

April 11, 1939.

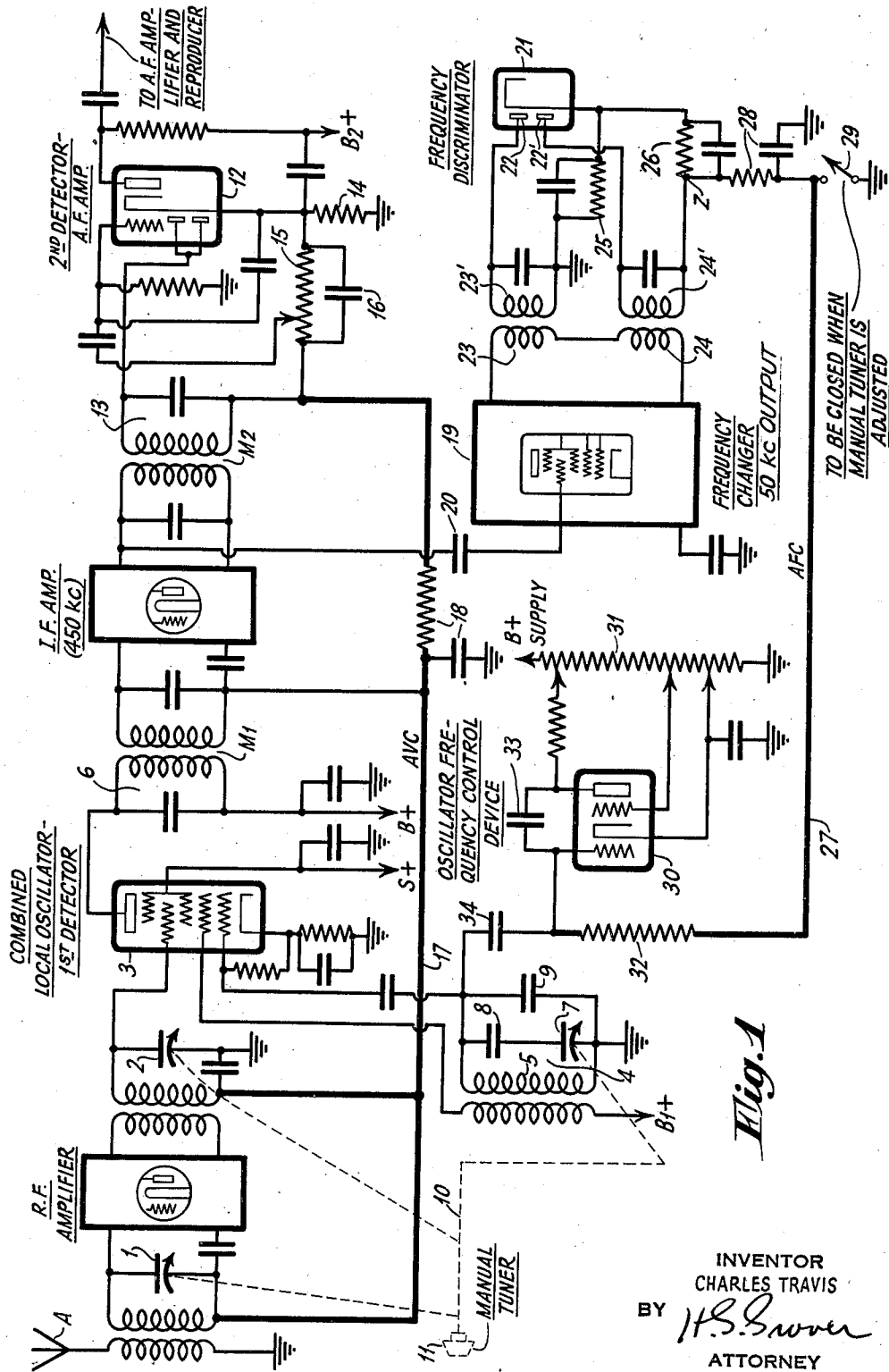
C. TRAVIS

2,153,779

AUTOMATIC OSCILLATOR FREQUENCY CONTROL SYSTEM

Original Filed Feb. 4, 1935

4 Sheets-Sheet 1



April 11, 1939.

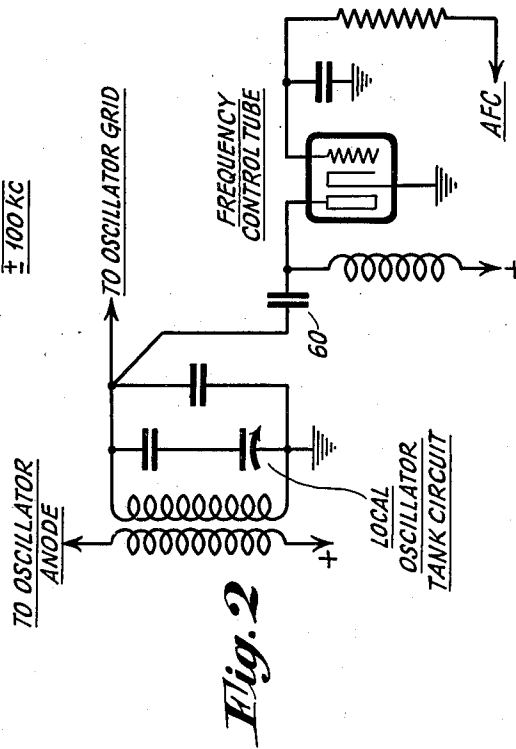
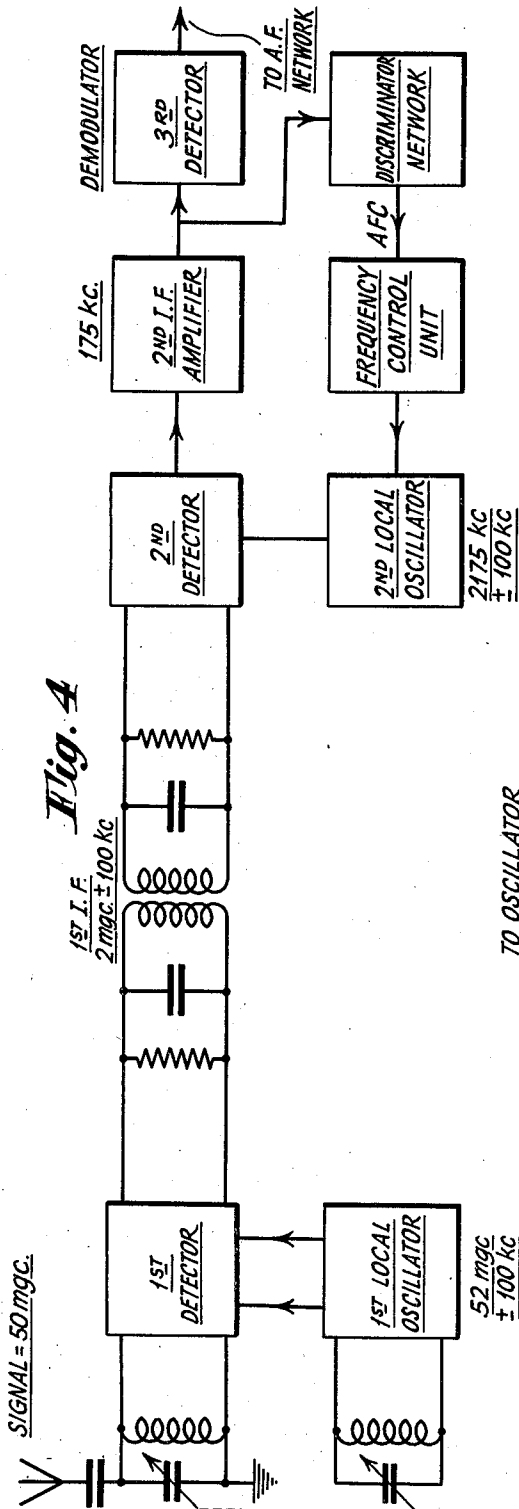
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2,153,779

