May 28, 1946. J. A. WORCESTER, JR 2,401,214

RECEIVER CIRCUITS

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Fig. 1.

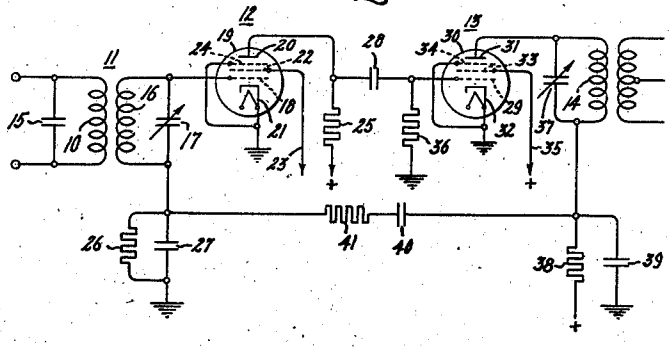
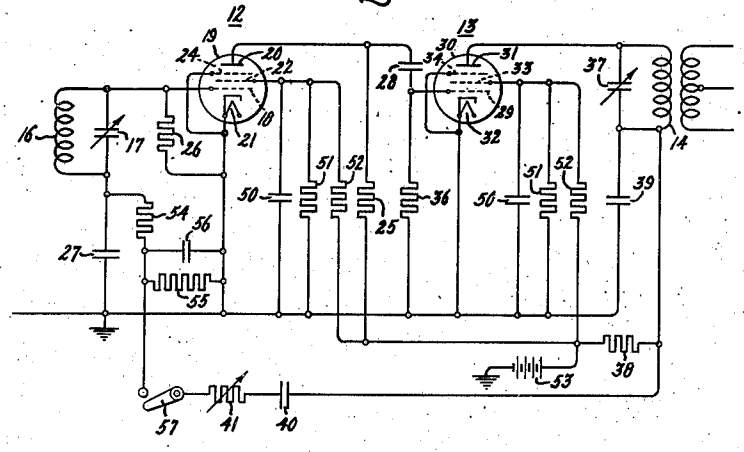


Fig. 2.



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RECEIVER CIRCUITS

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8 Claims. (Cl. 250—20)

My invention relates to radio receiver circuits and more particularly to the elimination of noise encountered in tuning from one station to another.

It is an object of my invention to provide an improved receiver circuit arrangement which eliminates noise when tuning between stations.

More specifically, it is an object of my invention to provide an improved receiver circuit in which a pair of electron discharge devices operating in cascade are employed, in the absence of incoming signals in the receiver circuits, to function as a multivibrator and, in alternation, block translation of noise to the receiver output.

In frequency modulation receivers it is customary, in order to obtain the full benefits of the noise reducing properties of frequency modulation, to employ an electron discharge device as a limiter to remove amplitude modulation components from the modulated high frequency carrier waves, the amplitude at which limiting occurs being determined by the amplitude of the weakest signal which it is desired to reproduce. Particularly effective limiting has been obtained by the use of a plurality of electron discharge devices in cascade, means being provided to prevent regeneration between the devices of the different stages of the limiter. In the absence of a carrier wave, however, noise impulses having a minimum R. M. S. amplitude of the aforesaid weakest signal appear in the receiver output unless special means is provided to eliminate noise pulses during such a period.

It is an object of my invention to provide an improved limiter circuit in which regeneration between stages is introduced to eliminate noise pulses in the absence of a high frequency wave.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents a portion of a receiver circuit embodying my invention and Fig. 2 is a modification of the circuit of Fig. 1.

As shown in Fig. 1, high frequency carrier waves are supplied to the primary winding 10 of an input transformer 11. These waves may be supplied directly from a receiving antenna or a radio frequency amplifier. However, in the usual form of superheterodyne receiving apparatus, they will be intermediate frequency carrier waves and in a frequency modulation receiver are supplied from the final intermediate frequency amplifier.

The high frequency carrier waves are subjected to amplitude limitation through limiter circuits 12 and 13. They are then supplied to the input winding of a transformer 14 which may be part of a discriminator or detector circuit, not shown. Subsequent to demodulation in the discriminator circuit, the low audio frequency signals may be amplified through further stages of amplification and ultimately supplied to a sound reproducer.

