July 23, 1946. J. E. TILLMAN 2,404,669

CONVERTER

Filed Sept. 25, 1942 2 Sheets-Sheet 1

Fig. 1.

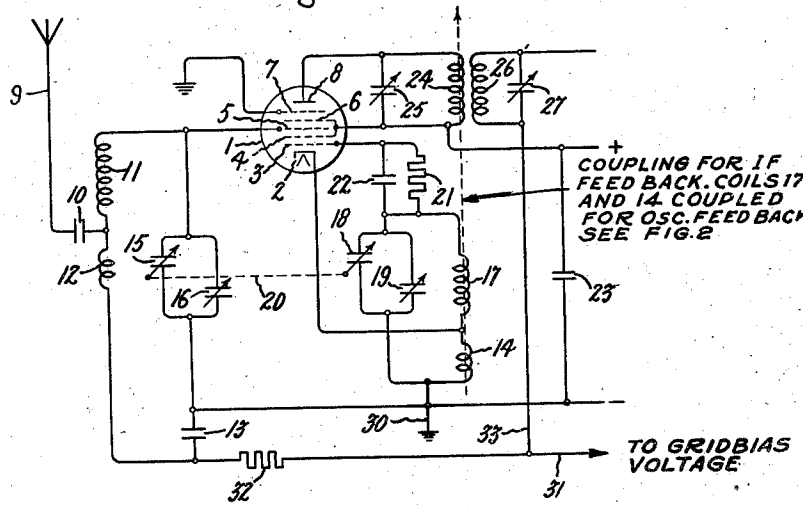


Fig. 2.

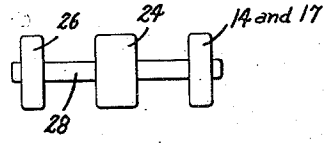
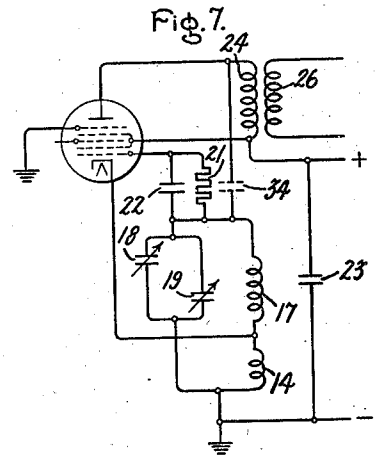


Fig. 7.



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Fig.3.

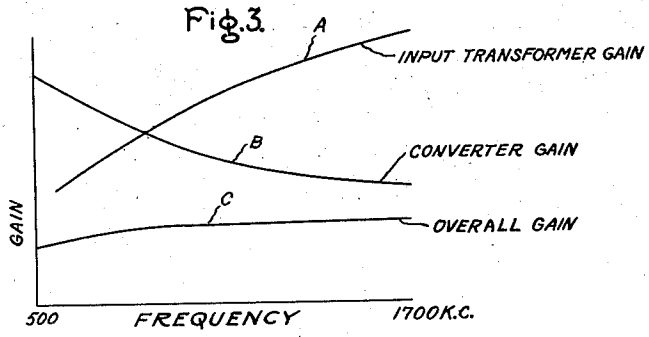


Fig.4.

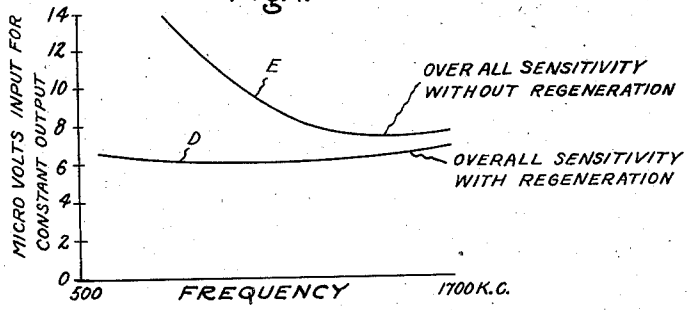


Fig.5.