AUTOMATIC OSCILLATOR FREQUENCY CONTROL SYSTEM

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4 Sheets-Sheet 2



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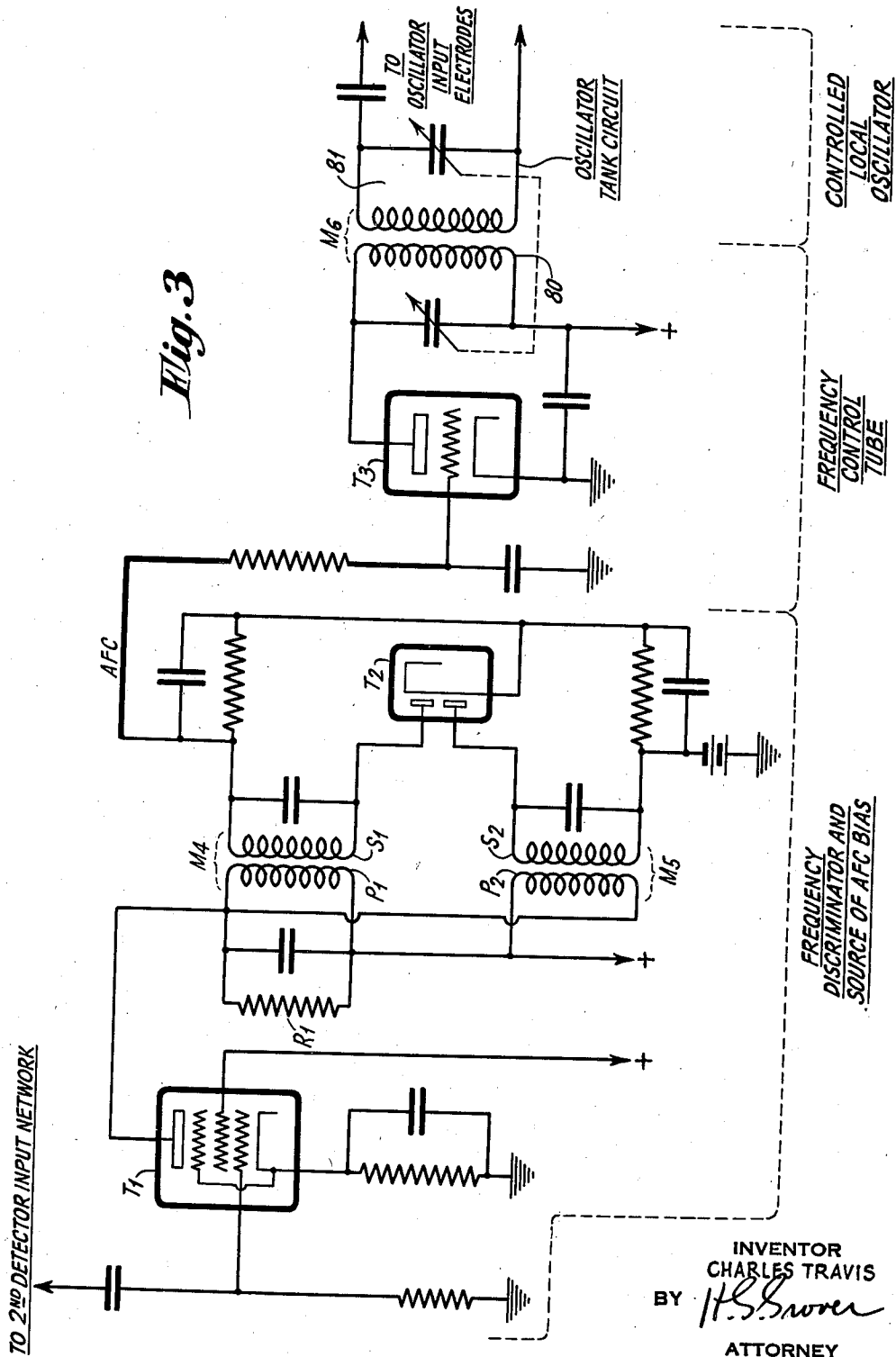
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AUTOMATIC OSCILLATOR FREQUENCY CONTROL SYSTEM

