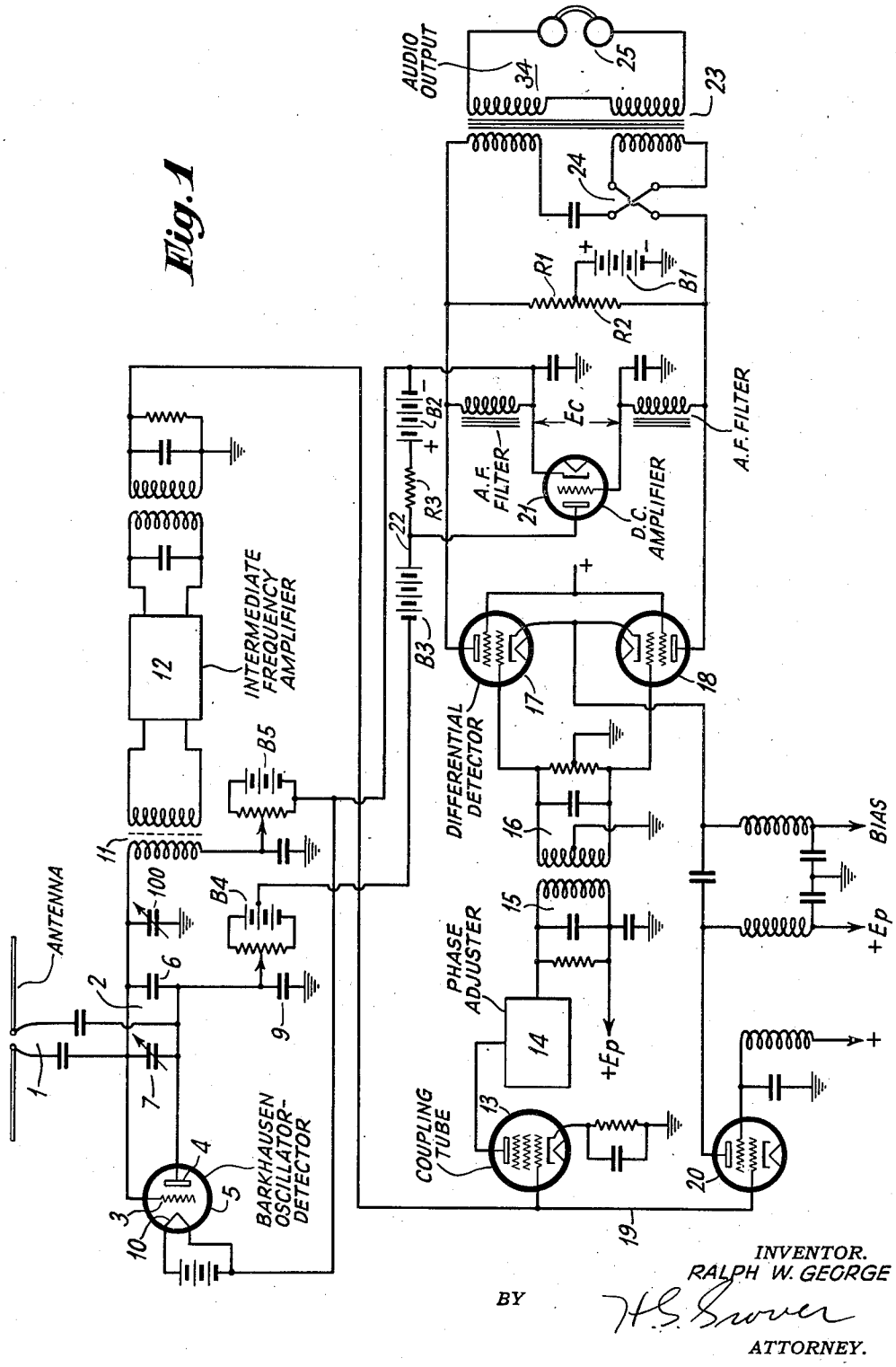
Sept. 16, 1941. R. W. GEORGE 2,256,083

AUTOMATIC FREQUENCY CONTROL SYSTEM FOR BRAKING-FIELD OSCILLATORS

Filed April 15, 1939 3 Sheets-Sheet 1

Fig. 1



INVENTOR.
RALPH W. GEORGE

BY H. S. Brown