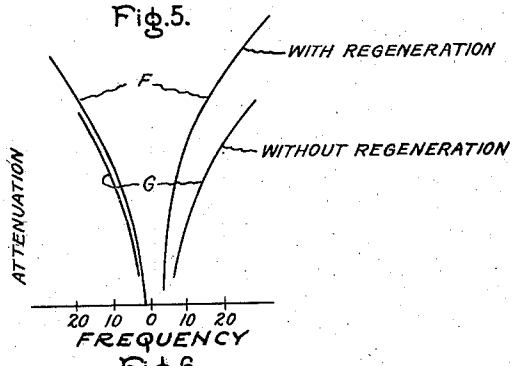
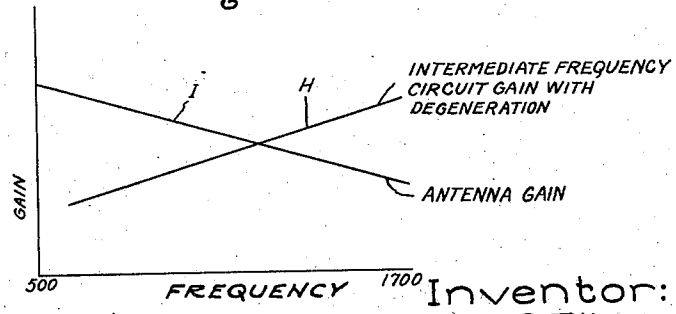


Fig.6.



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UNITED STATES PATENT OFFICE

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CONVERTER

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Application September 25, 1942, Serial No. 459,605

12 Claims. (Cl. 250—20)

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My invention relates to converters such as are used in superheterodyne receivers, and it has for one of its objects to effect certain improvements therein with respect to control of the gain had in such converters.

When employed in receivers for broadcast reception, as in household receivers, the signal input circuit and local oscillator circuit are tunable over corresponding ranges of frequency. The input circuit may be tunable, for example, from 550 kilocycles to 1700 kilocycles and the local oscillator from 1005 kilocycles to 2155 kilocycles giving a fixed intermediate frequency of 455 kilocycles.

It is desired in such receivers that the intensity of the intermediate frequency oscillations be constant throughout the range of such tuning.

An object of my invention is to provide improved means to reduce variations in the intensity of the intermediate frequency oscillations as the tuning of the circuit is varied.

A further object of my invention is to provide improved means to vary the gain had in the converter in a way to compensate for variations in gain had in the input circuit when the tuning is varied.

A further object of my invention is to utilize the effects of regeneration or degeneration as desired to effect such compensation and to vary such effects automatically with tuning.

Another object of my invention is to provide such means without materially increasing the cost of the apparatus or complicating its adjustment.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 represents a diagram of an embodiment of my invention; Fig. 2 represents a plan view showing the relative arrangement of certain coils thereof; Figs. 3, 4 and 6 represent certain graphs illustrating gain characteristics of my invention; Fig. 5 represents certain graphs illustrating selectivity characteristics of my invention, and Fig. 7 is a diagram of a modified circuit.

Referring to Fig. 1 of the drawings, I have shown therein an electron discharge device 1 having a cathode 2, control electrode 3, a screen

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electrode 4, a further control electrode 5, a further screen electrode 6, a suppressor electrode 7 and an anode 8. Radio frequency oscillations to be converted by the discharge device 1 may be intercepted by means of an antenna 9 and supplied between the control electrode 5 and cathode 2 by means of a coupling comprising condenser 10 and coils 11 and 12. The coils 11 and 12 are connected in series between the control electrode 5 and the cathode through a condenser 13 and an inductance coil 14, and the antenna 9 is connected through condenser 10 at a point between coils 11 and 12 whereby the coils 11 and 12 act as an autotransformer stepping up the oscillations received on the antenna 9 and impressing them between the control electrode 5 and the cathode. The input circuit of the converter comprising coils 11 and 12 may be tuned to the frequency of oscillations to be received by means of a variable tuning condenser 15. If desired, this condenser may be shunted by means of trimming condenser 16, as is common in the practice of such devices.

