

March 30, 1943.

M. WALD

2,315,173

ARRANGEMENT FOR NOISE ELIMINATION AT THE RECEIVER

Filed April 4, 1940

2 Sheets-Sheet 1

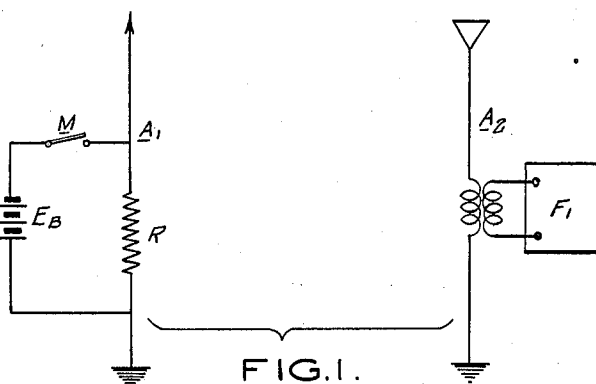


FIG. 1.

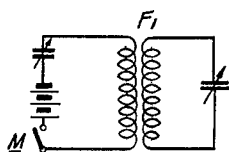


FIG. 3.

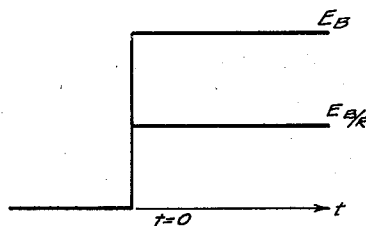


FIG. 2.

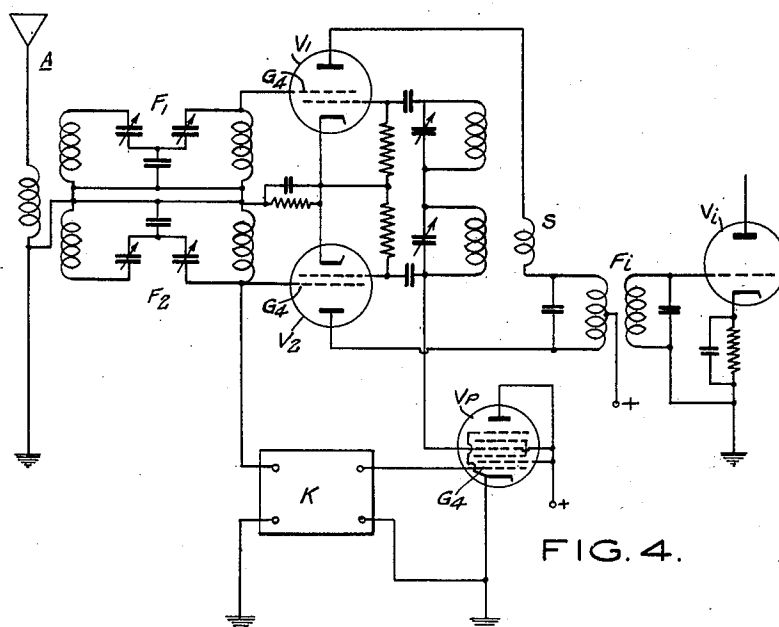


FIG. 4.

INVENTOR.

Martin Wald

BY

Samuel Ostrowsky

ATTORNEY

March 30, 1943.

M. WALD

2,315,173

ARRANGEMENT FOR NOISE ELIMINATION AT THE RECEIVER

Filed April 4, 1940

2 Sheets-Sheet 2

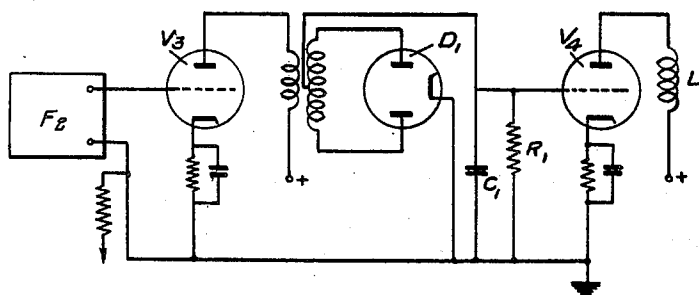


FIG. 5.