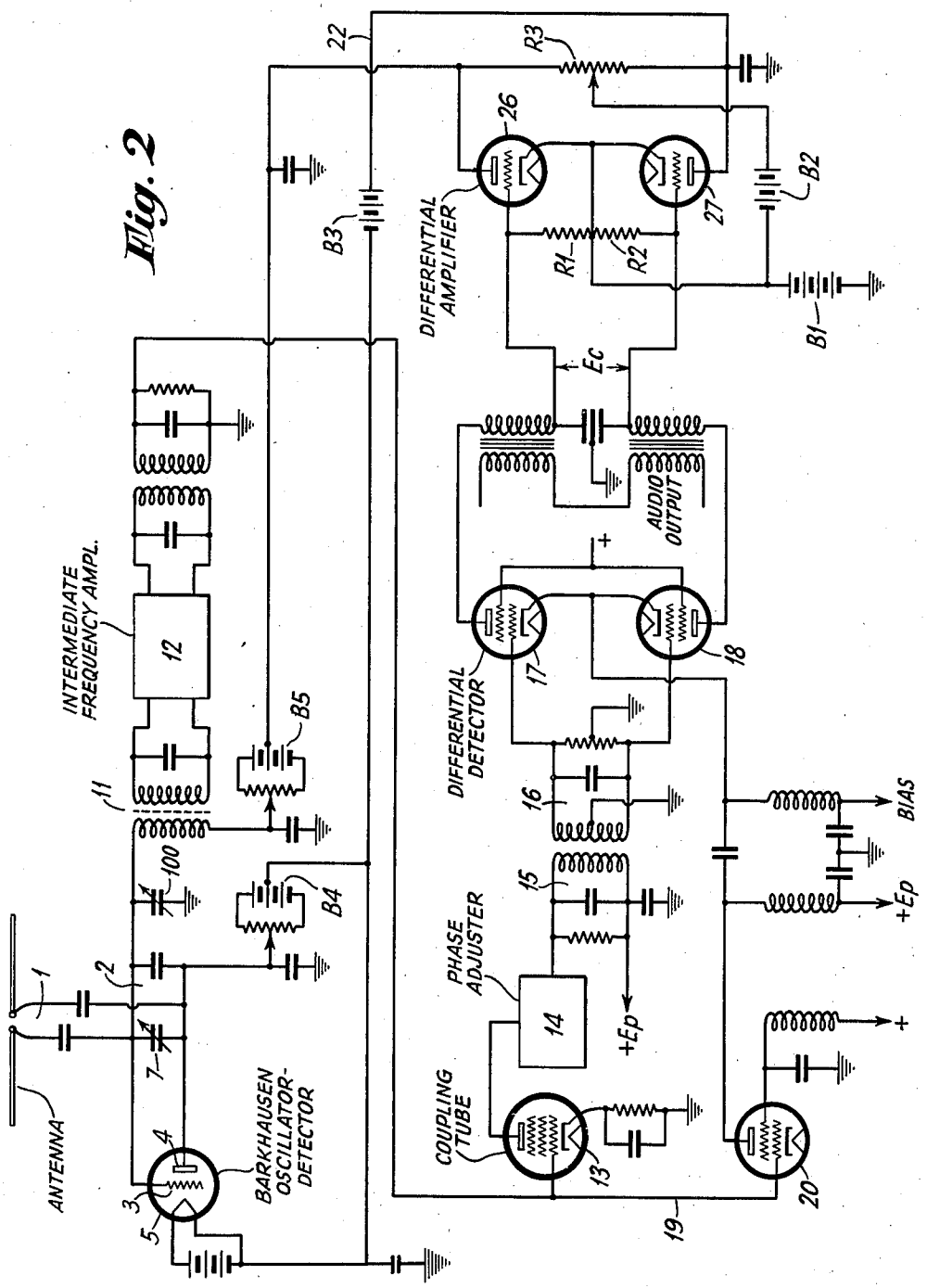
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AUTOMATIC FREQUENCY CONTROL SYSTEM FOR BRAKING-FIELD OSCILLATORS

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Fig. 2



INVENTOR.
RALPH W. GEORGE

BY H. G. Grover

ATTORNEY.