The local oscillator of this converter comprises a tuned frequency determining circuit including inductance 14 and inductance 17 across which is connected a tuning condenser 18, the latter of which may also be shunted by a trimming condenser 19. The tuning condenser 18 may be uni-controlled with the condenser 15 in the usual way, as indicated by the dotted lines at 20. The cathode 2 of the discharge device is connected to a point intermediate the inductances 14 and 17, one terminal of the frequency determining circuit being connected to the control electrode 3 through the usual grid leak 21 and grid condenser 22, these elements being proportioned to provide a suitable operating bias upon the control electrode 3. The opposite terminal of the frequency determining circuit is connected through by-pass condenser 23 to the screen electrodes 4 and 6 of the discharge device.

Thus, the circuit 14, 17, 18 and 19 having its intermediate point connected to the cathode, and having one terminal connected to the screen electrode and the other to the control electrode, provides the required feedback between the screen electrode 4 acting as an anode and the control electrode 3 to support oscillations in the local oscillating circuit. These oscillations have their frequency controlled by the tuning condenser 18. Such oscillations combine with the oscillations received by the antenna 9 in the converter to produce oscillations in the output circuit of the discharge device 1 having a frequency equal to the

difference in the frequency of the local oscillations and the received signals.

This output circuit comprises the primary winding **24** of an intermediate frequency transformer, which is tuned to the frequency of the intermediate frequency oscillations by means of a trimming condenser **25**. The secondary winding **26** of this transformer is also tuned to the same frequency by means of condenser **27**. Oscillations supplied through the transformer **24, 26** may be amplified and ultimately rectified to reproduce the modulations present thereon which, of course, may be of voice or music frequency or other type of signal as desired.

Anode operating potential for the discharge device may be supplied across by-pass and smoothing condenser **23** as indicated by the plus and minus signs shown on the drawings, the negative terminal of this source being grounded as indicated at **30**. Suitable bias for the control electrode **5** of the discharge device may be supplied through conductor **31** and resistance **32**. This conductor **31** may extend to the output of a signal rectifier in the receiver and have impressed thereon a negative unidirectional voltage varying in intensity with the intensity of the received signals thereby to produce automatic volume control. The resistance **32** is proportioned with respect to condenser **13** to act as a filter to suppress any audio frequency variations which may appear in the bias voltage supplied by conductor **31**. This bias voltage is also supplied over conductor **33** through the secondary winding of transformer **24, 26** to the input electrode of a subsequent amplifier which may be connected to receive oscillations from the transformer **24, 26**.

In accordance with my invention, the windings **14, 17** and **24** may be arranged in inductive relation with each other so that oscillations of the intermediate frequency present in the winding **24** are induced in the windings **14** and **17** and are thus impressed upon the input electrode **3** of the discharge device. To this end these windings may be arranged coaxially on a single form **28** as shown in Fig. 2. Thus the oscillating circuit **14, 17, 18** and **19** and the coupling between inductances **14, 17** and **24** serves as a feedback path for the converter operable at the intermediate frequency to produce regeneration, or degeneration, as may be desired in accordance with the polarity of the coupling. The extent of such regeneration or degeneration is, of course, dependent upon the efficiency with which oscillations of the intermediate frequency are supplied through the circuit **14, 17, 18, 19** to the input of the discharge device, and this transmission efficiency, in turn, is, of course, dependent upon the frequency to which the local oscillating circuit is tuned. That is, the transmission efficiency of this oscillating circuit at the intermediate frequency varies as the tuning of this circuit is varied from one end of its tuning range to the other. This variation in transmission efficiency may be taken advantage of to control the regeneration or degeneration to an extent sufficient to compensate for variation in the transmission efficiency of the input system comprising antenna **9**, condenser **10**, and windings **11** and **12**, thereby to reduce variations in the intensity of intermediate frequency oscillations in transformer **24, 26** with variation in the tuning of the receiver.

