

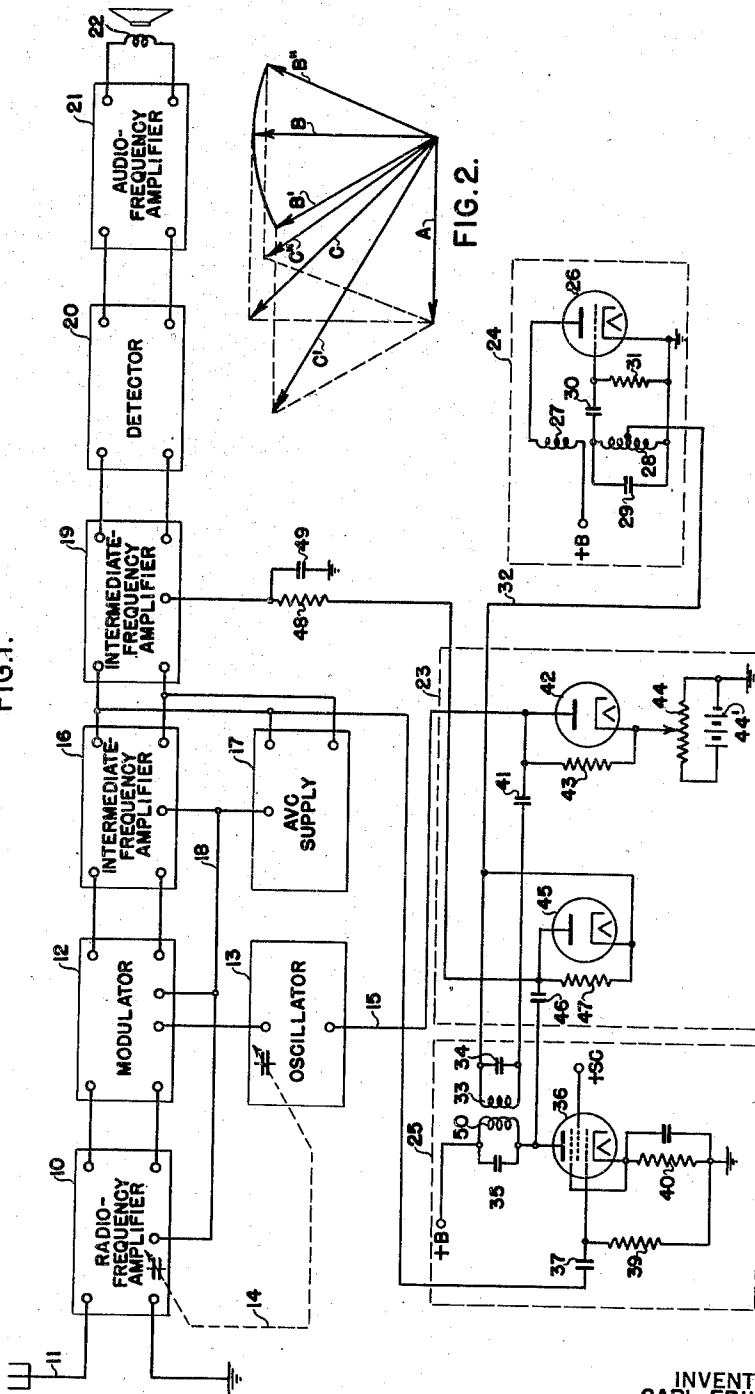
Oct. 31, 1939.

CARL-ERIK GRANQVIST
FREQUENCY-SELECTIVE NETWORK

2,177,713

Filed Feb. 16, 1938

FIG. 1.



INVENTOR
CARL-ERIK GRANQVIST
BY *Laurence B. Dodds*
ATTORNEY

UNITED STATES PATENT OFFICE

2,177,713

FREQUENCY-SELECTIVE NETWORK

Carl-Erik Granqvist, Stockholm, Sweden, assign-
or to Hazeltine Corporation, a corporation of
Delaware

Application February 16, 1938, Serial No. 190,680
In Sweden August 10, 1937

6 Claims. (Cl. 250—20)

The present invention relates to an improved frequency-selective network and particularly to a frequency detector having a very sensitive characteristic and adapted for automatic frequency control of a carrier-signal receiver, or for demodulation of a frequency-modulated carrier wave.

Various arrangements have been proposed for automatically and accurately controlling the resonant frequency of high-frequency circuits, such as those of carrier-signal receivers. As a rule, such arrangements have comprised a circuit tuned to a frequency that is slightly higher and a circuit tuned to a frequency that is slightly lower than the carrier frequency of the signal, each circuit thus being more responsive to the signal-carrier frequency on one side of its resonant curve than on the other side. By means of a balanced coupling between the circuits, a differential rectified voltage or current may be derived from a received signal transmitted through the detuned circuits to provide a control voltage for controlling the tuning of the receiver.

