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AUTOMATIC FREQUENCY CONTROL CIRCUIT

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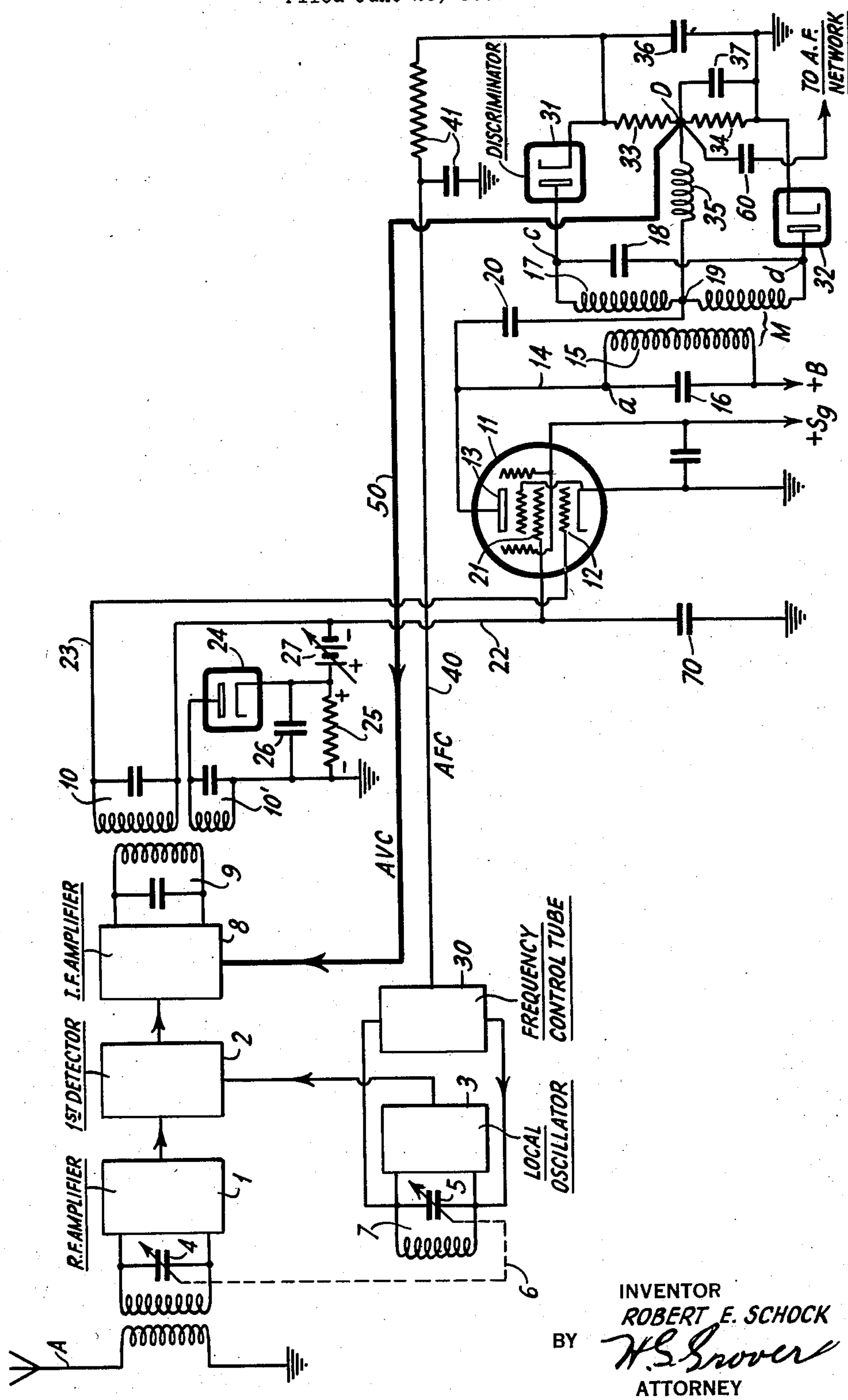

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AUTOMATIC FREQUENCY CONTROL CIRCUIT

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1 Claim. (Cl. 250—20)

My present invention relates to automatic frequency control circuits for radio receivers, and more particularly to signal-actuated regulation of the frequency control circuit.