For example, the input circuit **11, 12, 15, 16** may be tunable over a range extending from 550 kilocycles to 1700 kilocycles if the receiver be one used for ordinary home broadcast reception, for example, and the local oscillator circuit **14, 17, 18, 19** may be tunable in unison therewith over a range extending from 1005 kilocycles to 2155 kilocycles giving a fixed intermediate frequency in transformer **24, 26** of 455 kilocycles throughout the range. Winding **12** may tune with the capacity across it at a frequency above 1700 kilocycles with the result that the transmission efficiency of the input circuit increases as the frequency to which the circuit tunes is increased. At the same time, the circuit **14, 17, 18, 19** is tuned to a frequency increasingly removed from the intermediate frequency 455 kilocycles and thus its transmission efficiency to intermediate frequency currents is progressively reduced. These opposite effects tend to maintain a constant intensity of oscillation in the transformer **24, 26** throughout the tuning range.

This effect is illustrated in Fig. 3, the curves of which represent gain plotted as ordinates against frequency to which the receiver is tuned plotted as abscissa. The curve A represents the gain of the input system between antenna **9** and the control electrode **5**. It will be seen that it rises steadily with increase in frequency throughout the frequency range to which the receiver is tunable.

Curve B represents the gain in the converter itself and it will be seen that it decreases with increase in the frequency to which the receiver is tunable. This is brought about by reason of the reduced regeneration secured by reason of reduced transmission of the intermediate frequency oscillations through the circuits of the local oscillator to the input of the converter as the frequency of the local oscillator is increased.

Curve C represents the gain of the receiver between antenna **9** and transformer **24, 26**. It will be seen that this gain is substantially constant throughout the frequency range.

Fig. 4 represents certain sensitivity characteristics pertaining to my invention, these curves showing the relation between the input voltage necessary to produce a constant output from the system and the frequency to which the receiver is tuned. The curve D represents the characteristics secured by the use of regeneration supplied through the circuits of the local oscillator as previously described. This curve is substantially flat, indicative of constant sensitivity of the receiver throughout the tuning range. Curve E represents the sensitivity without regeneration. It will be seen that this curve rises toward the lower frequency, indicating reduced sensitivity at the lower frequencies.

Regeneration, employed as provided in accordance with my invention, also has the effect of very materially increasing the selectivity of the system. Fig. 5 represents certain characteristics showing this increased selectivity secured by my invention. These curves are plotted in terms of variation of the intermediate frequency from 455 kilocycles in either direction over a range of 20 kilocycles plotted against attenuation as ordinates. Curves F represent the attenuation of the converter as the intermediate frequency is varied from 455 kilocycles in either direction over the range of 20 kilocycles, these curves corresponding to the condition when regeneration is provided in accordance with my invention. Curves G, on the other hand, correspond to the selectivity present when no regeneration is employed.

It will be seen that the attenuation with variation in frequency is very greatly increased by the presence of the regeneration.

Of course, if desired, the oscillations supplied back to the input circuit from the output circuit may be supplied in degenerative phase rather than regenerative phase. The effect of such degeneration up the selectivity of the receiver is the opposite of that produced by regeneration and tends to broaden the band width of oscillations transmitted through the system.

This degeneration also has the opposite effect with respect to control of the gain of the converter, increasing the gain as the frequency is increased. This is shown by the curve H of Fig. 6, which shows the gain of the receiver plotted as ordinates against frequency plotted as abscissa. Such a characteristic may be advantageous in a receiver in which the input circuit has a gain characteristic such as that indicated at I in Fig. 6. This may occur if the winding 12, for example, be one having a natural frequency below 550 kilocycles.