It has also been proposed to utilize the natural phase displacement to which the signal is subjected in a resonant circuit in the signal channel for deriving a control voltage; that is, the current lags the voltage when the signal frequency is higher than that of the resonant circuit and leads the voltage when the signal frequency is lower than that of the resonant circuit. Such arrangements are, however, not as sensitive as might be desired. The resonance curves of the signal-selector circuits of the receiver are generally rather flat at their peaks over a band of several kilocycles. Thus, when the signal-selector circuits of the receiver are utilized for developing a control voltage, a high control sensitivity can be obtained only if the detuning is considerable so that the signal falls well out of the steep portion of the resonance curve. On the other hand, with such detuning the signals of adjacent channels pass through the detuned circuits and render difficult the reception of a distant station on a channel in the vicinity of that of a local station. Furthermore, this method is not sufficiently sensitive to provide an ideal control for accurately and automatically tuning a radio receiver. In order to obtain a phase displacement of, for instance, 30 degrees, a frequency deviation of several kilocycles between the frequency of the signal and the resonant frequency of the selective circuit is required. Even with a phase displacement of 30 degrees, the change is too small to provide a sensitive control. Thus,

for instance, the sum of two equal voltages which are in phase is reduced by only 3.4% if the voltages are displaced by 30 degrees.

In accordance with a preferred embodiment of the invention, a modulated-carrier signal receiver of the superheterodyne type comprises means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver and a local oscillator for generating oscillations of a fixed frequency equal to the normal intermediate frequency of the receiver. The receiver also includes means for repeating and limiting a signal derived from the intermediate-frequency signal of the receiver, a rectifier, a resonant circuit tuned to the frequency of the generated oscillations, and means for applying the repeated signal and the locally-generated oscillations in series to the rectifier through the resonant circuit. The voltage output of the rectifier is utilized for controlling the means for adjusting the frequency of the intermediate-frequency signal to maintain the frequency of the repeated voltage equal to the normal intermediate-carrier frequency. It will be understood that the frequency detector provided by the invention may be used for other purposes than that of automatically tuning a radio receiver. It may, for instance, be utilized as a demodulation arrangement for frequency-modulated carrier signals.

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 drawing, and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 is a circuit diagram, partly schematic, of a complete superheterodyne receiver embodying the invention as a frequency-selective circuit for an automatic frequency control circuit of the receiver, while Fig. 2 illustrates certain operating characteristics of the circuit of Fig. 1.

Referring now more particularly to Fig. 1, there is shown schematically a complete superheterodyne receiver of a conventional design embodying the invention in a preferred form. In general, the receiver includes a radio-frequency amplifier 10 having its input circuit connected to an antenna 11 and its output circuit coupled to a frequency changer or modulator 12. Connected in cascade with the frequency changer 12, in the order named, are an intermediate-frequency amplifier 16 of one or more stages, an intermediate-frequency amplifier 19 of one or

more stages, a detector 20, an audio-frequency amplifier 21 of one or more stages, and a sound reproducer 22. There is provided a separate automatic amplification control source or A. V. C. supply 17 coupled to the intermediate-frequency channel of the receiver. An automatic amplification control bias, derived from the A. V. C. supply 17, is applied over conductor 18 to the grids of one or more of the tubes of amplifier 10, modulator 12, and one or more of the tubes of intermediate-frequency amplifier 16 in order to maintain the input to the detector 20 at a substantially constant level for a wide range of received signal amplitudes. Local oscillator 13, the output circuit of which is coupled to modulator 12, has its frequency controlled in a conventional manner by means of a potential supplied over conductor 15 and derived from a circuit which will be hereinafter described.

It will be understood that the various circuits just described may be of a conventional construction and operation, details of which are well known in the art, rendering further description thereof unnecessary. Considering briefly the operation of the receiver as a whole and neglecting for the movement the operation of the frequency-selective circuit to be hereinafter described, a desired signal is selected and amplified by radio-frequency amplifier 10, converted to a modulated intermediate-frequency signal in modulator 12, amplified by intermediate-frequency amplifiers 16 and 19, and demodulated by detector 20, thereby deriving the audio frequencies of modulation. The audio frequencies of modulation are, in turn, amplified in audio-frequency amplifier 21 and reproduced by sound reproducer 22. The automatic amplification control serves to maintain the volume output of the receiver within a narrow range for a wide range of received signal amplitudes.

