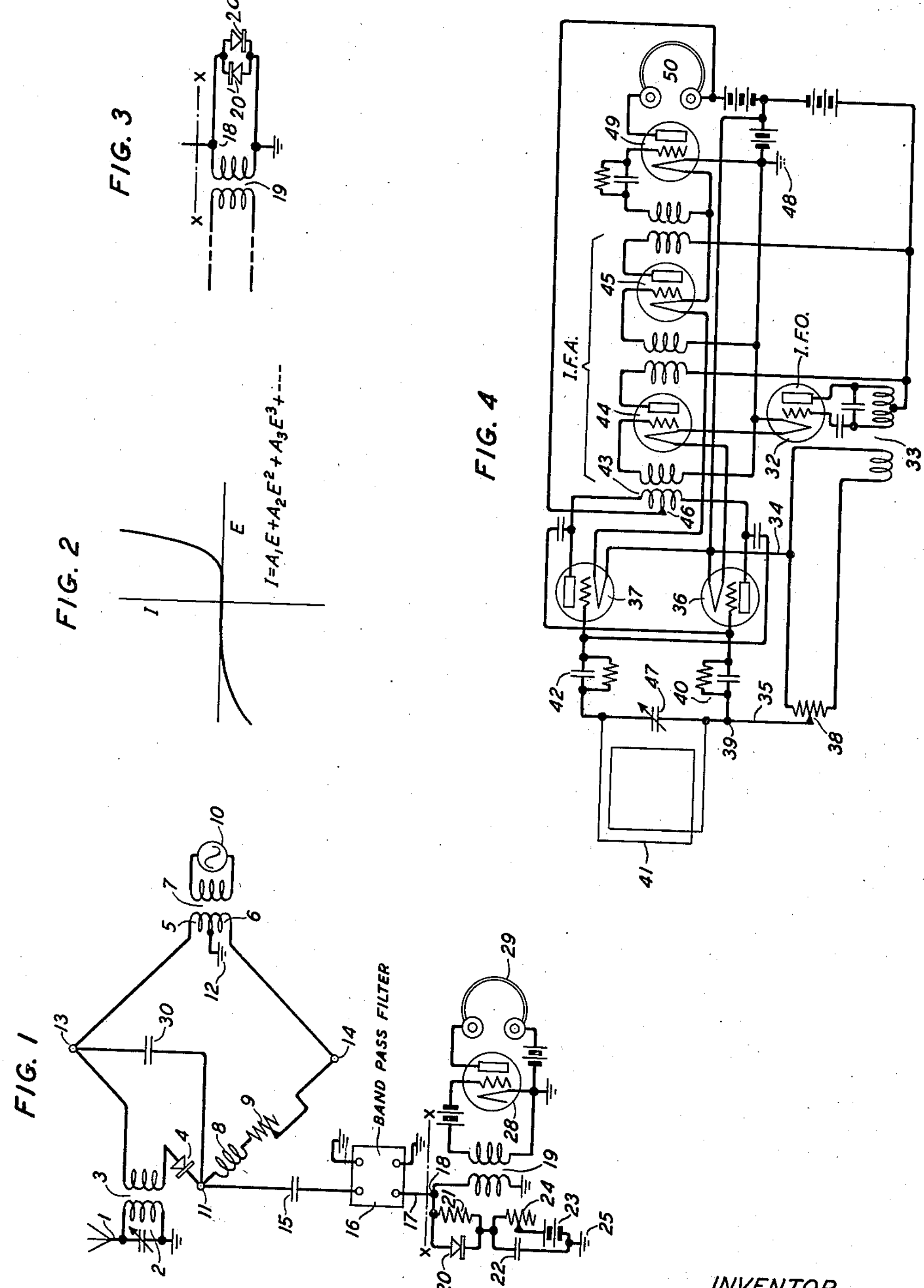
May 20, 1941. R. S. OHL 2,242,791

RADIO RECEIVING SYSTEM

Filed Sept. 1, 1939 2 Sheets-Sheet 1



INVENTOR
R. S. OHL

BY E. V. Griggs

ATTORNEY

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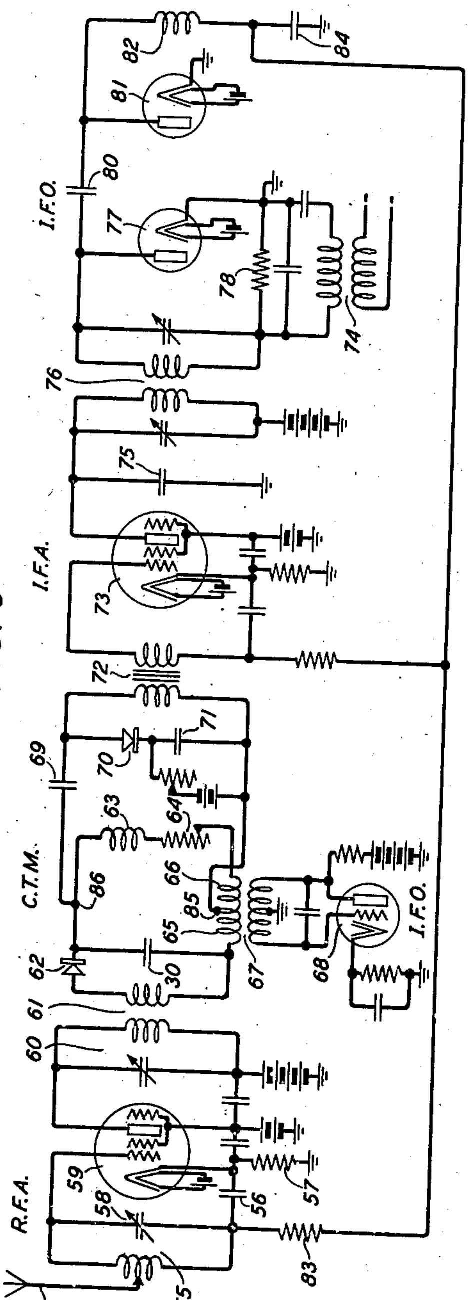

FIG. 5

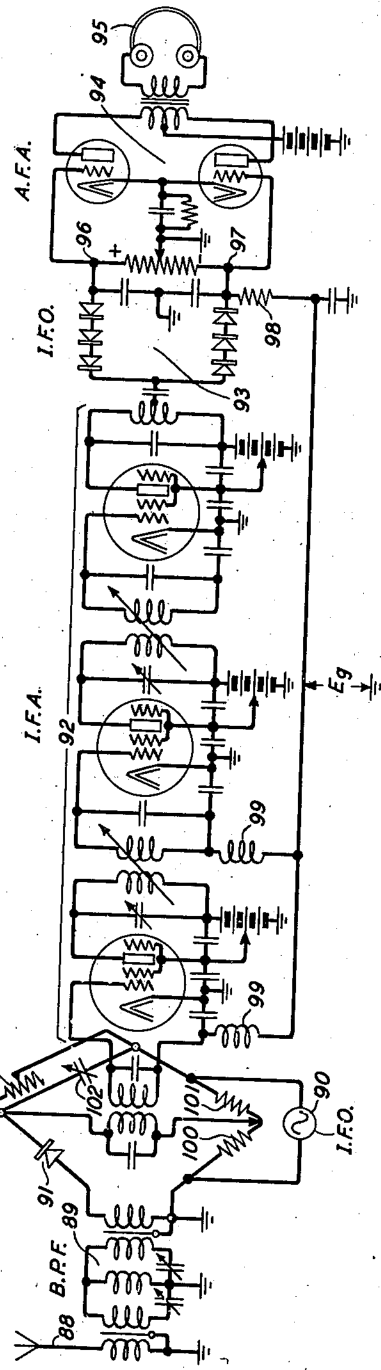

FIG. 6

INVENTOR
R. S. OHL

BY E. V. Griggs

ATTORNEY

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RADIO RECEIVING SYSTEM

Russell S. Ohl, Little Silver, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application September 1, 1939, Serial No. 293,010

12 Claims. (Cl. 250—20)

This invention relates to reception of modulated carrier waves and more particularly to methods and apparatus for carrier wave reception employing devices having cube law current characteristics.

An object of the invention is to transfer the modulations from an incoming carrier wave to a fixed frequency locally produced carrier wave without first demodulating the incoming carrier wave.

Another object of the invention is to enable incoming modulated oscillations to give rise to similarly modulated fixed frequency oscillations of a lower frequency which is not a function of the incoming carrier wave frequency and which may therefore be selected by fixed intermediate frequency circuits requiring no variable tuning appliances.

A further object of the invention is to provide a carrier wave system of the intermediate frequency type in which both the local carrier oscillator and the intermediate frequency selective circuit require no variable tuning.