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Fig. 3

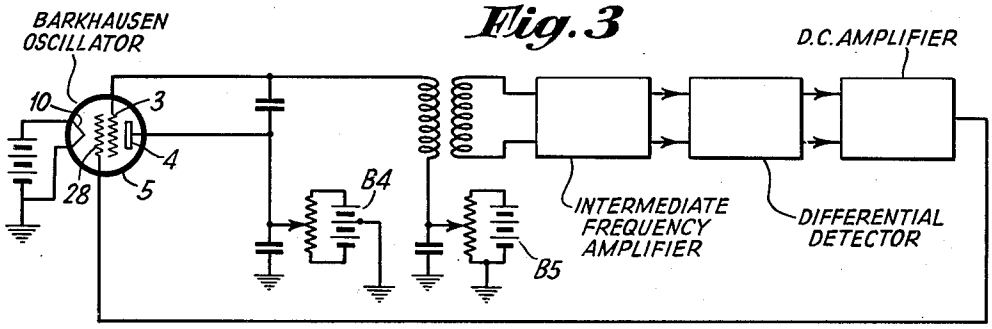


Fig. 4

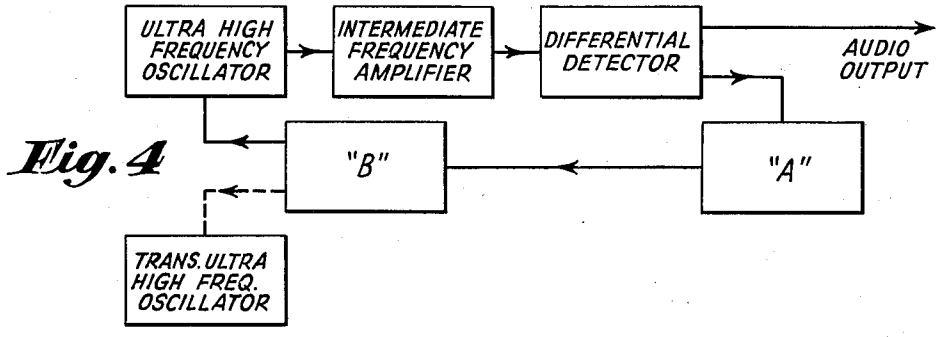


Fig. 5a

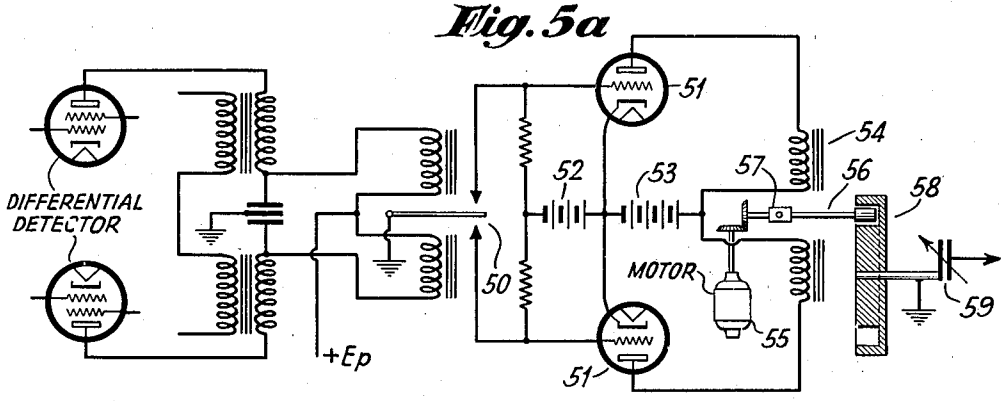
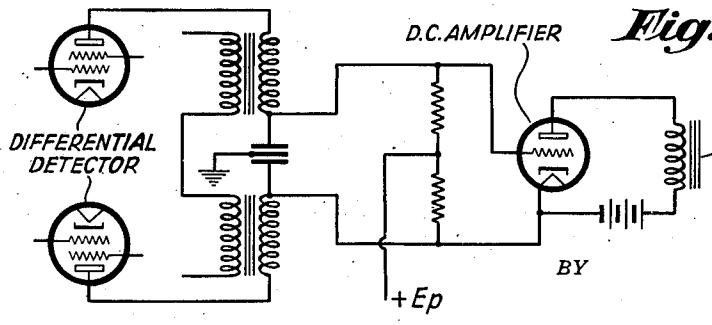


Fig. 5b



INVENTOR.
RALPH W. GEORGE
BY
H. S. Grover
ATTORNEY.