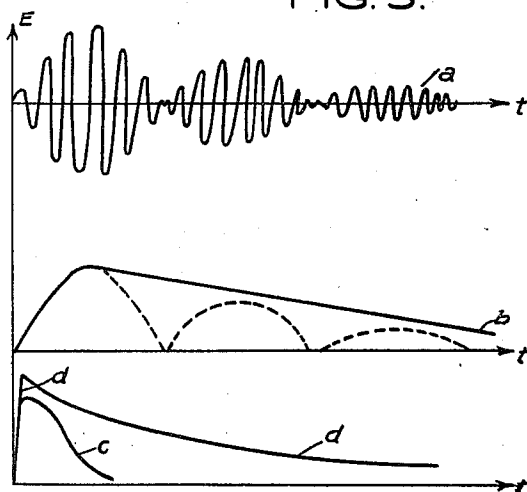


FIG. 6.

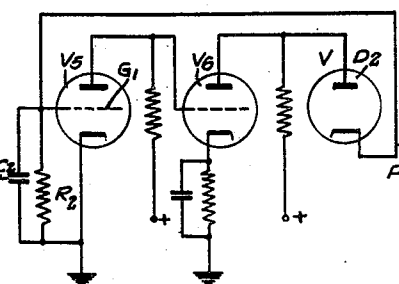


FIG. 7.

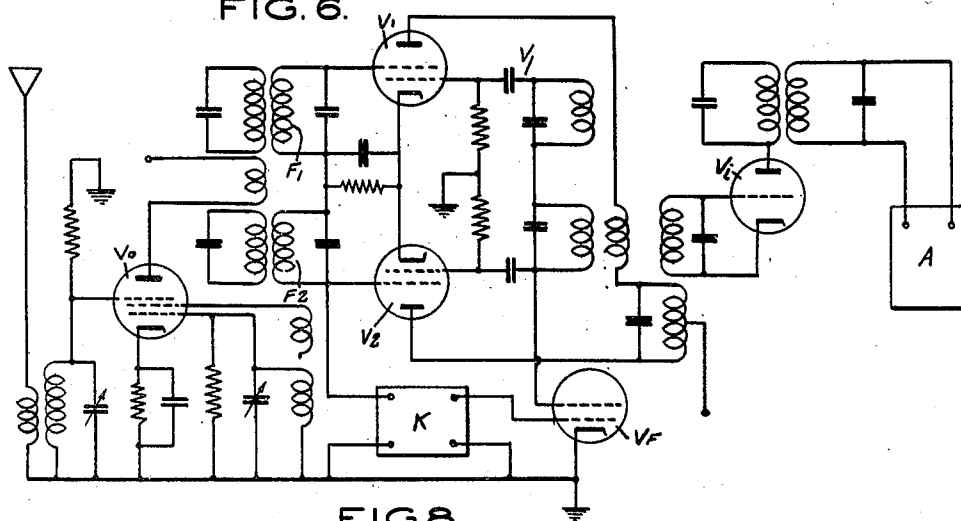


FIG. 8.

INVENTOR.
Martin Wald
 BY *Samuel O. Wolke*
 ATTORNEY

UNITED STATES PATENT OFFICE

2,315,173

ARRANGEMENT FOR NOISE ELIMINATION
AT THE RECEIVERMartin Wald, Bucharest, Rumania; vested in the
Alien Property Custodian

Application April 4, 1940, Serial No. 327,896

5 Claims. (Cl. 250—20)

This invention relates to a method for noise-elimination based on the principle of compensation. This principle is as follows:

Two closely neighbouring frequency-ranges are selected from the antenna output by similar tuned filters. The signal-filter receives the signal and the accompanying noises, while the other auxiliary-filter receives only the noises. It is clear that in connecting the two filters in opposition to each other, the noise-oscillations will not be eliminated because two voltages of different frequencies cannot neutralize each other, instead they will give rise to beats. To get real compensation the oscillations, which have to cancel each other, ought to be identical in frequency and in direct opposed phase. None of the methods hitherto known have fulfilled this condition. The difficulty arises in the practical realisation of the phase-compensation.