Original Filed Feb. 4, 1935

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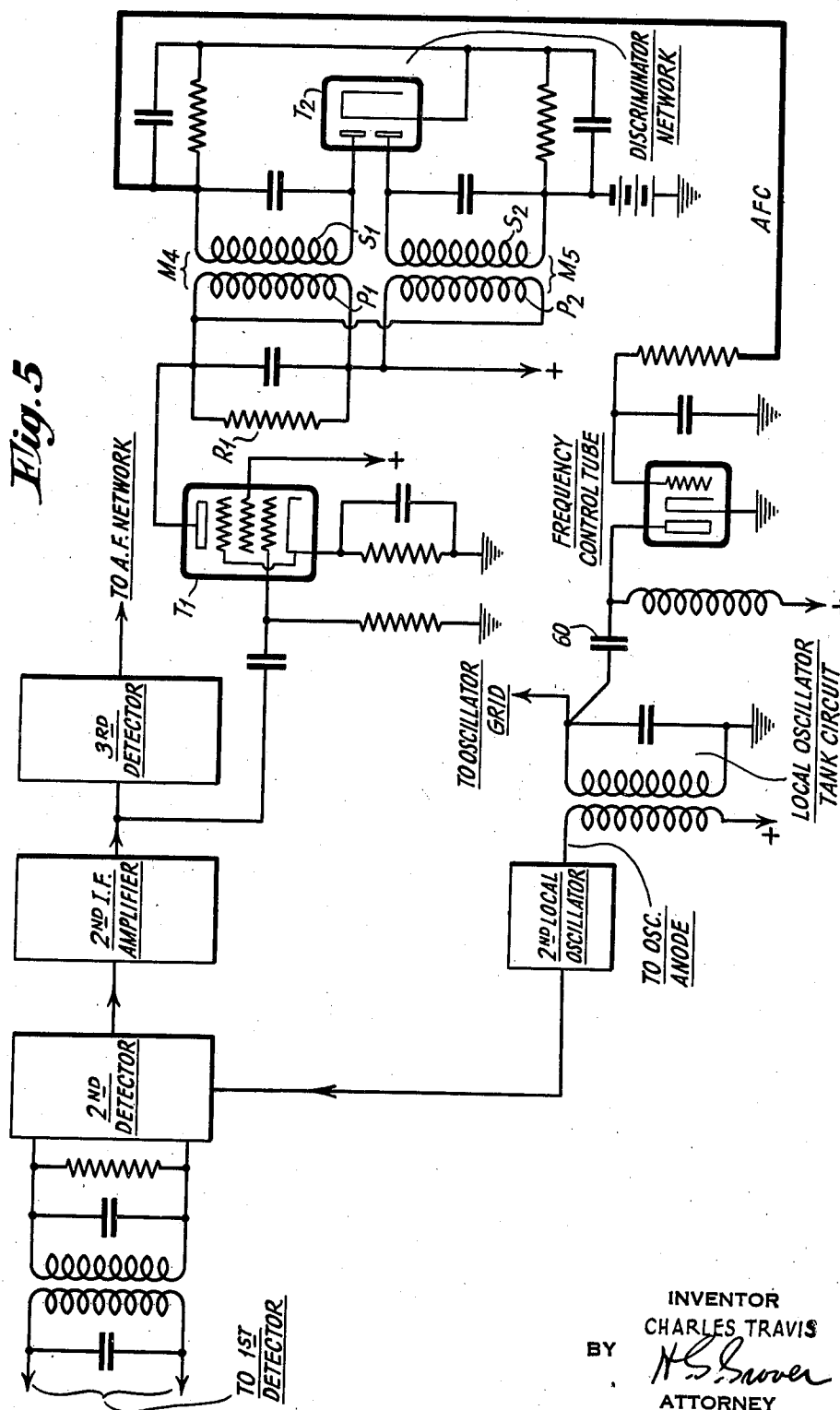
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2,153,779

AUTOMATIC OSCILLATOR FREQUENCY CONTROL SYSTEM

Original Filed Feb. 4, 1935 4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,153,779

AUTOMATIC OSCILLATOR FREQUENCY
CONTROL SYSTEM

Charles Travis, Philadelphia, Pa., assignor to
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of Delaware

Original application February 4, 1935, Serial No.
4,793. Divided and this application December
12, 1936, Serial No. 115,562

9 Claims. (Cl. 250—20)

My present invention relates to superhetero-
dyne receivers, and more particularly to improved
methods of, and means for, automatically stab-
ilizing the frequency of the local oscillator of
a receiver of the superheterodyne type. This
application is a division of application Serial No.
4,793, filed February 4, 1935.

The modern superheterodyne receiver is often
used under conditions such that the local oscil-
lator frequency, at any setting of the manually
operated tuner, tends to shift. Local oscillator
frequency shift may be due to thermal changes
as well as line voltage fluctuations. It is inher-
ent in the superheterodyne principle that the ac-
curacy with which tuning must be performed and
maintained is directly proportional to the sig-
nal frequency. Present day short wave super-
heterodyne receiver design, for example, is not
entirely adequate in regard to this accuracy. To
keep the intermediate frequency within the mid-
dle ten percent of a 10 k. c. pass band is not
particularly difficult at broadcast frequencies
(550 to 1500 k. c.). However, at 20 megacycles
it requires an oscillator stability of one part in
40,000. This is equivalent to fair crystal con-
trol without temperature compensation. At 20
megacycles local oscillator variations due to ther-
mal effects and line voltage fluctuations amount
to many kilocycles; in fact, frequency drifts of
40 or 50 k. c., are too often encountered.

Automatic frequency control (AFC) has been
proposed in the past to regulate the local oscil-
lator frequency. The utility of such a system in
connection with a short wave receiver is readily
appreciated when it is pointed out that even a
moderately successful AFC system in such a case
would greatly reduce the potential frequency
drift. A ratio of 25 to 1 would keep the signal
carrier well within the I. F. pass band for a
potential drift of as much as 50 k. c. It will be
recognized that the desired station would not be
entirely lost even though quality would suffer due
to lack of alignment with the carrier.

For superheterodyne receivers used in the
broadcast band the AFC system has many uses.
Fine manual tuning required in high fidelity re-
ceivers to obtain best results could be avoided
with such a system. The AFC, in general, may
be said to be highly desirable for use in a super-
heterodyne receiver employed in a manner such
that accurate tuning is important. In connec-
tion with remote tuning control systems an AFC
system will be found valuable in providing the
final adjustment that the remote control system
is unable to effect.

