selectivity decreasing means being arranged to control the gain of said tube.

6. In an automatic frequency control system for a super-heterodyne receiver of the type comprising a first detector, a local oscillator, an intermediate frequency network coupled to the first detector and means, responsive to a frequency difference between the intermediate frequency signals and a predetermined frequency value, for adjusting the local oscillator frequency in a sense to correct for said difference; the improvement which is characterized by said intermediate frequency network being selective for said intermediate signals, and means for decreasing the selectivity of said intermediate network during periods of said frequency difference, means for adjusting the tuning of said first detector and oscillator over a desired modulated carrier range, and means for adjusting said selectivity decreasing means concurrently with said tuning means.

7. In an automatic frequency control system for a super-heterodyne receiver of the type comprising a first detector, a local oscillator, an intermediate frequency network coupled to the first detector and means, responsive to a frequency difference between the intermediate frequency signals and a predetermined frequency value, for adjusting the local oscillator frequency in a sense to correct for said difference; the improvement which is characterized by said intermediate frequency network being selective for said intermediate signals, and means for decreasing the selectivity of said intermediate network during periods of said frequency difference and additional means for simultaneously adjusting the tuning of said receiver and said selectivity decreasing means.

8. In a radio receiver of the type having a main tuning means for selecting different carrier frequencies of a modulated signal carrier frequency range, a supplemental tuning means, responsive to a frequency difference existing between received modulated carrier energy and a predetermined carrier frequency value, for adjusting the receiver tuning in a sense to correct for said frequency difference; the improvement which is characterized by said supplemental means having a relatively sharp action at settings of said main tuning means at which said difference is a minimum, means for broadening said action in response to said difference exceeding said minimum and means for decreasing the receiver selectivity concurrently with actuation of said broadening means.

9. In a radio receiver of the type having a main tuning means for selecting different carrier frequencies of a modulated signal carrier frequency range, a supplemental tuning means, responsive to a frequency difference existing between received modulated carrier energy and a predetermined carrier frequency value, for adjusting the receiver tuning in a sense to correct for said frequency difference; the improvement which is characterized by said supplemental means having a relatively sharp action at settings of said main tuning means at which said difference is a minimum, and means for broadening said action in response to said difference exceeding said minimum and means for simultaneously varying the selectivity of the receiver in the same sense as said supplemental tuning action.

10. In a radio receiver of the type having a main tuning means for selecting different carrier frequencies of a modulated signal carrier frequency range, a supplemental tuning means, responsive to a frequency difference existing between received modulated carrier energy and a predetermined carrier frequency value, for adjusting the receiver tuning in a sense to correct for said frequency difference; the improvement which is characterized by said supplemental means having a relatively sharp action at settings of said main tuning means at which said difference is a minimum, means, responsive to said modulated carrier energy, for broadening said action in response to said difference exceeding said minimum and additional means responsive to said carrier energy for decreasing the receiver selectivity conjointly with actuation of said broadening means.

11. In a radio receiver of the type having a

main tuning means for selecting different carrier frequencies of a modulated signal carrier frequency range, a supplemental tuning means, responsive to a frequency difference existing between received modulated carrier energy and a predetermined carrier frequency value, for adjusting the receiver tuning in a sense to correct for said frequency difference; the improvement which is characterized by said supplemental means having a relatively sharp action at settings of said main tuning means at which said difference is a minimum, means for simultaneously decreasing the receiver selectivity and broadening said action in response to said difference exceeding said minimum, and means for simultaneously adjusting said main tuning means and said last means.

NOËL MEYER RUST.
OSWOLD EDWARD KEALL.