The feedback from transformer 24, 26 through windings 17 and 14 to the input of the discharge device may be secured capacitively rather than inductively as illustrated in Fig. 7. Fig. 7 is similar to Fig. 1 but differs therefrom in that capacitance 34 is shown connected between the upper terminals of coils 24 and 17 for capacitive feedback. This capacitance may be a condenser connected as shown or may comprise the inherent capacity between coils 24, 17 and 14. These coils may be poled so that such feedback is degenerative or regenerative as desired.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto since various modifications both in the circuit arrangement and in the instrumentalities employed may be made, and I contemplate by the appended claims to cover such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The combination, in a superheterodyne receiver, of a signal input circuit, a locally excited oscillatory circuit, a converter having an intermediate frequency output circuit, means to supply oscillations from said signal input circuit and from said locally excited oscillatory circuit to said converter to beat in said converter to produce oscillations of intermediate frequency in said intermediate frequency output circuit, and means to control the gain between said signal input circuit and said intermediate frequency output circuit, said means comprising means to supply oscillations of said intermediate frequency to said locally excited oscillatory circuit and thence to said converter in phase to produce desired control of the gain of said converter.

2. The method of controlling the gain of a superheterodyne converter which produces oscillations of intermediate frequency from signal oscillations combined with oscillations supplied thereto from a local oscillator which comprises supplying oscillations of said intermediate frequency to said local oscillator and thence to said converter in such phase and intensity as to produce desired control of said gain.

3. The method of controlling the gain of a superheterodyne converter which produces oscillations of intermediate frequency from signal oscillations combined with oscillations supplied thereto from a local oscillator which comprises supplying oscillations of said intermediate frequency to said local oscillator and thence to said converter in such phase and intensity as to produce desired control of said gain and varying the intensity of oscillations of said intermediate frequency supplied through said local oscillator to said converter by varying the frequency of the oscillations produced by said local oscillator.

4. The combination, in a superheterodyne receiver, of a converter having an output circuit tuned to the intermediate frequency to be produced, a local oscillator having a frequency determining circuit, a signal input circuit, said signal input circuit and local oscillator being tunable over respective ranges and being connected to supply oscillations to said converter of frequency different by the amount of said intermediate frequency, and a feedback path for said converter for currents of said intermediate frequency, said path extending from said output circuit to said frequency determining circuit and thence to said converter, said feedback path including said frequency determining circuit, and means to supply said intermediate frequency oscillations to said converter in such phase relation to said intermediate frequency oscillations in said output circuit as to produce desired change in gain of said converter with variation in tuning of said signal input circuit and local oscillator over said ranges.

5. The combination, in a superheterodyne receiver, of a converter having an output circuit for currents of intermediate frequency, a signal input circuit, a local oscillator having a frequency determining circuit, said signal input circuit and frequency determining circuit being tuned to frequences different by said intermedate frequency and being tunable over corresponding ranges of frequency, a feedback path for said converter comprising a coupling for oscillations of intermediate frequency between said output circuit and said frequency determining circuit whereby oscillations of said intermediate frequency are supplied through said coupling and said frequency determining circuit to said converter to control the gain thereof, and the intensity of said feedback oscillations is varied by the tuning of said frequency determining circuit, said feedback path being constructed and arranged to supply said intermediate frequency oscillations in such phase relation to said intermediate frequency oscillations in said output circuit as to produce desired control of the gain of said converter with said variation in tuning of said frequency determining circuit.

6. In a converter for superheterodyne receivers having a local oscillator circuit tunable over a range of frequencies and an output circuit tuned to a fixed frequency, the method of controlling the gain of said converter which comprises supplying oscillations of said fixed frequency from said output circuit to said tunable local oscillator circuit for transmission to said converter with the local oscillations generated thereby and regulating the intensity of said fixed frequency oscillations so transmitted by varying the tuning of said local oscillator over said range to produce desired gain of said converter over a range of frequencies corresponding to the tuning range of said local oscillator circuit.