Now, I have found, after investigation and ex-
perimentation, that an AFC system for a super-
heterodyne receiver should comprise a device,
having frequency discrimination, which is capa-
ble of producing a control bias dependent upon
the frequency of the intermediate frequency car-
rier, and an electronic local oscillator frequency
control network, operated by the control bias, for
adjusting the local oscillator frequency in a sense
such that it differs from a desired signal fre-
quency by the established intermediate frequency.

It may, therefore, be stated that it is one of
the main objects of the present invention to pro-
vide an automatic frequency control for a local
oscillator, wherein the control includes a dis-
criminator network comprising a pair of differ-
entially connected rectifiers which are mistuned
by equal amounts above and below the mid-
channel frequency of the intermediate frequency
band; the discriminator functioning to provide
a direct current bias voltage which is dependent
upon the mid-channel frequency, and the bias
voltage being utilized to vary an electrical char-
acteristic of an electron discharge device in a
manner such that the local oscillator frequency
is adjusted to a desired value.

Still another object of the invention is to im-
prove automatic frequency control systems for
superheterodyne receivers, the improvement com-
prising the reduction of the intermediate fre-
quency to a lower frequency, the derivation from
the lower intermediate frequency energy of a
control bias dependent in magnitude upon the
lower frequency, and the employment of the con-
trol bias to regulate the magnitude of an elec-
tronic reactance in a sense to adjust the local
oscillator frequency to a desired value.

And still other objects of the invention are to
improve generally the efficiency of tuning of
superheterodyne receivers, whether of the broad-
cast or short wave type, and more especially to
provide automatic local oscillator frequency con-
trol systems for such receivers which are not
only durable and reliable in operation, but read-
ily manufactured and assembled in radio re-
ceivers.

The novel features which I believe to be char-
acteristic of my invention are set forth in par-
ticularity in the appended claims, 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 drawings in which I have
indicated diagrammatically several circuit or-

ganizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows one embodiment of the invention,

Fig. 2 shows a modification of the local oscillator frequency control device used in Fig. 1,

Fig. 3 shows a modified form of an AFC system,

Fig. 4 schematically represents an AFC system applied to a superheterodyne receiver utilizing triple detection, and

Fig. 5 shows the system of Fig. 4 when employing the discriminator of Fig. 4 and the control device of Fig. 2.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 a circuit diagram of a superheterodyne receiver employing an AFC system. The receiver is of a conventional type well known to those skilled in the art, and comprises a signal collector A, such as a grounded antenna circuit, coupled to a radio frequency amplifier having a variable tuning condenser device 1 in its input network. The amplifier may consist of more than one stage, and in such case the input of each stage would include a variable tuning condenser. The amplifier output is coupled to the tunable signal input circuit of the converter network, the input circuit including the variable tuning condenser 2.

The converter network comprises a tube 3 known in the art as a pentagrid converter tube, also designated as a 2A7 type tube (or 6A7 when used for automobile receivers); the tube is designed to perform simultaneously the functions of a first detector and local oscillator. Since the particular construction of tube 3, and its circuits, is not a part of this invention, only a brief description will be given of the circuits thereof. The tunable signal circuit of tube 3 is connected between the signal grid and the grounded cathode. The local oscillator section of the network comprises the local oscillator tank circuit 4 connected between the grounded cathode and the first grid functioning as the local oscillator grid.

The second grid of tube 3 is magnetically coupled to the coil 5 of the tank circuit 4, and the second grid therefore functions as the oscillator anode. The third and fifth grids act as screen grids for the fourth, or signal, grid. The resonant circuit 6 disposed in the plate circuit of tube 3 is tuned to the operating intermediate frequency. The tank circuit 4 includes in addition to the variable tuning condenser 7, the padding condensers 8, 9 which function to keep the tuning of the tank circuit 4 "tracked" with that of the signal circuits.

The rotors of condensers 1, 2, 7 are arranged for mechanical uni-control, and the dotted lines 10 represent such control. A "manual tuner" knob 11 is used to adjust the rotors from the operating panel of the receiver. It is sufficient for the purposes of this application to explain that the condenser 7 tunes the tank circuit 4 through an oscillator frequency range differing at all times from the common signal frequency range of the amplifier and converter input circuits by the frequency of the circuit 6. For illustrative purposes the operating I. F. is assumed to be 450 k. c. It is to be clearly understood, however, that in place of the composite converter network there may be employed independent first detector and local oscillator tubes in a manner well known in the art. Further, the signal frequency range

may be the broadcast range, or it may be a short wave band.

The intermediate frequency energy in circuit 6 is transmitted to the diode second detector circuit of multiple duty tube 12 through a network including an I. F. amplifier. The latter may include one, or more, amplification stages, and is provided with an input transformer M₁ having its primary and secondary circuits each resonated to the intermediate frequency; the output transformer M₂ is similarly designed. Both transformers are designed to pass substantially uniformly a band of frequencies including the carrier and its modulation side band frequencies. The tuned secondary circuit 13 of transformer M₂ is the input circuit of the diode second detector network.

The tube 12 is of the duplex diode-triode type, also well known in the art as a tube of the 55 or 2A6 type; although it is to be understood that a pentode section may be used in place of the triode section of tube 12 (2B7 and 85 types). The diode anodes of tube 12 are strapped together, and connected to the cathode side of grounded bias resistor 14 through a path including circuit 13 and load resistor 15, the latter being shunted by a radio frequency by-pass condenser 16. The triode section of tube 12 has its control grid coupled to a desired point on load resistor 15 for deriving therefrom the audio component of the rectified intermediate frequency current. The amplified audio component in the plate circuit of tube 12 is then utilized in any desired manner.

The direct current component of the voltage developed across resistor 15 is used for AVC purposes. This may be accomplished in any manner well known in the art. By way of illustration the lead 17, designated as "AVC", is shown connected from the diode anode side of resistor 15 to the signal grid circuits of the radio frequency amplifier, the converter, and the intermediate frequency amplifier. The usual pulsating current filter elements 18, comprising a resistor and condenser, are disposed in the AVC connection. Those skilled in the art are fully aware of the mode of operation of the AVC system. As the received signal amplitude increases, the signal grids of the controlled tubes are biased increasingly negative thereby reducing the gain of these controlled tubes. In this way the signal input to the second detector is maintained substantially constant over a wide range of signal amplitude variation at the antenna A.