Another object of the invention is to provide a simple manually operable volume control for a radio receiver equipped with automatic gain control.

In accordance with the invention a carrier wave receiver is provided with a local source of intermediate frequency oscillations connected to a balanced or bridge circuit such that the normal alternating electromotive force across the output terminals of the bridge which are conjugate to the terminals connected to the oscillator is zero. One arm of the bridge comprises an impedance element as, for example, a contact rectifier including a body of silicon which has a substantially cubic relation between output current and impressed electromotive force. The incoming modulated oscillations are applied to the bridge arm having the cubic characteristic and serve to unbalance the bridge and to permit oscillations from the local source to pass to the output circuit. One component of the resulting output current comprises oscillations of the local carrier frequency modulated in amplitude by the square of the signal modulations carried by the incoming modulated oscillations. This component is subjected to a "rooting" action by which the amplitude of the modulation is derived from the squared signal modulation to provide a signal modulated intermediate frequency carrier wave which may thereafter be demodulated in the usual manner.

In one embodiment of the invention, a radio receiver employing the bridge modulator unit for transferring modulations from an incoming carrier wave to a locally produced or intermediate frequency carrier wave is provided with an automatic gain control system associated with the intermediate frequency amplifiers. In order to manually change the volume level as desired the bridge modulator unit is provided with a manually controlled potentiometer which permits varying the bridge in such manner as to unbalance it so that the ratio of unmodulated to modulated intermediate frequency carrier is varied, thus enabling the desired volume level to be varied at will without any manual readjustment of the automatic volume control apparatus.

In the drawings:

Fig. 1 discloses a radio receiving system in which the invention is employed to transfer signal modulations of an incoming wave to an intermediate frequency carrier wave without an intervening demodulation;

Fig. 2 is a graph of the current output characteristic of the modulation transfer device of the system of Fig. 1;

Fig. 3 illustrates a modification of a portion of the system of Fig. 1;

Figs. 4 and 5 are modifications of the radio receiving system of Fig. 1; and

Fig. 6 is a schematic circuit diagram of a radio receiver equipped for automatic gain control and for manual control of the volume level.

Fig. 1 illustrates an embodiment of the invention in a radio receiving system. An antenna or high frequency circuit 1 is connected to ground through the variable tuned circuit 2 which is made resonant to the frequency of the incoming oscillations which it is desired to receive. Connected to the circuit 2 by transformer 3 is a carrier transfer modulator device 4 of the contact rectifier type which may comprise a body of vacuum fused highly purified silicon with which is associated a point contact element. The device 4 constitutes one arm of a four-arm bridge including the two portions 5 and 6 of the secondary winding of the transformer 7 and an impedance arm consisting of inductance 8 and variable resistance 9. A source 10 of intermediate frequency oscillations is connected to the primary winding of transformer 7. The bridge 4, 5, 6, 8, 9 is normally (i. e. during absence of incoming carrier waves) so balanced at the intermediate frequency that no difference of potential exists between the point 11 and ground 12 for the intermediate frequency since during absence of incoming carrier waves these points are conjugate to points 13 and 14 across which the intermediate frequency electromotive force is impressed.

Connected from point 11 by way of a large stopping capacity element 15 and a band-pass filter 16 is a path 17 which divides at 18, one branch passing by way of the primary winding of transformer 19 to ground, the other including a crystal detector or contact rectifier 20 which may preferably consist of a body of iron-pyrites with an appropriate point contact element. The rectifier 20 is shunted by a fixed resistance element 21. A large capacity stopping condenser 22 completes the alternating current path to ground while the source 23 of unidirectional polarizing electromotive force is connected in series with variable resistor 24 to ground at 25. Coupled to the secondary winding of transformer 19 is the input or grid-cathode circuit of a thermionic detector 28 in the output current path of which is a loud-speaker or other speech indicating device or transmission circuit 29.