In the past difficulty has been experienced in the use of automatic frequency control (AFC) in radio receivers whenever the amplitude of the desired signal carrier decreased to, or near, the background noise level. In such cases the noise energy, and sometimes adjacent channel signal energy, affected the AFC network in a sense to detune the receiver from the desired carrier frequency. Upon the desired signal carrier amplitude returning to a usable level, the receiver was sufficiently detuned to prevent operation of the AFC. In application Serial No. 16,591 of M. G. Crosby, filed April 16, 1935, Patent No. 2,123,716, July 12, 1938, there are disclosed, and claimed, several arrangements for automatically preventing AFC action when the strength of the incoming signal carrier decreases below a usable level.

One of the main objects of my present invention is to provide an AFC network for a radio receiver; and an additional circuit, responsive to signal carrier amplitude variation, being utilized to control the signal feed to the AFC network thereby providing a control over the possibility of noise energy, or adjacent channel signal energy, operating the AFC network when the desired signal carrier amplitude is below a desired level.

Another important object of my invention is to provide a receiver of the type employing signal-actuated means accurately to tune the receiver at different carrier frequencies; and additional means being employed to suppress the signal feed to the aforesaid accuracy tuning means when a desired carrier amplitude decreases below a predetermined level.

Another object of the invention is to provide in a superheterodyne receiver an AFC network; and means utilizing rectified signal energy to cut off the signal supply to the AFC network whenever the signal to which the receiver is tuned drops below a predetermined level.

Still other objects of the invention are to improve generally the operating efficiency of receivers of the AFC type, and more especially to provide a signal responsive suppressor circuit for AFC receivers which is not only economical in construction, but reliable in operation.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claim; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring now to the accompanying drawing, wherein there is shown in schematic manner a superheterodyne receiver, the signal collector A may be of the grounded antenna type, a loop, a radio frequency distribution line, or the collector of a mobile vehicle such as an automobile. The collected signals, which may be in any desired frequency range, are impressed on a tunable radio frequency amplifier 1 feeding a tunable first detector network 2. The tunable local oscillator network 3 feeds local oscillations to the first detector; it will be understood that networks 2 and 3 may employ separate tubes, or they may use a common pentagrid converter tube of the 2A7 type. The numerals 4, 5 denote the usual variable tuning condensers whose rotors are arranged for unicontrol adjustment by a common means 6. Of course, the variable tuning condenser of the first detector network will, also, be coupled to the tuning means 6 for adjustment.

The oscillator tank circuit 7 is tuned through a frequency range different from, and usually higher than, the signal circuit frequency range. The signal energy in the output of network 2 is at an intermediate frequency (I. F.); the latter may be chosen from a range of 75 to 450 kc. when the signal range is from 500 to 1500 kc. The I. F. energy is amplified by the amplifier 8; the amplified I. F. energy in the output circuit 9 is impressed upon the networks to be described in detail. It will be understood that the I. F. transmission networks between the first detector 2 and the circuit 9 are each fixedly resonated to the operating I. F.

The system shown is adaptable to unmodulated signal energy, or to signal energy modulated by any known type of modulation (amplitude; frequency; phase; or I. C. W.). Again, the receiver may be of the type shown in said Crosby application. Regardless of the construction of the receiver prior to circuit 9, the I. F. energy is impressed on the input circuit 10 of a coupling tube 11. The circuit 10 is tuned to the operating I. F.; and the signal grid 12 of tube 11 has the I. F. energy impressed thereon. Tube 11 may be of the 6L7 type and has its cathode at ground potential; the plate 13 being connected to a source of positive potential (+B) through a path including lead 14 and primary winding 15 of transformer M. The condenser 16 resonates the coil 15 to the operating I. F. The secondary winding 17 is resonated to the I. F. by the condenser 18; the midpoint 19 of the winding 17 is connected to the high potential side of winding 15 by condenser 20.

The coupling tube 11 has one of its inner grids 21 connected by lead 22 to the low alternating potential side of the input circuit 10; the condenser 70 connecting lead 22 to ground. The signal grid 12 of tube 11 is connected by lead 23 to the high potential side of I. F. input circuit 10. The control grid 12 is electrostatically shielded from the grid 21 by a positive screen grid construction. I. F. energy is, also, impressed on the resonant circuit 10′, which circuit is fixedly tuned to the operating I. F.; the anode of a diode rectifier 24 being connected to the high potential side of circuit 10′. The cathode of the diode is connected to the grounded side of circuit 10′ through a load resistor 25, the latter being shunted by an I. F. by-pass condenser 26.