It is to be understood that the controlled tubes can be progressively decreased in AVC bias. This is the method of AVC biasing employed at the present time; a tube receiving less signal energy thus has applied to it stronger AVC bias. Again, the AVC bias may be derived from a separate diode rectifier; or from a point preceding the detector input circuit 13 whereby there will be less selectivity to the AVC rectifier than to the detector. These arrangements are all well known in the art. The specific type of AVC circuit employed in the receiver is immaterial; the essential thing is that such a system coact with the AFC system hereinafter described to produce satisfactory local oscillator frequency control.

To secure automatic control of the frequency tank circuit 4 there is employed a network comprising a "frequency changer" adapted to reduce the 450 k. c. I. F. to an I. F. of 50 k. c. The lower I. F. is then impressed upon a "frequency discriminator" which functions to pro-

duce a control bias dependent in magnitude upon the lower I. F. The control bias is used to regulate the effect of an electronic device upon the tuning of the tank circuit 4.

Considering, now, the AFC system from a specific viewpoint, the converter 19 is of the same type as that shown in connection with tube 3. The I. F. energy is impressed upon the signal grid through coupling condenser 20, and the local oscillation network (not shown) is tuned to a frequency of 500 k. c. Thus, there is produced in the plate circuit of tube 19 a reduced I. F. of 50 k. c. Those skilled in the art will be capable of constructing the circuit details of network 19 from the disclosed circuits associated with tube 3. The plate circuit of network 19 is coupled to the frequency discriminator network, the latter including an electron discharge tube of the duo-diode type.

The tube 21 may be of the type shown in connection with the tube 12; in that case the grid and plate will be left free and only the diode anodes 22 and 22' are used. The plate circuit of tube 19 includes a pair of coils 23, 24 arranged in series. Coil 23 is coupled to resonant circuit 23'; the latter is tuned to one side of the I. F. of 50 k. c. by a predetermined frequency amount. Thus, circuit 23' is turned to 49 k. c. Coil 24 is coupled to resonant circuit 24'; the latter being tuned to the other side of the I. F., as for example to 51 k. c. The diode anode 22 is connected to the cathode of tube 21 through a series path including circuit 23' and resistor 25, the latter being shunted by a by-pass condenser, and the low alternating current side of circuit 23' being grounded.

The diode anode 22' is connected to the cathode of tube 21 through a series path including a circuit 24' and resistor 26, the latter being shunted by a by-pass condenser. The anode side of resistor 26 has connected to it a lead 27, designated as "AFC"; the lead comprising the path through which the control bias developed in the discriminator is applied to the electronic frequency control device. The lead 27 includes a resistor-condenser network 28 which functions to suppress pulsating components in the control voltage transmitted through lead 27. A grounded switch 29 is connected to lead 27, and its function will be explained in detail at a later point.

The device which functions to change the tuning of the tank circuit 4 comprises an electronic reactance element. It includes an electron discharge tube 30, which may be, for example, of the screen grid type. A bleeder resistor 31, grounded at one end and connected at the other end to the +B side of the receiver voltage supply source, furnishes the requisite operating potentials of the electrodes of tubes 30. The lead 27 is connected to the control grid of tube 30 through a resistor 32, and a condenser 33 of a predetermined magnitude is connected between the control grid and anode of the tube. The control grid of the latter is also connected to the oscillator grid side of tank circuit 4 through a blocking condenser 34.

The operation of the AFC system shown in Fig. 1, as well as the characteristics of the component units thereof, will now be explained. In general, the operation of the AFC system is dependent on a change in I. F. An undesired change of local oscillator frequency changes the response of the discriminator. This, in turn, causes a variation in the control bias fed to the

grid of tube 30. There results, as a consequence, a change in the reactance of the tank circuit 4 in a direction such as to restore the tank circuit frequency to the desired value. The essential elements of the system are the discriminator and the reactance control device.

Considering the characteristics of the discriminator, it can be stated that the latter should be constructed so that it will not be affected by adjacent channel signals. For this reason the frequency discriminator must be preceded by a certain amount of I. F. selectivity, and the input for the discriminator is therefore taken off somewhere at, or near, the end of the I. F. amplifier. The system shown in Fig. 1 utilizes a second frequency changer network to reduce the 450 k. c. I. F. to 50 k. c. This second I. F. of 50 k. c. is employed to get greater selectivity in the frequency discrimination device. The frequency discriminator itself is shown as comprising a pair of differentially connected diode rectifiers, the rectifiers being mistuned by equal amounts above and below the mid-channel frequency.

By utilizing the differentially connected rectifiers in the frequency discriminator network the output of the network depends solely on frequency of the carrier. A change in carrier amplitude in that case only affects the sensitivity of the control action. In spite of this a satisfactory AVC system is desirable. As stated before the diode rectifiers of the discriminator are connected differentially. That is to say, the difference of the rectifier outputs is utilized as the control bias to be transmitted through lead 27. Instead of employing diode rectifiers, it is possible to utilize in the balanced detector arrangement a pair of plate circuit detectors arranged in push-pull. However, it is more desirable to employ diode rectifiers, because such an arrangement gives the difference in output directly.

The point on resistor 26 to which lead 27 is connected is at a negative direct current potential with respect to ground when the input from circuit 24' is greater than that from circuit 23', and it will be positive with respect to ground in the reverse case. When the I. F. is exactly between the resonant frequencies of circuits 23' and 24', the inputs to the two rectifiers balance, and the point on resistor 26 to which lead 27 is connected will, therefore, be at ground potential. Accordingly it will be seen that the magnitude and polarity, with respect to ground, of the voltage of point Z on resistor 26 is wholly dependent upon the frequency value of the intermediate frequency energy produced in the plate circuit of tube 19.

The device which changes the frequency of the tank circuit 4 is shown in the system of Fig. 1 as being of the type comprising an electron discharge tube whose control grid to cathode capacity is utilized as a tuning condenser across tank circuit 4. Without entering into any extended and detailed discussion of the electrical characteristics of tube 30 and its associated circuits, it is pointed out that the effect of the condenser 33 connected between the control grid and anode of tube 30 is to augment the capacitive magnitude of the control grid to cathode capacity of tube 30. It has been shown that in such a network, variation of the bias of the control grid results in a variation in the magnitude of the control grid to cathode capacity.