Assume, for example, that oscillations of a carrier frequency c_1 which have been amplitude modulated by signals of frequency s are to be received and that it is desired to transfer the modulations of the received wave to a locally produced wave of frequency c_2. The antenna 1 and the selective circuit 2 will, in accordance with the usual practice, be designed to select oscillations of a frequency c_1 or a desired band of frequencies in that region. The selected incoming modulated carrier wave may be represented by

$$E_1=A_0 \sin 2\pi c_1 t\ (1+B \sin 2\pi st) \qquad (1)$$

where $2\pi st$ is the angular frequency of the instantaneous modulating tone, B its amplitude and A_0 is a function of the amplitude of the unmodulated carrier wave at the transmitting station. The modulated incoming wave is impressed through transformer 3 upon transfer modulator 4 over a path including the capacity element 30 which presents small impedance at the incoming carrier wave frequency c_1 but which is of relatively high impedance at the frequency c_2 of the locally generated wave. Simultaneously there is impressed upon the transfer modulator 4 an electromotive force produced by the local source 10 which may be represented by

$$E_2=D \sin 2\pi c_2 t \qquad (2)$$

The transfer modulator 4 has a non-linear characteristic relating output current to total impressed electromotive force as illustrated in Fig. 2 and indicated by the equation associated with that figure.

$$I=A_1E+A_2E^2+A_3E^3+\ \ldots \qquad (3)$$

It is only necessary that A_3 be of the same order of magnitude or preferably greater than the other coefficients. It is apparent from Equation 3 that the output current of the device 4 will involve a number of components. Since by suitable selective circuits, such as the band-pass filter 16, we may select any of these components excluding the others we may legitimately drop those not of interest and confine our interest to a particular one. If, therefore, we consider only the purely cube term of the second member of Equation 3

$$I=A_3E^3+\ \ldots \qquad (4)$$

The total electromotive force E impressed upon the transfer modulator 4 is the sum of that of the received modulated wave and that of the local source and may be expressed by

$$E=E_1+E_2 \qquad (5)$$

Substituting the value of E from Equation 5 in Equation 4

$$I=A_3E_1^3+3A_3E_1^2E_2+3A_3E_1E_2^2+A_3E_2^3+\ \ldots \qquad (6)$$

Again, applying the principle that the use of proper selective circuits permits dropping of terms expressing components of frequencies excluded by the selective circuits and retaining only the second term of the right-hand member of Equation 6 the selected output current is expressed by

$$I=3A_3E_1^2E_2+\ \ldots \qquad (7)$$

Substituting in Equation 7 the magnitudes of E_1 and E_2 as given in Equations 1 and 2,

$$\begin{aligned} I&=3A_3[A_0^2 \sin^2 2\pi c_1 t(1+B \sin 2\pi st)^2]D \sin 2\pi c_2 t+\ldots \\ &=3A_3A_0^2D \sin^2 2\pi c_1 t \sin 2\pi c_2 t(1+B \sin 2\pi st)^2+\ldots \end{aligned} \qquad (8)$$

Substituting K_1 for $3A_3A_0^2D$,

$$\frac{1-\cos 4\pi c_1 t}{2}$$

for $\sin^2 2\pi c_1 t$ in (8)

$$\begin{aligned} I=K_1\left(\frac{1-\cos 4\pi c_1 t}{2}\right) \sin 2\pi c_2 t(1+B \sin 2\pi st)^2 &= \\ \frac{K_1}{2} \sin 2\pi c_2 t(1+B \sin 2\pi st)^2 &- \\ \frac{K_1}{2} \cos 4\pi c_1 t \sin 2\pi c_2 t(1+B \sin 2\pi st)^2 & \end{aligned} \qquad (9)$$

The second term of the right-hand member of Equation 9 involves the double carrier frequency $4\pi c_1 t$ which is filtered out, leaving

$$I=\frac{K_1}{2} \sin 2\pi c_2 t(1+B \sin 2\pi st)^2+\ \ldots \qquad (10)$$

The resulting selected output current accordingly has an amplitude factor

$$\frac{K_1}{2}$$

a carrier wave frequency c_2 and an envelope or modulation factor $(1+B \sin 2\pi st)^2$ which is the square of that of the received carrier wave electromotive force as indicated by Equation 1. Since the band-pass filter 16 is made selective for a band of frequencies within the region of the local carrier frequency c_2 there will appear in the path 17, as expressed in Equation 10 a modulated wave of the carrier frequency c_2 having a modulation corresponding to the square of the modulation of the incoming carrier wave.