Connected across the primary winding 10 is a capacitor 15 for tuning the primary transformer circuit to the intermediate frequency. The secondary winding 16 of transformer 11 is similarly tuned by means of the capacitor 17 and the high frequency voltages in this tuned circuit are supplied to the control electrode 18 of electron discharge device 19. The device 19 is shown to be of the pentode type having, in addition to the anode 20 and the cathode 21, screen electrode 22 connected by means of conductor 23 to any suitable source of operating potential, and a third control electrode 24 which may be directly connected to the cathode 21 to act as the usual suppressor grid. The anode 20 of device 19 is connected through a load resistor 25 to a suitable source of potential. The cathode 21 is directly connected to ground and the input circuit of limiter 19 is provided with a grid resistor 26 having a by-pass capacitor 27 connected thereacross.

The anode circuit of device 19 is coupled by means of capacitor 28 to control electrode 29 of electron discharge device 30 in the second stage limiter circuit 13. The device 30 is likewise of the pentode type having the anode 31, the cathode 32, and, in addition to the control electrode 29, screen electrode 33 and a suppressor grid 34, the latter being directly connected to the cathode 32 and electrode 33 being connected by means of the conductor 35 to a suitable source of potential, not shown. The cathode 32 is directly connected to ground and grid resistor 36 is connected between the control electrode 29 and ground. The output circuit for anode currents of device 30 comprises, in addition to the primary winding 14 of a discriminator transformer, the capacitor 37 for tuning the output circuit to the intermediate frequency and resistor 38 is connected between the tuned output circuit and any suitable source of anode potential to act as a decoupling resistor, as well as for certain other purposes which are pointed out in detail later.

The capacitor 39, connected across resistor 38, acts as the anode by-pass capacitor and is of a value such that the resistor 38 and capacitor 39 function as a low pass filter for removing currents having a frequency of the order of the intermediate frequency from the potential source.

The portion of the receiver circuit thus far described comprises the conventional type of cascade limiter circuit employed in a frequency modulation receiver, the two limiter devices 19 and 30 utilizing resistance-capacity coupling between the stages 12 and 13.

Cathode 21 is directly connected to ground and signals supplied to grid 18 cause grid current to flow and charge capacitor 27, thus providing a negative bias for device 19. During negative half cycles of the incoming signals, the charge on capacitor 27 leaks off, the rate of leakage being determined by the value of resistor 26. During the period of positive half cycles that grid current flows, capacitor 27 charges rapidly, the charging rate being determined by the relatively low grid resistance of device 19. Actually, because of the difference between the charging and discharging rates of capacitor 27, grid current flows only for a brief interval during the positive peaks of the signal supplied to grid 18. The smaller the grid leak resistor 26, the more positive the signal has to go, since then condenser 27 discharges more rapidly. It is seen that with a limiter operating in this manner, the plate current in device 19 flows in pulses produced by part of each positive half cycle. The remaining part of the positive grid cycle, as well as the entire negative half, drives grid 18 negative so that no grid current flows. When the signal at grid 18 increases, grid 18 is driven more positive and the plate current of tube 19 tends to increase. However, the pulse of plate current also becomes slimmer, with respect to time, since a smaller percentage of the total positive grid cycle produces plate current. This tends to reduce the average plate current.

Since it is desired to remove sharp impulses from the output of the receiver, the time constant of resistor 26 and capacitor 27 is made as small as possible. While this permits device 19 to amplify signals a slight amount, signals supplied by the output of tube 19 to the input of tube 30 are restricted to a limited range of amplitudes. Since noise impulses are reduced substantially by the first limiter tube, the selection of the time constant of the network comprising capacitor 28 and the resistor 36 in the circuit of the control electrode 29 of device 30 is less critical and is chosen with the view of further limiting the restricted input signal amplitudes so that the output currents of the second limiter have a substantially constant value. In a cascade limiter of this type, therefore, the first limiting device is effective partially to limit the amplitude of signals supplied to the second device and to remove a considerable amount of impulse noise from such signals. The second limiting device is effective to provide a substantially constant output over the very restricted range of signal input amplitude supplied by the first limiter. Since in this portion of the receiver circuit it is usually not necessary to provide appreciable additional gain for the signals being translated, it is customary to use resistance coupling between the limiter stages 12 and 13 both for simplicity of coupling and to prevent unwanted regeneration.