Patented Sept. 16, 1941 2,256,083

UNITED STATES PATENT OFFICE

2,256,083

AUTOMATIC FREQUENCY CONTROL SYSTEM FOR BRAKING-FIELD OSCILLATORS

Ralph W. George, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application April 15, 1939, Serial No. 268,014

1 Claim. (Cl. 250—20)

The present invention concerns an ultra high frequency oscillator system, such as a braking field or Barkhausen-Kurz type, whose frequency can be automatically controlled by varying the voltages of the oscillator or by the tuning of the oscillator circuit. According to the invention, a differential detector operates at a suitable intermediate frequency and sets up a plus or minus voltage which is amplified suitably and made to control the grid or plate voltage, or the tuning of the ultra high frequency oscillator in a manner to compensate for a change in the intermediate frequency. Where it is desired to control a receiver, it is proposed to make the ultra high frequency oscillator follow the transmitter frequency. Where it is desired to control a transmitting ultra high frequency oscillator, it is proposed to combine a relatively weak ultra high frequency of known stable frequency such as a harmonic of a local stable oscillator, or crystal controlled oscillator with the transmitter frequency to produce a suitable intermediate frequency which through the differential detector produces suitable controlling means which are applied to the ultra high frequency transmitting oscillator.

It is known that ultra high frequency oscillators are especially subject to slight and uncontrollable variations in their circuit conditions, etc., which cause frequency variations, and it is also known to use crystals as frequency stabilizing elements. Direct crystal control of the frequency of the oscillator through many stages of frequency multiplication, however, is complicated and expensive, and therefore not well suited for reception purposes and most transmission purposes.

The present invention is a means of obtaining automatic frequency control with a moderate amount of apparatus, which has an advantage that it will keep a receiver in tune with a transmitter over a long period of time and without attention.

Another advantage of the invention is that the frequency control achieved requires only a very small amount of power from the stable oscillator, when applied to frequency control of a transmitter oscillator.

A further and important advantage of the invention is that constant frequency or tuning is maintained regardless of any ordinary voltage changes to any of the component parts.

A description of the invention follows in conjunction with drawings, wherein Figs. 1 to 4, inclusive, illustrate four different embodiments of an ultra high frequency oscillator system embodying the principles of the present invention; Fig. 5*a* shows schematically an electromechanical circuit arrangement which can be used for some of the circuits of Fig. 4; and Fig. 5*b* shows a modified circuit which can be used for electromagnetic control of the oscillator. The same reference numerals appearing throughout the figures of the drawings designate the same or equivalent parts.

The term "Barkhausen" is herein used broadly as being descriptive of any type of electron discharge device using a grid which is maintained at a high positive potential and a plate or anode at a much lower potential with respect to the cathode, whereby oscillations of electrons about the grid may or may not be made to occur, depending upon the adjustment of the circuit constants and voltages.

Referring to Fig. 1 of the drawings, there is shown an ultra short radio wave frequency-modulation receiver having a differential detector and a direct current amplifier stage which gives a voltage output carrying plus or minus with the intermediate frequency. More specifically, the circuit of Fig. 1 shows a receiving antenna 1 of the dipole type which is coupled by means of a transmission line to the Lecher wire system 2 connected in turn to the grid 3 and anode 4 of a Barkhausen oscillator-detector 5. The Lecher wire system is shunted by a condenser 6 and an additional tunable condenser 7, the latter being utilized for tuning the resonant period of the oscillator detector circuit. Condenser 9 serves to ground the plate or anode 4 of the Barkhausen detector 5 for radio frequency potential. Batteries B4 and B5 provide suitable polarizing potentials to the plate 4 and grid 3, respectively, of the vacuum tube 5. The grid 3 is maintained at a high positive potential by a battery B5 and the plate 4 at an extremely low positive or negative potential with respect to the cathode 10.