The device 20, together with its associated elements 21, 22, 23 and 24, performs the function of a "rooter" which produces a response which instead of being proportional to the squared-signal amplitude of the impressed intermediate frequency carrier waves is generally proportional to its square root. The device 20 is a contact rectifier of iron-pyrites or the like and preferably has a square law characteristic. Both its characteristic and sensitivity are dependent upon a suitable polarizing electromotive force which is supplied through a series resistor which is carefully adjusted to enable an optimum performance to be had. The non-linear characteristic of the device 20 gives rise to an output electromotive force impressed across the input terminals of demodulator 28 which is of the desired intermediate carrier frequency and the modulation of which varies in amplitude in accordance with the modulations of the original incoming carrier wave.

It is not essential that the "rooter" be of the particular type disclosed since devices having an analogous function as disclosed in U. S. patents to Crisson, 1,737,830, December 3, 1929, and Doba 2,118,175, May 24, 1938, may be employed.

After the rooting operation the resultant electromotive force may be impressed upon the input circuit of the demodulator **28** from the output circuit of which signal currents are transmitted to the loud-speaker or transmission line **29**.

Fig. 3 illustrates a modification of that portion of the circuit of Fig. 3 beneath the line *xx* of Fig. 2. A full wave rectifier consisting of two reversely poled iron-pyrites units **20'** and **20''** takes the place of the elements **20, 21 . . . 25** of Fig. 1.

Fig. 4 discloses a modified receiving system for modulated incoming carrier waves in which a local carrier source is connected to the input circuits of two triodes having cubic characteristics, the output circuits of the triodes being connected in differential or opposing relation to a common output amplifier so that normally in the absence of incoming carrier waves no oscillations from the local source pass to the common output amplifier. This balanced condition is upset, however, whenever incoming carrier waves are received since the incoming carrier waves affect the potential of the grid of one triode but not that of the other.

Referring to the drawings the source of local or intermediate frequency carrier waves is represented by device **32** which as illustrated constitutes with its associated circuits a Hartley oscillator. Oscillations from source **32** are transmitted by way of transformer **33** and the leads **34** and **35** to the input circuits of the cubic characteristic triodes **36** and **37**. The magnitude of the electromotive force so applied is controllable by a potentiometer **38**. The electromotive force is applied effectively in parallel to the grids of the two triodes over a path through the low impedance potentiometer **38** to point **39**. The path leads from point **39** to the grid of the triode **36** by way of a grid leak and blocking condenser combination **40**. Another branch of the path for the locally produced oscillations leads from the point **39** by way of loop antenna **41** and the grid leak and condenser combination **42** to the grid of triode **37**. The output circuits of the cubic characteristic triodes **36** and **37** are connected in differential or opposing fashion by a transformer **43** to the intermediate frequency amplifying system comprising the tandem amplifiers **44** and **45**. The common plate current circuit of triodes **36** and **37** extends by way of a variable tap connection **46** which permits a nice balance to be obtained. In order to prevent feedback from the plate circuit to the input circuit of the discharge devices, the plate of each device is cross-connected through a neutralizing or balancing condenser to the grid of the other device.

Incoming modulated carrier waves are received by the loop antenna **41** which together with the variable capacity element **47** is tuned to the desired carrier frequency. The electromotive force of the incoming carrier waves developed across capacity element **47** is impressed upon the input circuit of device **37** the terminals of which are connected to those of the capacity element. Substantially no incoming carrier frequency electromotive force is impressed upon the device **36** since the grid of device **36** is connected to the point **39** which is in turn connected to earth by way of the low impedance potentiometer **38**, the lead **34** and the ground connection **48**. Accordingly when incoming modulated carrier waves are received and affect only the device **37**, the balance of devices **36** and **37** is disturbed and oscillations of the locally generated or intermediate carrier frequency produced by source **32** are impressed upon the tandem amplifier **44, 45**. These oscillations have amplitude modulations corresponding to the square of the modulations of the incoming carrier frequency waves in accordance with the principle of operation explained in connection with the previously-described system of Fig. 1. The circuits of amplifiers **44** and **45** may be made selective to the intermediate frequency carrier wave by well-known expedients and the tandem amplifiers will therefore select and pass on to the detector **49** modulated intermediate frequency carrier waves which upon demodulation by the detector yield speech currents to the loud-speaker or other speech translating device **50**. The detector **49** may be given a "rooting" characteristic by proper design of its grid leak path.