In the absence of a carrier wave in frequency modulated receiver circuits of the type thus far described, it is well known that noise impulses pass through the limiter circuits and appear in the receiver output unless special means is provided to eliminate noise impulses during such periods. In accordance with my invention, the passing of noise impulses through the limiter circuit in the absence of a received high frequency wave is prevented by causing the limiter circuits 12 and 13 to regenerate after the fashion of a multivibrator and to set up oscillations having a frequency outside the limits of the range of audio frequencies and having an amplitude large enough to cause a maximum or saturation current to flow in the devices 19 and 30 and eliminate noise pulses from the output circuit of the device 30.

In order to provide a circuit which oscillates in the absence of high frequency carrier waves, the output circuit of the device 30 is coupled to the tuned input circuit of the device 19 by means of the capacitor 40 and the resistor 41 so that these devices operate as a multivibrator. Oscillations in the multivibrator circuit thus established are started by a positive noise voltage in the input circuit or a voltage irregularity at the grid of one of the tubes, grid 18 for example. This voltage is amplified by the two devices and then reapplied to grid 18 in the correct phase and as a more positive potential to be again amplified. The more positive potential of electrode 18 is effective to produce a large anode current flow in device 19 and through load resistor 25, greatly reducing the potential of anode 20 and carrying the potential of control electrode 29 beyond the cutoff point of device 30, since the charge on capacitor 28 cannot change instantaneously. Cessation of current flow in device 30 causes a sudden increase in the potential of anode 31 and, through the action of capacitor 40, of control electrode 18, the increased potential of the latter being effective to increase the current flow in device 19 to its maximum, or saturation, value for the screen grid and anode potentials employed. The charge on capacitor 28 leaks off through resistors 25 and 36 at an exponential rate, returning the potential of grid 29 toward its normal operating value. At the same time capacitor 40 is charged at an exponential rate through the series circuit comprising resistors 41, 26, the potential source, and resistor 38 and reduces the positive potential of grid 18. When the potential of grid 29 reaches the point that amplification is again possible, there is repetition of the amplification action, this time in the opposite direction, which results in a rapid rise in potential of grid 29 and a rapid decrease in potential of grid 18. In this manner the operation of the multivibrator is reversed to bias grid 18 beyond cutoff and reduce the current flow in device 19 to zero.

The frequency of the oscillations, or reversals of current flow, in the multivibrator circuit is determined chiefly by the time constants of the resistors and capacitors used in the grid circuits of the two devices 19 and 30, that is, the time constant of resistor 26 and capacitor 40 and of resistor 36 and capacitor 28. Preferably, these values are adjusted so that the multivibrator oscillates at a frequency intermediate the frequencies of the audio signals and the carrier wave, for example about 30 kilocycles.

In the absence of high frequency carrier waves in the primary circuit of the transformer 11, in accordance with my invention, therefore, the multivibrator circuit operates to provide voltages hav-

ing a frequency above audibility and below the frequency of the tuned input and output circuits of the devices 19 and 30. This multivibrator voltage has sufficient strength to produce, in alternation, saturation current flow in one of the devices 19 and 30 at the anode and screen electrode voltages at which they are operating and to block current flow in the other of the devices. Since one or the other of devices 19 and 30 is thus nonconducting at all times, any noise currents in the preceding circuits of the receiver are prevented from reaching the output circuits of the receiver.

When a carrier wave from the preceding portion of the receiver is again supplied to the tuned input circuit of the device 19, it is effective to produce a negative bias across resistor 26 and capacitor 27, decreasing the transconductance and reducing the gain of device 19 to the point that oscillation in the multivibrator circuit ceases. For alternating currents a portion of the output circuit of device 30 comprises two parallel paths to ground; one comprising the capacitor 39, and the other comprising capacitor 40, resistor 41, and resistor 26 in parallel with capacitor 27. The elements 26 and 27 are also present in the input circuit of the device 19 and voltages developed thereacross by the alternating currents in the output circuit of device 30 are of such polarity and phase that they comprise a source of positive, or regenerative, feedback to said input circuit. Operation of the multivibrator ceases when the negative bias voltages developed across resistor 26 by signal currents in the limiter 12 are of a magnitude sufficient to overcome the positive peaks of the feedback voltage thereacross.