Reference is made to application Serial No.

638,514 of Jacob Yolles, filed October 19, 1932, patented Oct. 15, 1935 as U. S. P. 2,017,270 for a disclosure of a voltage operated electronic condenser device which may be utilized, with suitable change of circuit constants for the purpose of the present invention. The magnitude of condenser 33 is chosen so as to furnish a control grid to cathode capacity suitable for adjustment of the frequency of tank circuit 4. It will be seen that this control grid to cathode capacity is connected in series with condenser 34, and both capacities are connected in shunt across the variable tuning condenser 7. Hence, by varying the bias of the control grid of tube 30 with respect to ground, there is secured a variation in the magnitude of the capacitive reactance which has been described as in shunt with tuning condenser 7. As the bias of the control grid of tube 30 is made negative, the gain of tube 30 is reduced, and the control grid to cathode capacity magnitude is diminished. This results because the magnitude of this capacity is dependent upon the gain of tube 30.

It will now be seen that a change in the frequency of the intermediate frequency energy, flowing in the plate circuit of tube 19, away from the lower I. F. frequency of 50 k. c. results in a simultaneous shift of the frequency of tank circuit 4. Of course, it will be understood that the change in the control grid to cathode capacity magnitude of tube 30 is to be in that direction which will cause the tank circuit frequency to be restored to its desired value. Those skilled in the art will be able to choose suitable constants for the circuits of the AFC system disclosed in Fig. 1 to suit the particular signal and oscillator frequency ranges employed.

Merely by way of example, let it be assumed that the signal frequency to which the set is tuned is 1500 k. c. In that case the frequency of the tank circuit 4 which is required in the production of the 450 k. c. I. F. is 1950 k. c. If, for some reason or other, the frequency of tank circuit 4 changes to 1951 k. c., there will be produced in the output circuit of the I. F. amplifier energy of 451 k. c. Since the second frequency changer is operating with a local oscillator frequency of 500 k. c., it follows that the second intermediate frequency energy, produced in the plate circuit of tube 19, will have a frequency of 49 k. c. Since this frequency of 49 k. c. is that of the circuit 23', the point Z will have a direct current potential which is positive with respect to ground, due to rectification in the rectifier circuit including diode anode 22.

As a consequence the bias of the control grid of tube 30 will be positive thereby increasing the gain of tube 30, and increasing the magnitude of the control grid to cathode capacity of tube 30. An increase in this control grid to cathode capacity magnitude results in an increase in the total capacity in the tank circuit 4; it therefore follows that the frequency of the tank circuit will be reduced. It will be understood that the constants of the oscillator frequency control device are so chosen that a change in frequency of the tank circuit away from the desired frequency value will result in the production of control bias at point Z in the discriminator network sufficient in magnitude to vary the control grid to cathode capacity of tube 30 in that sense which will restore the tank circuit frequency to the desired value. In the illustrative case given above, the control grid to cathode capacity of tube 30 will be increased to such a point that

the frequency of the tank circuit 4 will be decreased from 1951 k. c. to 1950 k. c. Those skilled in the art will readily be able to work out the circuit constants for the reverse case wherein the tank circuit frequency shifts to a value below the desired value.

A practical difficulty of the receiving system shown in Fig. 1 is found in the difficulty of dislodging a strong signal to make way for a weaker one on a closely adjacent channel, without having the weaker station jump right across the band to disappear on the other side. To overcome this difficulty the switch 29 is used; the function of the switch is to ground the bias voltage derived from point Z, and render the AFC system inoperative during tuning. After the signal has been tuned in the switch 29 may be opened, and the ground connection removed. The manner of closing switch 29 during tuning depends upon the construction of the controls of the receiver. If there are too many operating controls on the panel of the receiver, it will be advisable to mechanically couple switch 29 with the tuning knob 11 so that the switch 29 will be automatically closed when the operator's hand moves the tuning knob.

For example, the tuning knob may be depressible against a spring to close switch 29, and rotary motion of the tuning knob then instituted to vary the position of the rotors of the tuning condensers. Any other mechanical arrangement can be employed to keep the switch 29 closed during tuning of the receiver. If there are not many controls on the receiver panel, the switch 29 may be operated as a separate switch to be used only before tuning from one station to another one.

In Fig. 2, the frequency control tube has its plate impedance vary with the bias upon the grid. When coupled to the tank circuit through condenser 60 (whose reactance is equal to R_p), the frequency change of the tank circuit, in kilocycles, for a given proportionate variation in R_p is independent of frequency, and is fixed by the time constant of R_p and the tank tuning capacity. If the latter is made as small as possible, for example of the order of 20 mmf., and the R_p of the tube is 10,000 ohms, a ten percent change in the latter will produce a frequency shift of 20 k. c.

In Fig. 3 is shown another AFC system modification; both the discriminator network and frequency control unit being modified and different from those disclosed up to this point. A portion of the I. F. carrier voltage at the input of the second detector is impressed upon the grid of tube T₁. The receiver up to the second detector may be the same as that shown in Fig. 1. In the plate circuit of this tube the primaries P₁ and P₂, of two similar I. F. transformers M₄ and M₅ are connected in parallel, and tuned to the exact center of the I. F. band; the resonance curve of this composite primary is broadened by the shunt resistance R₁ of from 25,000 to 50,000 ohms. The secondaries S₁ and S₂ are tuned respectively at equal increments above and below the I. F. band mid-frequency.

Owing to the presence of R₁ across the common primary the latter is essentially a constant voltage source, and as there is no direct coupling between the two secondaries, the total effective coupling between the latter is negligible. The secondaries each operate into one of the anodes of double diode rectifier T₂ having a common cathode which is ungrounded for direct current.

This connection gives a direct current output which is the difference between the rectified voltages from the two diodes. At a frequency near the resonance of S_1 the output is negative, while at a symmetrical frequency near the resonance of S_2 it is positive.