The grid 21 of tube 11 is not only connected by lead 22 to the circuit 10, but, also, to the cathode side of resistor 25; the negative biasing voltage source 27 being connected between lead 22 and the cathode side of resistor 25. It will be observed that the signal grid 12 of tube 11 is connected to the cathode side of resistor 25 through a path which includes lead 23, tuned circuit 10 and bias source 27. The function of the rectifier 24 is to produce a uni-directional voltage across resistor 25 when the received carrier amplitude increases above a predetermined amplitude, and thereby overcome the initial cut-off bias impressed on grids 12 and 21 by bias source 27. The bias source 27 can be supplied by any direct current potential source, such as properly filtered, rectified A. C., which will be independent of ground and be of low resistance.

When the I. F. amplitude is of sufficient strength to overcome the bias from source 27, then the coupling tube 11 transmits I. F. energy to the discriminator network which is coupled to the circuit 16—15. The discriminator network, and the frequency control tube 30, may be constructed as disclosed in application Serial No. 45,413 of S. W. Seeley, filed Oct. 17, 1935, Patent No. 2,121,103, June 21, 1938. Since the AFC arrangement now to be described has been fully disclosed in all its details in the Seeley application, it is not believed necessary to describe it in this application in more than general terms. Of course, it is to be understood that the AFC network may be of any well known form; for example, that disclosed in the aforesaid Crosby application may be utilized. All that is essential to a proper understanding of this application, is that it be understood that the I. F. coupling tube 11 feed the discriminator of an AFC arrangement, and that the coupling tube 11 be dependent in transmission efficiency upon the amplitude level of the I. F. carrier energy.

Referring now to the discriminator network, the latter is of a type employing a pair of diodes 31 and 32; the anode of diode 31 being connected to one side *c* of winding 17, whereas the anode of diode 32 is connected to the other side *d* of the same winding. The cathodes of the two diodes are connected in series by a pair of resistors 33 and 34, the junction point D of the resistors being connected to midpoint 19 of winding 17 through an I. F. choke coil 35. The condenser 36 is connected across resistors 33 and 34, whereas condenser 37 is connected across resistor 34; the cathode side of resistor 34 is at ground potential. The cathode side of resistor 33 is connected by lead 40, the AFC lead, to a gain control electrode of the frequency control tube 30.

The AFC line 40 includes a filter network 41 for suppressing any pulsating components in the AFC voltage. An AVC (automatic volume control) lead 50 may be connected to the point D for impressing AVC bias upon the I. F. amplifiers, and, if desired, upon any of the signal transmission stages preceding the amplifier 8. Furthermore, the audio voltage component of the rectified I. F. energy may be taken off from point D, and transmitted through coupling condenser 60 to one, or more, stages of audio frequency amplification followed by a reproducer. It is to be understood, however, that the audio demodulator of the receiving system may be coupled to the I. F. circuit 9, and thus the second detection will be rendered independent of the discriminator action.

The frequency control tube 30 is connected to the tank circuit 7 of the local oscillator in such a manner that a variation of the gain of the control tube 30 results in a change in effective reactance (capacitative or inductive) in a sense such as to adjust the local oscillator frequency to maintain the desired I. F. value. The frequency control tube circuit may be of the type wherein the control tube has its input capacity shunted across the tank circuit 7; a change in gain of the control tube thereby varying the effective capacity reactance in the tank circuit. On the other hand, the control tube 30 may follow the teachings in the aforesaid Seeley application; and, if desired, the frequency control tube circuit used in the aforesaid Crosby application may be employed.

When the I. F. energy produced in circuit 9 varies in frequency from the operating I. F. value, then a bias will be developed by the discriminator network; the bias is transmitted through line 40 to the frequency control tube 30, and the latter is varied in gain so as to adjust the tuning of tank circuit 7 in a sense to maintain the operating I. F. In this way whenever the tuning device 6 is adjusted to a tuning position corresponding to a desired station, the reception of signal carrier energy above a predetermined amplitude results in actuation of the discriminator network so as to cause the receiver to be "pulled into" tune with the desired station.