The object of the invention is a method in which the phase and frequency of the noise-oscillations we have to neutralize are exactly considered, allowing a correct phase-compensation. According to the invention the noise-oscillations occurring in the auxiliary-filter or filters will be first transformed by means of non-linear circuits in such a way, that they become identical in frequency and in direct opposed phase to the noise-oscillations existing in the signal-filter. The operation indicated we will further designate as phase-compensation.

The means for carrying this out in practice according to the invention are illustrated by way of examples in the accompanying drawings.

Fig. 1 illustrates the transmitting and receiving of a so-called "ideal-shock-voltage."

Fig. 2 shows the time-curve of an "ideal-shock-voltage."

Fig. 3 shows an equivalent circuit diagram on the receiving end.

Fig. 4 shows a diagram of an arrangement for phase-compensation by means of frequency-shift in the local oscillator.

Fig. 5 shows a diagram of an arrangement for producing the necessary impulse voltage.

Fig. 6 shows the time-curve of the voltages occurring in different points of the arrangement in Fig. 5.

Fig. 7 shows a diagram of a "Kipp" amplifier.

Fig. 8 shows the diagram of a receiver designed according to the method of phase-compensation by means of frequency-leap in the local oscillator.

Before passing to a description of the methods according to the invention, the time curve of the

noise oscillations caused by a so-called "ideal-shock-voltage" will be examined. We suppose that the key M on the left-hand part of Fig. 1 is closed suddenly at the time $t=0$. Across the pure ohmic resistance R the voltage will rise suddenly from zero to the value of the battery-voltage E_B . The current through R will also suddenly rise to the value E_B/R . This time-curve is shown in Fig. 2 and the curve of the same kind will be designated as an "ideal-shock-voltage." This wave-form can really be achieved only approximately, since in every electrical circuit there is also inductance and capacitance. The inductance flattens the rise of the current while the capacitance flattens that of the voltage.

For the sake of simplicity, at first we will treat the noise elimination in the case that the noise occurs in the form of an ideal-shock-voltage. As will be shown hereafter the results can be generalized to the case where the noise-oscillations have any wave-form. An ideal-shock-voltage can be considered as the sum of sinusoidal oscillations according to the well known theorem of Fourier. A continuous frequency-spectrum will be found with a bandwidth from zero to infinity. All these components of different frequencies will be radiated from the aerial A_1 in Fig. 1 and afterwards they will energize the receiving-aerial A_2 . The wave-form of the noise-oscillations occurring in the receiving-aerial A_2 will be different from that of an ideal-shock-voltage since the components of different frequency will be damped in different measure during their propagation from A_1 to A_2 . To the aerial A_2 is coupled a filter F_1 having a small pass-band. For the frequencies lying within this small pass-band the space-damping during the propagation from A_1 to A_2 can be considered as constant and therefore the oscillations across the output terminals of filter F_1 will be the same as if an ideal-shock-voltage would be impressed directly on the receiving-aerial A_2 . We have the equivalent scheme in Fig. 3. The ideal shock-voltage is produced by closing the key M which suddenly impresses the battery-voltage across the primary circuit of the band filter. As is well known, the voltage occurring across the condenser of the secondary circuit has the wave-form of damped fluctuating-oscillations as follows:

$$u_1 = U \{ e^{-at} \cos 2\pi(f+p)t - e^{-bt} \cos 2\pi(f-q)t \} \quad (1)$$

wherein f denotes the natural frequency of the uncoupled circuit, $f+p$ and $f-q$ are the two frequencies of the double humps of the resonant-

curve, and a and b the damping-factors of the circuits. The Equation 1 is applicable at any time $t > 0$ if we set for $t=0$ the instant at which the key M was closed. We think now of a second filter F_2 to be coupled to the receiving-aerial A_2 in Fig. 1 having the same coupling and damping factors as filter F_1 , but its circuits being tuned to a frequency $f+\Delta f$ neighbouring to f . For the noise-oscillations occurring across the secondary circuit of filter F_2 we obtain:

$$u_2 = U \{ e^{-2at} \cos 2\pi(f+p+\Delta f)t - e^{-bt} \cos 2\pi(f-q+\Delta f)t \} \quad (2)$$

which equation is applicable at any time $t > 0$, if $t=0$ denotes the instant at which the key M was closed. As is shown in Equations 1 and 2 the amplitudes of the noise-oscillations occurring in the filters F_1 and F_2 are equal to each other, but they have different frequencies.