It is necessary to separate the resonant points of the two secondaries S_1 and S_2 by a minimum amount approximately equal to the I. F. mid-band frequency divided by the

$$Q \left(\text{or } \frac{\omega L}{r} \text{ ratio} \right)$$

of the circuits. At 450 k. c., without considering losses introduced by the primary and by the diode load, a value of Q of 200 is about the highest that can be obtained in the usual size commercial I. F. coils. This corresponds to a minimum separation of 2.25 k. c. between the two secondary resonant points. After losses are accounted for, a separation of 4 or 5 k. c. would probably be excellent at this frequency. If a more selective discriminating device were necessary, recourse must be had to bulkier coils, or else a double heterodyne system used as in Fig. 1, the tube T_1 operating as a converter with its output circuit tuned to a new and lower second I. F., 50 k. c. for example. The output from the balanced rectifier network is impressed upon the grid of the control tube T_3 . This tube, by means of any of several possible forms of reactive coupling circuit, causes the frequency of the oscillator to vary in accordance with the AFC bias, tending to return the I. F. carrier to the center of the I. F. band.

In the arrangement of Fig. 3 the coupling reactance is an inductance; this takes the form of a coil loosely coupled to the oscillator tank inductance. The excess inductive admittance of this coil is tuned out by a variable condenser across the control tube. The coupling becomes the familiar case of loosely coupled resonant circuits. It is well known that if the tuned winding 80 is loosely coupled, as at M_a , to the tank circuit 81 of the local oscillator the frequency of the latter may be considerably changed by varying the tuning of the coil 80, and, other things being equal, the amount of variation depends upon the damping of the circuit including coil 80. For the present purpose the coil 80 is mistuned by a fixed amount, and the damping is varied by the variable shunt tube resistance. This method was experimented with in the 4 to 10 megacycle band, and it was found that a frequency variation of about one percent could be obtained over the whole band. It is pointed out that in this particular case one of the chief reasons for AFC would be to compensate for physical changes in the tank circuit due to thermal expansion, warpage and the like. The variable condensers in circuits 80, 81 are uni-controlled in order to keep the impedance reflected across the tank circuit a combination of a reactance and resistance of equal magnitude, or essentially so. This is the 45° condition, and results in no change in load on the tank circuit when the resistance is changed (electronically), and likewise maximum change in frequency. If the reactance and resistance were very unequal, there would be a small change in frequency and a relatively large change in load. The uni-control is not intended to tune the circuits to the same resonance point; the control circuit is tuned so that it was always reactive, by an amount equal in this case to the average R_p of the tube.

In Fig. 4 there is shown an AFC system applied to a receiver wherein is used the repeated application of the heterodyne principle, with the controlled oscillator operating at a fixed frequency, lower than that of the first tunable oscillator. Without the frequency control feature, this is equivalent to a short wave converter connected to the input of a receiver intended for a lower frequency band; in the present case the second unit is provided with fixed input tuning. In the circuit a signal frequency of 50 megacycles has been taken as a concrete example, and a nominal first I. F. of 2 megacycles has been assumed. It is further assumed that unwanted variations in the first oscillator may cause the actual I. F. to vary by +100 k. c. The coupling means between the output of the first converter and the input to the second is a band pass filter capable of passing 200 k. c. The second I. F. must be at least one half of this band width if image interference is to be avoided. The second I. F. of 175 k. c. is demodulated. It is also used for frequency control.

Thus, the discriminator and frequency control operate on the second local oscillator. Frequency drifts as high as 100 k. c. in either direction from 2175 k. c. will be corrected by the AFC system. Specifically, there may be employed in the AFC system of Fig. 4, the discriminator network of Fig. 3 followed by the frequency control unit of Fig. 2. For the purpose of this divisional application, there is shown in Fig. 5 the manner of employing the discriminator of Fig. 3 with the control device of Fig. 2 in the AFC system of Fig. 4. To preserve simplicity, the portion of the system of Fig. 4 preceding the first I. F. transformer is omitted.

This particular superheterodyne method is employed for the 50 megacycle signal range to provide a fixed nominal frequency for the oscillator to be controlled, it being simpler to control a non-tunable oscillator than one that is tunable over a wide range coverage band. A frequency in the neighborhood of 2 megacycles is shown for this second controllable oscillator as this seems to be optimum to obtain a wide AFC variation in k. c. A very low frequency is not good because a large percent change would be required, and a very high frequency is subject to a limitation from tube capacities.

While I have indicated and described several systems 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 organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What is claimed is:

1. In a superheterodyne receiver of the type comprising a pair of frequency changer networks arranged in cascade and a local oscillator connected to each of said frequency changers, the local oscillator connected to the second frequency changer being operated at a fixed frequency value and the local oscillator connected to the first frequency changer being tunable over a desired frequency range, an automatic frequency control system including a discriminator network having an input circuit connected to receive the second frequency changer output energy and adapted to produce a direct current voltage whose magnitude is dependent solely upon the frequency shift of the energy in the output of said second frequency changer from an assigned frequency value, and a frequency control device connected between the

fixed frequency oscillator and the discriminator network, responsive to said direct current voltage, for adjusting the resonance of said fixedly tuned local oscillator in a direction such as to compensate for said shift.

2. In a superheterodyne receiver of the type provided with a first detector having a signal input circuit including means for tuning it over a wide range of signal frequencies, a local oscillator having a circuit with means for tuning it over a range of frequencies differing from the first range by a desired intermediate frequency, means for simultaneously adjusting both said tuning means to select different signals, an intermediate frequency transmission network, a second detector having an input circuit, fixedly tuned to said intermediate frequency, coupled to the transmission network a second local oscillator circuit, operatively associated with the second detector and being fixedly tuned to a frequency differing from said intermediate frequency by a second intermediate frequency, a third detector circuit arranged to detect the second intermediate energy, and an automatic frequency control circuit for said fixedly tuned oscillator, said control circuit comprising an electron discharge device operatively associated with the second oscillator tank circuit to produce a reactance of predetermined sign and value thereacross, a discriminator network operatively associated with the second detector output circuit to derive a direct current voltage which depends in polarity and value upon the amount and direction of frequency shift of said second intermediate frequency from its fixed value, and means for applying said direct current voltage to said discharge device in a sense to vary said reactance value sufficiently to adjust the second oscillator tuning to compensate for said shift.