Fig. 5 illustrates another embodiment of the invention in a radio receiving circuit in which an antenna or high frequency receiving conductor **54** is associated with selective tuned circuit **55** and is connected to ground through the stopping condenser **56** and resistor **57**. Connected across the terminals of the variable capacity element **58** of the tuned circuit **55** are the input terminals of a radio frequency amplifier **59** perferably of the screen grid type, the tuned output circuit **60** of which is connected by transformer **61** to a contact rectifying device **62** similar in its construction and characteristic to the cube law characteristic device **4** of Fig. 1. The device **62**, together with the secondary winding of the transformer **61** and condenser **30**, constitutes one arm of a bridge circuit another arm of which comprises the inductance **63** and variable resistor **64**. The remaining two arms consist of the two portions **65** and **66** of the transformer **67** by which intermediate frequency carrier oscillator **68** is coupled to the bridge. The output terminals of the bridge are connected through a stopping condenser **69** to a contact rectifier "rooter" **70** which may correspond in structure, characteristics and function to the square law device **20** of Fig. 1. Connected across the terminals of device **70** through the large capacity element **71** is a transformer **72**, the secondary winding of which leads to the input terminals of intermediate frequency amplifier **73**, the output circuit of which is coupled to the rectifying system of diode **77**.

Intermediate frequency amplifier **73** is provided with a by-pass condenser **75** to short-circuit any residual high incoming carrier frequency oscillations from its output circuit. Intermediate frequency current energy transferred by transformer **76** to the input of the rectifier **77** sets up a signal frequency potential difference across the series resistor **78** in shunt to which is connected the primary winding of a transformer **74** connected to an outgoing telephone line. Alternating speech or other signal current produced by the demodulating action of device **77** is also transferred through a series capacity element **80** to a second rectifier **81**. The resulting unidirectional potential across rectifier **81** is additionally smoothed by series inductance **82** and resistance **83** which cooperate with the shunt capacitances

84 and 56 as a smoothing filter for the rectified electromotive force to be impressed on the grid of radio frequency amplifier 59.

In operation, incoming radio frequency oscillations received by circuit 54 and selected by tuned circuit 55 are amplified by amplifier 59 and again selected by tuned circuit 60 by which they are impressed upon the carrier transfer modulator 62, together with intermediate frequency oscillations from the local source 68. As has been explained, the device 62 is included in a bridge so balanced that normally no energy from the source 68 reaches the output circuit connected to conjugate points 85 and 86 of the bridge. However, application of the input carrier oscillation electromotive force to the device 62 with its cubic order characteristic so alters the impedance of device 62 that the bridge is no longer balanced and the unbalance manifests itself as an electromotive force across the points 85 and 86. This unbalance electromotive force is accordingly impressed across the rooting device 70. As has already been explained, the unbalanced output energy of the bridge contains a component of the intermediate carrier wave frequency modulated in accordance with the square of the modulations of the initially received modulated high frequency oscillations. Modulated incoming frequency carrier waves are operated upon by the device 70 to derive the signal modulated intermediate frequency carrier waves, the resulting signal modulated currents are impressed upon the intermediate frequency amplifier 73 and after amplification are demodulated by diode rectifier 77. The demodulated signal current electromotive force impressed across the resistance 78 gives rise to currents which are transferred to the outgoing circuit connected to the secondary winding of transformer 74 for retransmission as may be desired. Speech current energy applied by the rectifier 77 to the rectifier 81 is utilized after smoothing of its potential by the smoothing filter to provide an automatic volume control potential for the grid of the radio frequency amplifier 59 and, also, if desired for the grid of the intermediate frequency amplifier 73. This feature is of particular advantage in connection with the carrier transfer modulator and the rooter since control of the volume of energy supplied to these devices insures that they operate in the most efficient region of their load characteristics without overloading. Control of the level of the intermediate frequency amplifier output performs a corresponding function for the diode rectifying system 77.

The radio receiver circuit of Fig. 6 includes an antenna 88, a band-pass filter 89, a bridge with a local intermediate frequency carrier source 90 and a cube law carrier transfer modulator 91, a three-stage intermediate frequency amplifier 92, a full wave rectifier type of demodulator 93, a balanced or push-pull signal or speech current amplifier 94 and a signal indicating device 95. The unidirectional current from device 93 traverses the resistance between points 96 and 97 with the polarity indicated. The negative potential at 97 is impressed by way of resistance 98 and the individual choke coils 99 to the grids of the first two amplifiers of the intermediate frequency amplifier system. Accordingly, the amplification introduced by the amplifier system 92 and the resulting signal volume in the indicating device 95 are held at a regulated level in well-known manner. This level, as is well known, is dependent upon the relative amplitudes of the unmodulated component and the modulated component of the intermediate frequency carrier wave as impressed upon the intermediate frequency amplifier system 92.