In accordance with the present invention and in order to provide a control potential for oscillator 13, there is provided a rectifier 42 to which is supplied a voltage from a standard control oscillator 24 as well as a voltage from the intermediate-frequency amplifier 16 through a limiter and amplifier 25. The oscillator 24 may be of any well-known type; as shown, it comprises a vacuum tube 26, a frequency-determining circuit comprising a condenser 29 and an inductance 28, and a feed-back circuit from the anode of tube 26 to the frequency-determining circuit which includes an inductance 27 inductively coupled to inductance 28. The frequency-determining circuit 28, 29 is accurately tuned to the mean frequency of the selective circuits included in the intermediate-frequency channel of the receiver. For deriving a voltage from the intermediate-frequency signal, there is provided a limiter and amplifier 25 comprising a tube 36 having an input circuit coupled through condenser 37 to the output circuit of intermediate-frequency amplifier 16 and a double-tuned output circuit 35, 50, 33, 34 tuned to the mean frequency of the selective circuits of the intermediate-frequency channel of the receiver. A grid leak 39 and a cathode-biasing resistor 40 are provided for tube 36 of limiter and amplifier 25.

Tuned secondary circuit 33, 34 and a portion of frequency-determining circuit 28, 29, connected in series through conductor 32, are coupled through condenser 41 to the rectifier 42; that is, means are provided for applying in series the signal repeated by limiter and amplifier 36 and the oscillations generated by oscillator 26 to

rectifier 42 through resonant circuit 33, 34. Rectifier 42 is provided with a load resistor 43 and its cathode is biased by connection to an adjustable tap on a voltage divider 44 connected across a direct current source 44' as shown.

Reference is made to Fig. 2 for an explanation of the operation of the portion of the arrangement just described. The frequency correction depends upon a comparison of the frequency of the intermediate-frequency signal with that of oscillator 24. In this explanation it will be assumed that the receiver is initially accurately tuned for the reception of a comparatively powerful station, the frequency of its intermediate-frequency signal thus equaling that of the oscillator 24. It is further assumed that a definite phase relationship, corresponding to that of equilibrium of the control arrangement, exists between the two oscillations that are to be compared. The input potential of limiter and amplifier 25, derived from the intermediate-frequency signal of the receiver, is amplified to a constant amplitude by the limiter and amplifier. Thus, it is seen that a voltage derived from the intermediate-frequency signal in series with a voltage derived from oscillator 24 is supplied to rectifier 42. The output voltage of rectifier 42 is so adjusted that, under the conditions assumed, the amplitudes of these two voltages are equal and the above assumed phase displacement is such that these two voltages, as applied to the rectifier 42, are displaced by 90 degrees, as indicated by vectors A and B in Fig. 2. Thus, vector A represents the voltage derived from oscillator 24 which is applied to rectifier 42 and vector B represents the voltage derived from limiter and amplifier 25 and applied to rectifier 42 under the conditions assumed. The rectifier 42 develops a unidirectional voltage proportional to their resultant which appears across the load resistor 43. This resultant vector is shown as C in Fig. 2. With the connection shown, however, the voltage across resistor 43 is of opposite polarity to the bias of rectifier 42 derived from voltage divider 44. The tap of voltage divider 44 is so adjusted that the two voltages are equal and opposite under the conditions assumed so that the frequency-correcting bias voltage supplied over conductor 15 is zero under the condition corresponding to accurate tuning of the receiver. No frequency adjustment takes place under these conditions.

If for some reason, however, the frequency of the intermediate-frequency signal changes, there is a corresponding change in the frequency of the output voltage of limiter and amplifier 25. If the frequency of the intermediate-frequency signal increases, the vector B, representing the first condition of equilibrium, is retarded by the tuned circuit 35, 50, 33, 34 to the position B', representing a new condition of equilibrium. If the frequency of the intermediate-frequency signal decreases, the vector B is advanced to the position B''. It will be seen that the resultant vector C', which is the sum of vectors A and B', is very much larger than the vector C and, consequently, the voltage developed across the load resistor 43 exceeds that derived from voltage divider 44 and the difference in voltage is transmitted over conductor 15 to cause the oscillator frequency to be corrected in any well-known manner and the intermediate-frequency signal to regain its correct value. It is noted that the resultant C'', which is the sum of vectors A and B'', is very much smaller than vector C, corre-

sponding to the first condition of equilibrium and, consequently, the voltage developed across resistor 43 is, under these conditions, less than that derived from voltage divider 44. Therefore, under these conditions a potential is supplied over conductor 15 which is of opposite polarity to the corrective potential derived from vector C' and the oscillator frequency is corrected in an opposite sense so that the intermediate frequency regains its correct value.