The I. F. carrier is delivered by coupling tube 11 to circuit 15—16. The coil 15 is coupled loosely to circuit 17—18. The point *a* of circuit 15—16 is connected to the midpoint 19 of the winding 17, it being understood that condenser 20 is assumed to be so large that the voltage drop in it is negligible. The voltage at the cathode side of resistor 33 will be either positive or negative with respect to the grounded side of resistor 34, depending on which way the selector circuits are detuned. The point *a* and point 19 are at the same alternating potential because of the large magnitude of condenser 20. The phase of point *a* with respect to ground potential is zero, when the I. F. energy is at the operating I. F. At resonance there is no phase shift in the circuit 15—16. Hence, point 19 is at zero phase. The current in circuit 15—16 induces a voltage in circuit 17—18, and this voltage is distributed equally about point 19. At a given instant point c is as much positive as point d is negative. The voltages impressed on the two rectifiers are therefore equal, although opposite in phase. The rectified outputs depend only on the magnitudes, and, hence, the voltage drops across 33 and 34 will be equal. Since rectifiers 31 and 32 are connected in series opposing relation, the potential difference between ground and the cathode side of resistor 33 will be zero. This balance occurs only when the frequency is equal to the resonant frequency of the two loosely coupled I. F. circuits.

If, now, the signal frequency differs considerably from the resonant frequency, there will be a phase shift of nearly 90 degrees in the circuit. The voltages induced in the two halves of the secondary 17 are still equal in magnitude, and opposite in phase with respect to point 19. The voltage drop across circuit 15—16 is now added vectorially to the voltages induced in circuit 17—18. Thus, the potential at one side of the secondary 17, say c, will be the sum of the induced voltage (19—c) and the voltage drop across 15—16; while the potential of the other side, d, will be the difference between the drop in 15—16 and the voltage induced in (19—d). It follows that the input voltage of one rectifier, the upper one in the assumed case, is much greater than that in the other. Therefore, the voltage drop across resistor 33 will be greater than that across resistor 34, and the cathode side of resistor 33 will be positive with respect to ground.

Depending on the sense of frequency departure of the I. F. energy from the operating I. F., the cathode side of resistor 33 assumes either a positive or negative potential with respect to ground. The magnitude of this AFC bias depends on the amount of frequency departure. The AFC bias determines, in this way, the gain of the control tube 30; as well as the sense of gain change. This, in turn, determines the magnitude and sense of change of the simulated reactance across the tank circuit 7. Point D is always negative relative to ground; hence, the AVC line 50 is connected to this point. Of course, AVC bias and audio voltage can be derived from a separate detector coupled to I. F. circuit 9.

The bias source 27 is preferably adjusted to impress a negative bias on grids 12 and 21 which is of sufficient magnitude to bias coupling tube 11 to cut-off when the I. F. energy impressed on circuit 10' is of an amplitude below a usable value. As the I. F. carrier energy increases in amplitude to the value above the desired level, the direct current voltage drop across resistor 25 increases in a positive potential sense to a point such that it overcomes the negative bias from source 27 to an extent sufficient to permit normal operation of the coupling tube 11. Of course, sufficient bias will then be supplied by source 27 to permit the tube 11 to operate as an efficient I. F. amplifier. It will, therefore, be seen that the magnitude of the voltage from source 27 determines the level of signal required before the tube 11 will pass a signal, and that this level of operation may be predetermined.

It is to be understood that the circuits 10 and 10' need not be fed from the same source, or by the same frequency. For example, the frequency discriminator may be one which operates at audio frequency, and circuit 10 may be an audio frequency circuit fed by audio frequency energy which has been heterodyned from the radio or intermediate frequency signal in the receiver under frequency control. At the same time, the circuit 10' may utilize a radio, or intermediate, frequency signal. The circuit 10' may be fed with any of the I. F. energies in a multiple detection heterodyne receiver; or it may be fed with heterodyned audio frequency energy. Again, while the coupling tube 11 has been shown of the multi-grid type employing a control voltage on two grids, it is to be clearly understood that the control bias may be applied to one control grid, and that, in general, any type of tube can be employed in place of tube 11 as long as its signal transmission efficiency is greatly minimized when the signal amplitude falls too low.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claim.

What I claim is:

In a superheterodyne receiver of the type including a tunable local oscillator, an intermediate frequency transmission network and an automatic frequency control circuit, responsive to a frequency departure of the intermediate frequency energy from an assigned frequency value, for controlling the oscillator frequency; the improvement comprising a tube provided with a cathode, anode and at least two cold electrodes, means impressing intermediate frequency energy upon one cold electrode, means coupling the anode to said control circuit for feeding said intermediate energy thereto, means responsive to amplitude variation of said intermediate energy for automatically controlling the bias of the second cold electrode thereby to control the gain of said tube, said last means consisting of a diode rectifier having an input circuit coupled to said transmission network, said rectifier including a load resistor, and a connection, including a source of voltage normally adapted to cut-off said tube, between said second cold electrode and a point on said resistor adapted to assume a positive potential.

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