The level at which the automatic volume control device holds the final signal output as indicated by receiver 95 may be changed as desired by varying the relationship between the unmodulated and modulated components of the intermediate frequency carrier wave. The bridge including the carrier transfer modulator 91 is provided with a potentiometer input for the local carrier wave so that the bridge may be unbalanced in varying degree at will. In operation the potentiometer of the bridge may be set so that part 100 presents a resistance of about 100 ohms while part 101 has a value of say 900 ohms. The bridge arm including capacitance 102 and the volume control resistor 103 is adjusted for best balance when no signal is being received on the antenna. The grid bias electromotive force E_g is at its minimum magnitude for this condition. Upon receipt of incoming carrier waves the balance of the modulation transfer bridge is upset and E_g increases so as to hold the receiver output at a predetermined level. If the resultant signal is deemed too intense the operator may slightly adjust the magnitude of the volume control resistor 103 to unbalance the bridge to the desired degree. This changes the relation between the unmodulated and the modulated components or the percentage modulation as it is usually termed. The automatic volume control accordingly changes the biasing potential on the grids of the amplifier system 92 to bring the output level at receiver 95 to the correct magnitude.

Although a rooting device may be employed in this circuit, as in those previously described, it is not an essential. The "rooting" operation may be accomplished at the transmitter in the general manner of volume compression and expansion systems commonly known as "compandor" systems. If the distortion of the speech or other signal is not too great it is feasible to dispense with the rooting operation altogether.

It will be understood that although only single intermediate frequency stage conversion systems have been disclosed the principle of the invention may equally well be applied to multistage frequency transforming receivers in which several intermediate frequency stages, each employing its own intermediate carrier frequency source, are utilized. The invention may also be employed in an apparatus for stepping up the carrier frequency at transmitting stations or for changing the carrier frequency in any desired manner at a repeating station. In general, the invention may be employed to transfer signal modulations from one carrier wave to another carrier wave without an intermediate step of demodulation to the signal frequency. Moreover, the frequency of the new carrier wave to which the signal modulations are transferred may be entirely independent of any frequency characteristics of the carrier wave from which the signal modulations are transferred.

What is claimed is:

1. The method of modulated carrier wave reception which comprises subjecting an incoming modulated carrier wave and a locally produced wave to an interaction having a cube law characteristic and selecting from the resultant oscillations of the frequency of the locally produced wave having modulations corresponding approximately to those of the incoming wave.

2. In combination, a device having a response characterized by a cube law term, means for impressing thereon received incoming oscillations, a source of locally produced oscillations of a fixed frequency connected thereto whereby incoming oscillations and locally produced oscillations are caused to interact therein, and an output circuit connected to said device selective for oscillations of the locally produced frequency.

3. In combination, a source of oscillations of a fixed intermediate frequency, a bridge circuit connected thereto and so balanced that between two fixed points in the circuit conjugate to those of the oscillator connection the normal potential difference at the intermediate frequency is zero, the bridge comprising a plurality of arms one of which has a non-linear impedance characteristic, means for impressing received modulated high frequency oscillations upon the non-linear impedance bridge arm, and means connected to the fixed conjugate points selective to a band of frequencies including that of the intermediate frequency oscillator to derive therefrom modulated intermediate frequency oscillations having the carrier frequency of the intermediate frequency oscillations and modulations corresponding to those of the received wave.

4. A receiver for waves having modulated and unmodulated components comprising amplifiers, an automatic volume control device for controlling the gain of the amplifiers, and means independent of the amplifiers for varying at will the relative magnitudes of the modulated and unmodulated carrier components impressed upon the amplifiers to enable the volume level to be varied as desired.

5. An intermediate frequency type carrier wave receiver comprising a Wheatstone bridge balanced at a preassigned frequency, a cube law device constituting an element of one arm of the bridge, an input circuit for receiving incoming waves and arranged to supply energy of said waves to the cube law device, a local source of oscillations of the preassigned frequency connected to two diagonally opposite terminals of the bridge to intermodulate with incoming waves in the cube law device, an amplifier having an automatic gain control connected to the other two terminals of the bridge, and means for varying the normal balance of the bridge to vary the relation between the intermodulated oscillations and the unmodulated oscillations of the preassigned frequency which are passed by the bridge to the amplifier.