In order that the output of oscillator 24 shall not cause interference in the main signal channel of the receiver when it is being tuned, an arrangement is provided for silencing the receiver during this interval. For this purpose, there is provided a rectifier, shown as a component of unit 23, comprising a diode 45 having a load resistor 47. The diode 45 is coupled between the anode of tube 36 and conductor 32. A condenser 46 is provided having such a value that equal voltages from the limiter and amplifier 25 and the local oscillator 24, displaced 180 degrees at the condition of equilibrium of the system, are applied in series with diode 45. The anode of diode 45 is connected to one or more tubes of intermediate-frequency amplifier 19 in a conventional manner to silence the receiver. A suitable filter comprising resistor 48 and condenser 49 is provided to prevent the application of alternating potentials to amplifier 19.

In considering the operation of the silencing arrangement just described, it is evident that the normal phase displacement, that is, the displacement at the condition of equilibrium of the system, between the two voltages supplied to tube 45 is 180 degrees. The value of condenser 46 is so chosen that these two voltages are normally equal and opposite and no potential is supplied by rectifier 45. If, however, the frequencies of the intermediate-frequency signal and that of the control oscillator are not the same, a voltage is applied to rectifier 45 which, in turn, develops across load resistor 47 a direct voltage which is utilized to silence the receiver.

While there has been described what is at present considered to be the preferred embodiment of this 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 modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator for generating oscillations of a fixed frequency equal to the normal intermediate-carrier frequency of the receiver, means for repeating and limiting said signal, a rectifier, a resonant circuit tuned to the frequency of said oscillations, means for applying said repeated signal and said oscillations in series to said rectifier through said resonant circuit, and means for utilizing the output voltage of said rectifier for controlling said adjusting means to maintain the frequency of said repeated voltage equal to the normal intermediate-carrier frequency.

2. A modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator for generating oscillations of a

fixed frequency equal to the normal intermediate-carrier frequency of said receiver, means for amplifying said signal to a predetermined amplitude, a rectifier, means for applying said amplified signal and the output voltage of said oscillator in series to said rectifier, a source of fixed bias voltage, means for deriving a potential, comprising the sum of the output voltage of said rectifier and said fixed voltage which varies in accordance with the phase relation between said signal and the voltage of said oscillator, and means for applying said potential to said first-mentioned means to maintain the frequency of said amplified signal equal to said normal intermediate-carrier frequency.

3. A modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator comprising an output circuit for generating oscillations of a fixed frequency equal to the normal intermediate-carrier frequency of said receiver, a selective circuit resonant at said normal frequency, said selective circuit comprising an output circuit and being coupled to said channel, a rectifier, and means comprising the output circuit of said selective circuit and the output circuit of said local oscillator coupled in series with said rectifier for controlling said adjusting means to maintain the frequency of said first-mentioned signal equal to said normal intermediate-carrier frequency.

4. A modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator comprising an output circuit for generating oscillations of a fixed frequency equal to the normal intermediate-carrier frequency of said receiver, an amplifier comprising an output circuit for amplifying said signal to a predetermined amplitude, a double-tuned transformer comprising primary and secondary circuits tuned to said normal intermediate-carrier frequency and having said primary circuit in circuit with the output circuit of said amplifier and said secondary circuit in series with a portion of said circuit of said oscillator, and a rectifier coupled in series with said secondary circuit and said portion of said oscillator circuit and comprising an output impedance coupled to said adjusting means to maintain the frequency of said amplified signal equal to said normal intermediate-carrier frequency.

5. A modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator for generating oscillations of a fixed frequency equal to the normal intermediate-carrier frequency of the receiver, means comprising a tuned circuit resonant at the frequency of said oscillations and a rectifier coupled to said source of oscillations and to said intermediate-frequency channel through said tuned circuit, said last-named means being responsive jointly to phase displacement and frequency difference of said intermediate-frequency signal and said oscillations for controlling said adjusting means to maintain the frequency of said intermediate-frequency signal equal to said normal intermediate-carrier frequency, means for deriving from said signal and said oscillations a potential which varies in accordance with phase displacement and frequency difference between

said signal and said oscillations, and means for applying said potential to a tube of said receiver to silence said receiver.

6. A modulated-carrier signal receiver of the superheterodyne type comprising, means for adjusting the frequency of the signal applied to the intermediate-frequency channel of the receiver, a local oscillator for generating oscillations of a fixed frequency equal to the normal intermediate-carrier frequency of said receiver, means for amplifying said signal to a predetermined amplitude, a rectifier, a resonant circuit tuned to the frequency of said oscillations, means for applying said amplified signal and the output voltage of

said oscillator in series to said rectifier through said resonant circuit, means comprising the output voltage of said rectifier for adjusting said first-mentioned means to maintain the frequency of said intermediate-frequency signal equal to that of said normal frequency, means for deriving from said amplified signal and said oscillations a potential which varies in accordance with phase displacement and frequency difference between said signal and said oscillations, and means for applying said voltage to a tube in said receiver to silence said receiver when said adjusting means is not in a state of equilibrium.

CARL-ERIK GRANQVIST.