7. The combination, in a superheterodyne receiver, of a converter having an output circuit for currents of intermediate frequency, a signal input circuit and a local oscillator circuit tuned to frequencies different by said intermediate frequency and tunable over respective ranges, the

efficiency of transmission through said input circuit varying from one end of said range to the other, a feedback path for currents of intermediate frequency including said local oscillator circuit and a coupling from said output circuit to said local oscillation circuit, the efficiency of transmission of currents of intermediate frequency through said path varying with the tuning of said local oscillator over said range, said variations in transmission being proportioned relative to each other to reduce variation in the intensity of intermediate frequency oscillations in said output circuit during tuning of said input and local oscillator circuits over said ranges.

8. The combination, in a superheterodyne receiver, of a signal input circuit, a local oscillator circuit, a converter having an intermediate frequency output circuit, means to supply oscillations from said input circuit and local oscillator circuit to said converter, means to supply oscillations of said intermediate frequency from said output circuit through said local oscillator circuit to said converter in regenerative phase, and means to vary the tuning of said signal input circuit and said local oscillator circuit in unison to maintain constant said intermediate frequency and simultaneously to vary oppositely the transmission efficiency of said input circuit to signal currents and that of said local oscillator circuit to intermediate frequency currents thereby to maintain currents of said intermediate frequency of constant intensity.

9. The combination, in a superheterodyne receiver, of a signal input circuit, a local oscillator circuit, a converter having an intermediate frequency output circuit, means to supply oscillations from said input circuit and local oscillator circuit to said converter, means to supply oscillations of said intermediate frequency from said output circuit through said local oscillator circuit to said converter in degenerative phase, and means to vary the tuning of said signal input circuit and said local oscillator circuit in unison to maintain constant said intermediate frequency and simultaneously to vary oppositely the transmission efficiency of said input circuit to signal currents and that of said local oscillator circuit to intermediate frequency currents thereby to maintain currents of said intermediate frequency of constant intensity.

10. The combination, in a superheterodyne receiver, of a signal input circuit, a local oscillator circuit, a converter having an input circuit and an intermediate frequency output circuit, means to supply oscillations from said signal input circuit and local oscillator circuit to the input of

said converter, and means to supply oscillations of said intermediate frequency from said output circuit to said local oscillator circuit and thence to said converter with intensity to produce desired selectivity of said receiver.

11. The combination, in a superheterodyne receiver, of an electron discharge device having an anode, a cathode, and a plurality of control electrodes, an output circuit between said anode and cathode, an oscillatory circuit connected to said cathode and at least one of said control electrodes to have oscillations excited therein, an input circuit connected between one of said control electrodes and said cathode and tuned to a frequency different from the frequency to which said oscillatory circuit is tuned, means to vary the tuning of said input circuit and oscillatory circuit over corresponding ranges of frequencies in unison, whereby oscillations of intermediate frequency are produced in said output circuit, said oscillations of intermediate frequency being subject to variation in intensity with said variation in tuning, and a feedback path for oscillations of said intermediate frequency including said oscillatory circuit, said path being so poled with respect to said intermediate frequency and so affected by said variation in tuning of said oscillatory circuit as to reduce said variation in intensity of said intermediate frequency oscillations with variation in said tuning.

12. The combination, in a superheterodyne receiver, of a pentagrid converter having an output circuit, a tuned signal input circuit, and a local oscillatory circuit all connected to respective electrodes thereof, said converter exciting oscillations in said oscillatory circuit to be combined with oscillations received in said input circuit to produce intermediate frequency oscillations in said output circuit, and a coupling for intermediate frequency oscillations between said output circuit and said oscillatory circuit, whereby intermediate frequency oscillations are supplied from said output circuit back through said oscillatory circuit to said converter with intensity varying with the tuning of said oscillatory circuit, means to vary the tuning of said input and oscillatory circuits in unison, said input circuit having gain variable with tuning, the variation in gain of said input circuit and the variation in intensity of said intermediate frequency oscillations supplied back through said oscillatory circuit to said converter being so related to each other as to produce desired intensity of oscillations in said output circuit for all variations in said tuning.

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