The intermediate frequency which is produced by combining the signal and oscillator frequencies in detector 5 is taken from the grid side of the Lecher wire system 2 and is coupled through transformer 11 to intermediate frequency amplifier 12, the output of which is passed to the grid of the coupling tube 13. A condenser 100 is used to tune the primary coil of transformer 11 to the desired intermediate frequency. The output of the coupling tube 13 is passed to a phase adjustment circuit 14, the latter of which may be enclosed in a shield. Although not shown in the drawings, it should be understood that all radio frequency circuits are properly shielded in

conventional manner. The phase adjuster 14 may take the form of an artificial line. The signal energy derived from the phase adjuster is resonated in parallel tuned circuit 15, in turn coupled to parallel tuned circuit 16, the latter being connected between the grids of balanced modulator detectors 17 and 18. The detectors 17 and 18 comprise a differential detector circuit whose purpose will be given later. The same signal energy applied to the grid of the coupling tube 13 is also applied through connection 19 to the grid of the phase shifting transformer coupling tube 20, from whose anode cophasal signal potentials are fed to the cathodes of the differential detectors 17 and 18, as shown. It will thus be appreciated that a differential signal is applied to the grids of the detectors 17 and 18 while a cophasal signal is applied to the cathodes of these detector tubes. This portion of the frequency modulation receiver comprising the stages 12 to 20 is very similar to and adequately described in my United States Patent No. 2,035,745, granted March 31, 1936, particularly Fig. 2, to which reference is herein made for a more detailed description thereof. Coupled across the anodes of the differential detector 17 and 18 there is provided a direct current amplifier stage 21 which applies a control voltage to the plate 4 of the Barkhausen oscillator detector tube 5 over connection 22 which includes in series therewith battery B3 and part of battery B4. The battery B2 supplies plate power to the direct current amplifier 21 while the battery B3 is used to reduce the plate voltage of the direct current amplifier 21 to a value more suitable for use in circuit with the plate of the Barkhausen oscillator 5. The battery B1 serves to apply positive polarizing potentials to the mid point of the potentiometer resistor R1, R2, the resistors of which are serially connected with respect to each other and in shunt to the output of the differential detector 17, 18. A suitable audio frequency output circuit 34 is shown coupled through an audio output transformer 23 to the anodes of the differential detector 17, 18. Connections suitable for receiving amplitude or frequency modulation are obtained by employing a reversing switch 24 in one section of the primary winding of the audio frequency transformer, as shown. Element 25 comprises a suitable head phone or other signal utilization means. A suitable low pass (audio frequency) filter, as shown, serves to pass only low frequency variations of the direct current control voltage to the first heterodyne oscillator.

In the operation of Fig. 1, the receiver functions substantially identically with the frequency modulation receiver described in my above mentioned United States Patent No. 2,035,745 with the following differences. The anode current of the two vacuum tubes 17 and 18 of the differential detector is passed through the potentiometer branches R1 and R2, respectively, before being connected with the detector plate supply B1. The voltages across the resistances R1 and R2 are equal and opposite as long as the signal intermediate frequency is at the mid band of the detector, as is also the case when no signal is present. Normally, the resultant voltage Ec across the grid and cathode of the direct current amplifier 21 is zero, and the voltage across the anode impedance R3 is constant, and the plate voltage of the Barkhausen oscillator is constant. However, when the intermediate frequency changes, due to an undesired change in the frequency of the Barkhausen oscillator, the anode current of one tube 17 or 18 of the differential detector will increase while that of the other tube 18 or 17 will decrease, with the result that the voltage Ec impressed on the direct current amplifier 21 will be changed, in turn producing a change in the voltage across R3 which is impressed on the plate 4 of the Barkhausen oscillator 5. The polarity of the potential Ec is so chosen that the resulting voltage on the plate of the Barkhausen oscillator 5 will change the frequency of the oscillator in a direction to bring the intermediate frequency back to the mid band of the differential detector.

Fig. 2 shows a modification of Fig. 1 in that the automatic frequency controlling voltage from the differential detector is applied both to the grid 3 and to the plate 4 of the Barkhausen oscillator-detector 5, although it will be appreciated that if desired this controlling voltage may be applied only to the grid of the Barkhausen detector. In Fig. 2, there is also provided a differential direct current amplifier comprising vacuum tubes 26, 27 for producing differential changes in the plate and grid voltages of the Barkhausen oscillator 5. The circuit arrangement here used for supplying the differential voltage Ec to the differential direct current amplifier eliminates the necessity for the low pass filter of Fig. 1. In operation, one-half the voltage across resistor R3 appears as positive and negative (or negative and positive) increments of voltage in series with the grid and plate voltage supplies for the braking field oscillation detector 5. Since the plate voltage of the Barkhausen oscillator 5 varies in an opposite manner to the grid voltage in the oscillator, there will result a greater shift in frequency in the Barkhausen oscillator 5, and thus a greater control of frequency is had than is the case if the potential of only one of the electrode elements of the Barkhausen oscillator is varied for frequency control. I have found that the frequency of the Barkhausen oscillator 5 can be maintained practically constant with varying power supply, if the plate and grid thereof are arranged to take suitable proportional amounts of the power voltage change and both in the same direction, whether this change is in a positive or a negative direction.