The method according to the invention is shown diagrammatically in Fig. 4 and may be called "phase-compensation by means of frequency-shift in the local oscillator." In Fig. 4 are two filters F_1 and F_2 coupled to the antenna A. The filter F_1 is tuned to the signal-frequency while the filter F_2 is tuned to a closely neighbouring frequency (for instance 10 kc. higher or lower). The filter F_1 feeds—as usual—the grid G_1 of the tube V_1 , while the filter F_2 is connected to the grid G_2 of the tube V_2 . To the anodes of both tubes and filter F_1 is connected in push-pull arrangement and is tuned to the intermediate frequency and feeds into the I. F. part of the receiver, which is as usual. The oscillator-modulator tube V_1 produces—as usual—the local oscillator-frequency $f_0 = f + f_1$, which is higher by the I. F. frequency f_1 upper than the signal-frequency. During the time at which there is no noise-voltage in the aerial, the filter F_2 remaining currentless. The oscillator-frequency in V_2 is the same as in V_1 that is $f + f_1$, while the phase of the oscillator voltage in V_2 is identical to the phase of the oscillator voltage in V_1 . This accordingly is accomplished by a synchronising voltage originating from the oscillator circuit in V_1 and used for controlling the oscillator voltage in V_2 . In Fig. 4 the synchronising device is designated with S. The oscillator frequency in V_2 can be also influenced by the device K in such a manner that if across the output terminals of K there suddenly occurs an impulse voltage, this causes a sudden increase of the frequency in V_2 by the amount Δf , which is the tuning-difference between the filters F_1 and F_2 . During the time there is no noise-voltage and only the signal-voltage acts on the aerial, this signal will be transposed by the tube V_1 in the normal way to the intermediate frequency and fed into the I. F. stage V_1 . The tube V_2 has no influence on this operation since the signal-frequency can not pass through the filter F_2 and thus the grid G_2 of valve V_2 is not excited. Now we will consider the case that at time $t=0$ an ideal-shock-voltage occurs in the aerial. Across the filters F_1 and F_2 noise-oscillations will arise, the time-curve of which may be represented by the Equations 1 and 2. The frequency of the oscillator-voltage v_1 in the valve V_1 is $f + f_1$ and supposing that the phase angle of it at the instant in which the shock-voltage occurs has the value $+\phi$, we obtain:

$$v_1 = V \{ \cos [2\pi(f+f_1)t + \phi] \} \quad (3)$$

The I. F. voltage delivered from the tube V_1 can be obtained—as known—by forming the product $u_1 v_1$, that is the voltages on the modulator-

grid and oscillator-grid, calculating the I. F. component of this product and multiplying by the mutual conductance g of the tube. Thus we obtain:

$$u_1 = g \frac{U \cdot V}{2} \{ e^{-at} \cos [2\pi(f_1-p)t + \phi] - e^{-bt} \cos [2\pi(f_1+q)t + \phi] \} \quad (4)$$

The Equation 4 which represents the I. F. voltage delivered by the tube V_1 is built up in the same way as Equation 1 and therefore the waveform of it is the same as that of the noise-oscillations in filter F_1 , yet here is also the phase angle ϕ being equal to that of the oscillator-voltage which existed at the instant $t=0$ (the instant at which the ideal shock-voltage was occurring). Now we will consider the phenomena occurring in the tube V_2 . The voltage on the modulator-grid is given by the noise-oscillations in filter F_2 which are represented by Equation 2. Until the instant $t=0$ at which the shock-voltage appears, the oscillator-voltage in V_2 has the same frequency and phase angle as that in tube V_1 . The noise-voltages beginning at the time $t=0$ in filter F_2 will be amplified and rectified by the arrangement K to be described further and the produced negative voltage will be fed into the grid of tube V_2 causing the capacitance between the grid G_2 and cathode to be decreased and thus there results a sudden increase of the oscillator-frequency by the amount Δf . At any time $t > 0$ the oscillator-voltage may be represented as follows:

$$v_2 = V \cdot \cos [2\pi(f+f_1+\Delta f)t + \phi] \quad (5)$$

Wherein the phase angle ϕ is the same as in Equation 3 in the expression for the oscillator-voltage of the tube V_1 since until $t=0$ both oscillator-voltages were in phase-accordance. Multiplying the voltages acting on the modulator and oscillator-grid, that is the expressions in Equations 5 and 2 together, and considering only the I. F. component of this product, we obtain for the I. F. voltage delivered from the tube V_2 :

$$u_2 = g \frac{U \cdot V}{2} \{ e^{-at} \cos [\pi(f_1-p)t + \phi] - e^{-bt} \cos [2\pi(f_1+q)t + \phi] \} \quad (6)$$

which expression is identical with that for the I. F. voltage delivered from V_1 according to Equation 4. As Fig. 4 shows, the two tubes V_1 and V_2 work in opposite phase with respect to the I. F. filter F_1 and therefore in the latter the noise-oscillations originated from the tubes V_1 and V_2 cancel each other and only the signal-voltage remains. After the noise-oscillations in filter F_2 originating from the shock-voltage have decayed, the grid-voltage of tube V_2 become zero and the grid-cathode capacitance as well as the frequency of the oscillator-voltage in V_2 , again take normal values. By virtue of the synchronising voltage delivered from the devices S, the phase-accordance between the oscillator-voltages in both tubes V_1 and V_2 will be established again and therefore the whole arrangement is able to compensate another noise-impulse.

We supposed till now, that the rectified impulse voltage resulting from the arrangement K occurs at time $t=0$ without any delay. Really it will take a finite time depending on the construction till the necessary value of the impulse voltage will be achieved to produce the frequency-leap in tube V_2 . This delay causes a fault of phase in the compensation and therefore it must be kept as small as possible. Fig. 5 shows the diagram of an arrangement for producing of the neces-

sary impulse voltage. The filter F_2 which feeds the tube V_2 in Fig. 4 is also connected to the grid of the high frequency amplifier V_3 which operates as an aperiodic amplifier. Aperiodic amplifying is chosen since this operates without any delay while amplification with tuned anode-circuits requires a finite time till the amplitude of the amplified oscillations will achieve its final value. The amplification factor of the tube V_3 determines the lower limit of the noise-oscillations at which the arrangement for noise-eliminating will operate. A smaller noise-voltage produces an impulse voltage which is not able to cause the frequency-shift in the oscillator-modulator tube V_2 . This lower limit of response of the noise-eliminating arrangement ought to be directly proportional to the amplitude of the signal voltage. For this purpose the A. V. C. of the receiver acts also on the tube V_3 as is indicated by the arrow in Fig. 5. In the case of a strong signal the lower limit of response will be larger, while with a weak signal the lower limit will be lower. The oscillations amplified by the tube V_3 will be rectified in the diode D_1 . In Fig. 6 the upper curve a shows the shape of the oscillations according to Equation 2. The curve b shows the shape of the detected voltage. The dotted line corresponds to the envelope of curve a . The condenser C_1 is so chosen that the time-constant of charging it through the diode D_1 is so small that the voltage across it at any time follows the increasing voltage curve. When the voltage according to curve a is decreasing (dotted line) the condenser will be discharged through the resistance R_1 , the value of which is so chosen, that the exponential curve of discharging is a little slower than the decay of the oscillations according to curve a . The time-curve of the voltage across the condenser C_1 which is impressed on the grid of tube V_4 is shown in the curve b in Fig. 6. For the anode-load of V_4 is chosen a pure inductance, the value of which is, at the frequencies in question, much smaller than the plate-resistance of V_4 . Under this condition the anode-current has the same wave-form as the grid-voltage and the voltage drop across the anode coil is