3. In a superheterodyne receiver of the type comprising a pair of frequency changer networks arranged in cascade and a local oscillator connected to each of said frequency changers, the local oscillator connected to the second frequency changer being operated at a fixed frequency value and the local oscillator connected to the first frequency changer being tunable over a desired frequency range, an automatic frequency control system including a discriminator network adapted to produce a direct current voltage whose magnitude is dependent solely upon the frequency shift of the energy in the output of said second frequency changer from an assigned frequency value, a frequency control device connected to the said fixed frequency oscillator, responsive to said direct current voltage, for adjusting the resonance of said fixedly tuned local oscillator in a predetermined direction, said discriminator network comprising a pair of diodes connected to rectify the second frequency changer output, each diode including a resistor in its space current path, and the voltages across the resistors being in polarity opposition to provide said direct current voltage.

4. In a superheterodyne receiver of the type comprising a pair of frequency changer networks arranged in cascade and a local oscillator connected to each of said frequency changers, the local oscillator connected to the second frequency changer being operated at a fixed frequency value and the local oscillator connected to the first frequency changer being tunable over a desired frequency range, an automatic frequency control system including a discriminator network adapted to produce a direct current voltage whose magnitude is dependent solely upon the frequency

shift of the energy in the output of said second frequency changer from an assigned frequency value, and a frequency control device, responsive to said direct current voltage, for adjusting the resonance of said fixedly tuned local oscillator in a predetermined direction, said control device comprising a tube having its plate impedance connected across the tank circuit of the fixedly tuned oscillator, and means for impressing the direct current voltage upon a gain control electrode of the control tube.

5. In a superheterodyne receiver of the type comprising a pair of frequency changer networks arranged in cascade and a local oscillator connected to each of said frequency changers, the local oscillator connected to the second frequency changer being operated at a fixed frequency value and the local oscillator connected to the first frequency changer being tunable over a desired frequency range, an automatic frequency control system including a discriminator network having an input circuit connected to receive the second frequency changer output energy and adapted to produce a direct current voltage whose magnitude is dependent solely upon the frequency shift of the energy in the output of said second frequency changer from an assigned frequency value, a frequency control device connected between the fixed frequency oscillator and the discriminator network, responsive to said direct current voltage, for adjusting the resonance of said fixedly tuned local oscillator in a direction such as to compensate for said shift, said tunable oscillator being adjustable to frequencies of the order of 50 megacycles, and said other oscillator being tuned to operate at a frequency of the order of 2 megacycles.

6. In a superheterodyne receiver, adapted to receive signals in the 50 megacycle range, comprising a first detector network provided with a signal input circuit including means for tuning the latter over said range, a local oscillator network having a tank circuit with means for tuning the latter over a range of frequencies differing from the first range by a desired operating intermediate frequency, means for simultaneously adjusting both said tuning means, an intermediate frequency transmission network, a second detector network provided with an input circuit, which is fixedly tuned to said intermediate frequency, coupled to said transmission network, a second local oscillator network operatively associated with said second detector network and being fixedly tuned to a frequency differing from said intermediate frequency by a second operating intermediate frequency, the magnitude of said fixed oscillator frequency being of the order of 2 megacycles, means for detecting the second intermediate frequency energy, an automatic frequency control circuit for said fixedly tuned oscillator network, said control circuit comprising a discriminator network operatively associated with said second detector network to derive a direct current voltage therefrom depending in polarity and magnitude upon the direction and amount of frequency shift of said second intermediate frequency from its operating value, and means for applying said direct current voltage to said fixed frequency oscillator network in a sense to adjust the frequency of said tank circuit to compensate for said frequency shift.

7. The method of selective reception of signal-modulated carrier waves which includes: selectively tuning to any desired one of a plurality of modulated signal waves; generating and com-

binning therewith a wave of approximately constant but incidentally variable frequency separation from the carrier frequency thereof to produce a modulated carrier wave of first intermediate frequency; broadly selecting the carrier wave of first intermediate frequency corresponding to said desired signal wave to permit normal deviations in the frequency of said carrier wave without substantial attenuation of the modulation frequencies thereof; generating and combining with said selected first intermediate-frequency carrier wave a second wave of substantially constant frequency to produce a modulated carrier wave of second intermediate frequency; modifying the frequency of said second generated wave within a range of a small per cent of its mean value in accordance with, and responsive to, predetermined deviations of the carrier frequency of said second intermediate-frequency wave from its normal frequency to restore it thereto; sharply selecting the carrier wave of second intermediate frequency corresponding to said desired signal wave; and thereafter converting and utilizing said modulated carrier wave of second intermediate frequency.

8. A tunable radio receiver comprising; a tunable first frequency changer for converting a selected signal wave into a first modulated intermediate-frequency carrier wave of approximately constant frequency; broadly selective means for selecting said first intermediate-frequency carrier wave while permitting normal deviations in the frequency thereof without substantial attenuation of the modulation frequencies thereof; an untunable second frequency changer for converting said selected first intermediate-frequency carrier wave into a second modulated intermediate-frequency carrier wave subject to minor deviations

from a given normal frequency; means responsive to said deviations of said second intermediate-frequency carrier wave for modifying the tuning of said second frequency changer to restore the frequency of said second intermediate-frequency carrier wave to said given frequency; sharply selective means for selecting said second intermediate-frequency carrier wave; and means for converting and utilizing said selected second modulated intermediate-frequency carrier wave.

9. A tunable superheterodyne receiver comprising; a tunable frequency changer for converting a selected signal wave into a first modulated intermediate-frequency carrier wave of approximately constant frequency; a first intermediate-frequency channel for broadly selecting said first intermediate-frequency carrier wave while permitting normal deviations in the frequency thereof without substantial attenuation of the modulation frequencies thereof; an untunable second frequency changer for converting said selected first intermediate-frequency carrier wave into a second modulated intermediate-frequency carrier wave subject to minor deviations from a given normal frequency; a second intermediate-frequency channel for sharply selecting and amplifying said carrier waves of second intermediate frequency, said second channel having a center frequency equal to said normal frequency; a device responsive to deviations in frequency of said second intermediate-frequency carrier wave from said center frequency; and means controlled by said device for controlling the frequency of said untunable frequency changer to maintain the frequency of said second intermediate-frequency carrier wave at said center frequency.

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