It is contemplated, in accordance with the invention, that any one or all of the factors controlling the frequency of an ultra high frequency oscillator may be used in the automatic control of the frequency including any other electrodes and the emission control of the cathode. For instance, a preferred modification of Fig. 1 would be as in Fig. 3, in which the frequency controlling voltage is applied to a special grid 28 placed between the cathode 10 and grid 3 of the tube 5 and drawing no current.

It is also contemplated, in accordance with the invention, that electro-mechanical means may be used to control the tuning and/or voltages of an ultra high frequency oscillator from a differential detector or its equivalent. In Fig. 4, there is shown conventionally, in box form, means designated A for converting the output of the differential detector to suitable electrical values which are utilized by other means B in applying frequency control to either a transmitting oscillator or to the receiving ultra high frequency oscillating detector. The means B may apply electrical control through a mechanically driven voltage control system, or it may apply tuning control by means of a mechanical system, or it may apply magnetic control in either a mechanical or

electrical manner. Fig. 5*a* shows an arrangement for achieving the results set forth in Fig. 4. In Fig. 5*a*, the differential direct current amplifier is replaced by a sensitive differential relay **50**, the relay tubes **51** are normally at plate current cut-off by means of bias battery **52**. A change of frequency causes relay **50** to short circuit the bias on one of the tubes **51** which causes plate current to flow in that tube, thus operating the electromechanical device **54** as follows. The rotating shaft **56** is driven continuously by motor **55** through the flexible coupling **57**. Normally, the shaft rotates without touching either side of the groove in the wheel **58**, in which case the frequency controlling condenser **59** is not moved. When plate current flows in one of the relay tubes **51**, the armature **56** is pulled up or down accordingly, thus engaging one side of the groove in **58** and causing the condenser **59** to be rotated in the proper direction to correct the frequency change.

It is further contemplated that the automatic control feature of the invention for use with a Barkhausen or other type ultra high frequency oscillator may be applied to the oscillator by the method of varying a suitable magnetic field placed in the region of the elements of the tube; such magnetic field can be varied in amplitude and/or in its relative position by the means B in Fig. 4. Thus, mechanical control of a magnetic field may be had in Fig. 5*a*, for instance, by attaching a magnet to the shaft of **58** in place of condenser **59** so that the position of the field, or its strength, is changed by rotation of the shaft. If magnetic control is really desired (which might be the case in magnetron type oscillators), it might be preferable to use direct current amplifier stages fed by the differential detector, in order to control the current in an electromagnet suitably placed near the oscillator tube. Such an arrangement in simple form is shown in Fig. 5*b*, the operation of which will be evident from an inspection of the drawings.

If desired, the principles of the invention may be applied to an ultra high frequency transmitter, wherein the Barkhausen oscillating detector of Figs. 1 and 2 is replaced by a suitable oscillating detector of known stable frequency which is designed to have its frequency controlled, or by a Barkhausen oscillator of improved frequency stability; or it may be an ordinary rectifying detector in which the transmitter frequency and a known stable frequency such as the harmonic of a crystal controlled oscillator may be combined to produce the intermediate frequency. Also, the control voltages or currents of the differential detector would be utilized to control the frequency of the transmitting oscillator which might be of the Barkhausen type which is controlled in the embodiments described, or any known oscillator subject to frequency control.

What is claimed is:

In an ultra short wave frequency-modulation receiver, a multi-electrode Barkhausen oscillator coupled to a receiving antenna for beating with the received signal to produce an intermediate frequency, an intermediate frequency amplifier, a detector coupled to the output of said intermediate frequency amplifier, a direct current amplifier and a low pass audio frequency filter coupled to the output of said detector, and a circuit from said direct current amplifier to an electrode of said oscillator for maintaining the frequency thereof at a steady value differing from that of the incoming wave by a predetermined amount, whereby only low frequency variations of the direct current voltage are passed to said oscillator.

RALPH W. GEORGE.