$$L \frac{di}{dt}$$

where L is the inductance and

$$\frac{di}{dt}$$

the time derivative of the anode-current. The shape of this voltage is shown by the curve c in Fig. 6. As it is seen the voltage arises suddenly, yet this rise will be a little flattened by the unavoidable capacitances (these of the tubes etc.) connected parallel to the load coil. The voltage according to the curve c coming from the tube V_4 is impressed on an arrangement which will be hereinafter called a "Kipp-amplifier." The "Kipp-amplifier" according to the invention is a back-coupled amplifier in which the feed-back voltage acts through a rectifier and therefore only in one direction. Fig. 7 shows a diagram of a "Kipp-amplifier" according to the invention. The tube V_5 is connected with condenser-resistance coupling to the tube V_6 which serves as a phase-inverting tube to make possible the back-coupling in correct phase. To the anode of tube V_6 is connected the diode D_2 in series with the condenser C_2 and resistance R_2 and to the common-point P of diode D_2 and condenser C_2 , the grid of the tube V_5 connected. If a positive grid-voltage is sud-

denly impressed on the tube V_5 , the back-coupling does not act since the cathode of the diode D_2 becomes more positive than its anode and therefore no current will flow through it, but if the voltage at the grid of tube V_5 is negative, the cathode of the diode D_2 becomes more negative than its anode and a strong current will start through it causing the negative voltage of the grid G_1 to increase rapidly until the anode current in the tube V_5 will be suppressed and the condenser C_2 will be negatively charged so that the anode of the diode D_2 becomes as negative as its cathode. After this the condenser C_2 will be discharged through the resistance R_2 . The time-curve of charging and discharging of the condenser C_2 is shown by the curve d in Fig. 6. It consists of two exponential curves. The rising part has the time-constant

$$\frac{\lambda S}{C_2}$$

wherein λ denotes the amplification factor of V_5 , S the transconductance of V_5 and C_2 the capacitance. The falling part has the time constant $C_2 R_2$ since no back-coupled voltage is acting, where R_2 is so chosen that the discharging will be a little slower than the decay of the oscillations in the filter F_2 in Fig. 4. Supposing the diode D_2 to have an ideal rectifier curve, every negative voltage-impulse of any small finite value will cause voltage-variation at the grid G_1 of valve V_5 according to the curve $6d$. In reality the diode D_2 has for very small positive voltages a very high resistance so that it may be considered as an open circuit and therefore it will set a lower limit of response for the negative impulse acting on the grid G_1 of tube V_5 .

Fig. 8 shows by way of example the diagram of a receiver containing the noise-eliminating arrangement described above. The input filter acting on the octode V_0 is deliberately damped so that its bandwidth (about 20 kc.) is twice more than the signal frequency range. The octode V_0 transforms the input signal in a high I. F., f (about 1600 kc.) the signal-filter F_1 is tuned to this. To a closely neighbouring frequency (cca. 10 kc. higher or lower) the auxiliary filter F_2 is tuned. The filter F_4 is connected to the octode V_1 which transforms the signal-oscillations of the frequency f to those of the second I. F. f_1 (about 460 kc.) the filter F_1 is tuned to this. The auxiliary filter F_2 is connected to the grid G_4 of the octode V_2 and feeds in addition the "Kipp" amplifier of Fig. 7 through the high frequency amplifier shown in Fig. 5. The "Kipp" amplifier acts on the first grid of the octode V_7 , the fourth grid of which is parallel-connected to the oscillator circuit of the octode V_2 . If there is no noise voltage in the aerial, the incoming signal will be changed in frequency by the octode V_0 and passing through the filter F_1 will feed the second frequency changer octode V_1 . The signal thus transformed passes the filter F_1 tuned to the second I. F. frequency f_1 which feeds the I. F. amplifier V_1 and the following audio frequency part A of the receiver built up as usual. The octode V_2 is not operating since the signal cannot pass the filter F_2 and thus its input grid will be not excited. If a noise-voltage occurs in the aerial the damped fluctuating oscillations occurring in the filter F_2 will feed the valves V_2 and V_3 . This latter acts on the "Kipp" amplifier and causes a negative voltage according to Fig. $6d$ on the grid G_1 of the octode V_7 and the electron-current in it will be suppressed suddenly. This