6. The combination of claim 2 characterized in this, that the device consists of a contact rectifier comprising a small point conductor bearing against a body of vacuum fused silicon of a high degree of purity.

7. In combination, a local source of oscillations of a fixed intermediate frequency, a bridge circuit coupled thereto and normally so balanced that between two fixed points in the circuit, conjugate to the points of coupling to said source, the normal potential difference at the local source frequency is zero, the bridge having a plurality of arms at least one of which contains an element responsive to received modulated waves and adapted to upset the balance of the bridge in response thereto, means for impressing received modulated waves on said element, a circuit arrangement selective to a band of frequencies including the frequency of the local source connected to the fixed conjugate points to derive therefrom modulated intermediate frequency oscillations having the carrier frequency of the local source and modulations corresponding to those of the received wave, at least one arm of the bridge containing a manually variable impedance element for altering at will the amount by which received waves of a particular strength will upset the balance of the bridge.

8. In combination, a local source of oscillations of a fixed intermediate frequency, a bridge circuit coupled thereto and normally so balanced that between two fixed points in the circuit, conjugate to the points of coupling to said source, the normal potential difference at the local source frequency is zero, the bridge having a plurality of arms at least one of which contains an element responsive to received modulated waves and adapted to upset the balance of the bridge in response thereto, means for impressing received modulated waves on said element, a circuit arrangement selective to a band of frequencies including the frequency of the local source connected to the fixed conjugate points to derive therefrom modulated intermediate frequency oscillations having the carrier frequency of the local source and modulations corresponding to those of the received wave, at least one arm of the bridge containing a manually variable impedance element adapted to upset, in a desired amount, the normal balance of the bridge.

9. In combination, a local source of oscillations of a fixed intermediate frequency, a bridge circuit coupled thereto and normally so balanced that between two fixed points in the circuit, conjugate to the points of coupling to said source, the normal potential difference at the local source frequency is zero, the bridge having a plurality of arms at least one of which contains an element responsive to received modulated waves and adapted to upset the balance of the bridge in response thereto, means for impressing received modulated waves on said element, a circuit arrangement selective to a band of frequencies including the frequency of the local source connected to the fixed conjugate points to derive therefrom modulated intermediate frequency oscillations having the carrier frequency of the local source and modulations corresponding to those of the received wave, the relative amplitudes of modulated and unmodulated components of said modulated intermediate frequency oscillations depending on the values and arrangement of the bridge elements, an amplifier and a detector associated with said selective circuit arrangement and adapted to derive usable signals from said modulated intermediate frequency oscillations, an automatic volume control arrangement for maintaining the level of said signals at a constant value independent of variations in the strength of said received modulated wave, and manually operable means for altering at will the relative magnitudes of said modulated and unmodulated components to enable the signal level to be altered as desired.

10. The method of transferring modulations of an incoming received carrier wave to a second carrier wave by a single frequency conversion which comprises subjecting the modulated incoming carrier wave and oscillations of the second carrier wave frequency to an interaction characterized by a cube law characteristic and selecting directly from the resultant a band of oscillations in the region of the second carrier wave frequency of sufficient frequency extent to including the desired modulated sideband components of the second carrier wave but too re-

stricted in extent to include oscillations of the incoming carrier wave frequency.

11. The method of carrier wave transmission comprising subjecting an amplitude modulated carrier wave and an unmodulated carrier wave of different carrier frequency to an interaction having a cube law characteristic whereby there is produced a complex resultant including as one component a wave having the carrier frequency of the unmodulated carrier wave and having an amplitude modulation corresponding to the square of that of the modulated carrier wave, selecting the said component and subjecting it to a rooting operation to cause the amplitude modulation to more closely simulate that of the original modulated carrier wave.

12. In combination, a receiving circuit, a source of local oscillations, a device having a cube law characteristic connected to the receiving circuit and to the source of local oscillations whereby received oscillations and local oscillations are subjected to an interaction having a cube law characteristic, means connected to the cube law device to select from the resultant of the interaction oscillations of the frequency of the local source carrying a modulation which is a function of that of the received waves, and a rooter circuit connected to the selecting means for deriving from the selected modulated oscillations, oscillations of the same local source frequency and having an amplitude modulation corresponding to the square root of the amplitude modulations of the selected carrier wave.

RUSSELL S. OHL.