causes a decreasing of the capacitance grid G_4 —cathode of V_F and thus the necessary frequency-shift in the oscillator frequency of the octode V_2 . The I. F. voltages delivered from the tubes V_1 and V_2 in the filter F_1 during the noise-impulse correspond to the Equations 4 and 6 and thus cancel each other. Only the signal voltage will reach the I. F. amplifier V_1 . After the noise-oscillations in F_2 have decayed (cca. $\frac{1}{5000}$ sec. in usual circuits) the negative voltage on the first grid of V_F will disappear and the oscillator frequency in V_2 will become again the same value as that of tube V_1 . The phase of the oscillator-voltage in V_2 will be also corrected by the synchronizing voltage due to the coil S connected to the anode of V_1 and coupled to the oscillator circuit of V_2 and thus both the frequency and phase become again the same as in the octode V_1 . The whole arrangement is again ready to eliminate a new noise-impulse.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. In a radio receiver, an antenna, a first filter for selecting the transmitted signal from said antenna, and a second filter for selecting from said antenna an auxiliary frequency range close to said transmitted signal, oscillators associated with each of said filters for producing an intermediate frequency signal in each filter, and means operative upon the receipt of a disturbance for causing the frequency of the oscillator associated with said auxiliary frequency range to change by an amount equal to the tuning difference between the two filters and means for combining the disturbance signal outputs of said first and second filter in opposed relation for balancing out disturbances.

2. In a radio receiver, an antenna, a first filter for selecting the transmitted signal from said antenna, and a second filter for selecting from said antenna an auxiliary frequency range close to said transmitted signal, oscillators associated with each of said filters for producing an intermediate frequency signal in each filter, means operative upon the receipt of a disturbance for causing the frequency of the oscillator associated with said auxiliary frequency range to change by an amount equal to the tuning difference between the two filters, means for combining the disturbance signal outputs of said first and second filter in opposed relation for balancing out disturbances, and means for synchronizing the voltages of said oscillators when no disturbances are being received.

3. In a radio receiver, an antenna, a first filter for selecting the transmitted signal from said antenna, and a second filter for selecting from said antenna an auxiliary frequency range close

to said transmitted signal, oscillators associated with each of said filters for producing an intermediate frequency signal in each filter, means operative upon the receipt of a disturbance for causing the frequency of the oscillator associated with said auxiliary frequency range to change by an amount equal to the tuning difference between the two filters, means for combining the disturbance signal outputs of said first and second filter in opposed relation for balancing out disturbances, and means for synchronizing the voltages of said oscillators when no disturbances are being received, said last mentioned means comprising a coupling coil for interconnecting said oscillators.

4. In a radio receiver, an antenna, a first filter for selecting the transmitted signal from said antenna, and a second filter for selecting from said antenna an auxiliary frequency range close to said transmitted signal, oscillators associated with each of said filters for producing an intermediate frequency signal in each filter, means operative upon the receipt of a disturbance for causing the frequency of the oscillator associated with said auxiliary frequency range to change by an amount equal to the tuning difference between the two filters, said means comprising a multi-grid tube having one grid joined to said last-mentioned oscillator and another grid joined to said second filter, means for combining the disturbance signal outputs of said first and second filter in opposed relation for balancing out disturbances, and means whereby the effective capacitance of said tube is varied when a negative voltage is impressed upon said first grid.

5. In a radio receiver, an antenna, a first filter for selecting the transmitted signal from said antenna, and a second filter for selecting from said antenna an auxiliary frequency range close to said transmitted signal, oscillators associated with each of said filters for producing an intermediate frequency signal in each filter, means operative upon the receipt of a disturbance for causing the frequency of the oscillator associated with said auxiliary frequency range to change by an amount equal to the tuning difference between the two filters, said means comprising a multi-grid tube having one grid joined to said last-mentioned oscillator and another grid joined to said second filter, means for combining the disturbance signal outputs of said first and second filter in opposed relation for balancing out disturbances, a negative feedback amplifier in circuit with said multi-grid tube, said feedback being supplied through a half wave rectifier, circuit means for impressing the output of said amplifier upon said multi-grid tube for varying the effective capacitance thereof.

MARTIN WALD.