Since resistance 41 does not affect the normal operation of the cascade limiter circuit, the intensity of the signal modulated carrier wave which is required to stop operation of the multivibrator may be determined by selection of the value of this resistance. Capacitor 39 likewise does not affect the normal action of the limiter circuit so the cutoff point of the multivibrator may be determined also by the value chosen for this element. Adjustment of either resistance 41 or capacitor 39 controls the division of alternating currents in the above-described parallel paths of the output circuit of device 30. Increase of resistance 41 is effective to decrease the amount of output current of device 30 which flows through the path common to the input circuit of device 19. Hence, when either the resistance 41 or capacitance 39 is increased, multivibrator action is stopped by a weaker signal supplied to limiter 12.

In Fig. 2 is shown a modification of the limiter circuit shown in Fig. 1. In the two figures corresponding reference numerals have been placed on corresponding elements to facilitate a comparison.

In the circuit of Fig. 2 the grid resistor 26 for device 19 is shown as directly connected between the control electrode 18 and ground. Likewise, the control circuits for screen electrodes 22 and 33 are shown in detail. These circuits include capacitors 50 short-circuiting these electrodes to the cathodes of the devices for currents of the frequencies to be amplified and the voltage divider comprising resistors 51 and 52 connected across the source of operating potential shown as the battery 53, the common point of resistances 51 and 52 being connected to the screen electrode.

In the form of the multivibrator circuit shown in Fig. 2, a network comprising resistors 54, 55 and capacitor 56 is included in the multivibrator circuit, resistors 54 and 55 forming a voltage divider circuit between the control electrode 18 and the cathode 21. The capacitor 56, connected across the resistor 55, forms therewith a path of sufficiently long time constant that any "hiss" or transient currents introduced into the limiter circuit by the currents of the multivibrator are bypassed to ground preventing their reproduction in the output circuits of the receiver.

In order to provide means for adjusting the multivibrator circuit for operation at a desired frequency, in the modification shown in Fig. 2, resistor 41 is made a variable resistor and switch 57 is provided in the feedback circuit between the two electron discharge devices. For reasons explained above in connection with the description of the operation of the circuit of Fig. 1, by varying the positive feedback between the output circuit of device 30 and the input circuit of device 19 by adjustment of the resistor 41, the noise suppression circuit may be adjusted to operate at a desired level to permit reception of signals of a minimum intensity. Also, the switch 57 is provided to facilitate, in the absence of a carrier wave in the input circuit of the device 19, comparison of noise in the receiver during periods when the multivibrator is operating and periods when its effect is removed from the receiver circuits.

As thus described, my invention provides, in a translating circuit for carrier waves which are modulated by desired signals and subject to undesired noise transients, an inter-channel noise suppression circuit which combines, with a pair of amplifying devices connected in cascade, a feedback circuit for producing in the cascade circuit, in the absence of received carrier waves, an oscillation having a frequency intermediate the frequencies of the carrier waves and signals by which they are modulated and which, by alternately stopping current flow in one of the devices while causing saturation current to flow in the other of the devices, prevents translation of noise to the output circuits of the receiver.

Merely for the purposes of illustration, the following data is given for a radio receiving apparatus embodying my invention. These values were found to give satisfactory results in a particular case although they are not to be regarded as necessarily applicable to all embodiments of my invention.

Resistors 38, 54	ohms	22,000
Resistors 26, 55	do	47,000
Resistor 41	do	100,000
Resistor 25	do	10,000
Resistor 36	do	180,000
Capacitor 40	mmf	470
Capacitor 56	do	220
Capacitors 27, 39	do	47
Capacitor 28	do	22
Tubes 19 and 33		Type 6SJ7

It is found that in the absence of signal, the two devices 19 and 30 act as a multivibrator oscillator having a frequency around 30 kilocycles. It is also found that when resistor 41 is adjusted to a value of 50,000 ohms, a 3 to 1 noise reduction is obtained; whereas when this value is adjusted to 10,000 ohms, a 20 to 1 noise reduction is obtained. The action is such that if a higher level of noise suppression is used, stations above the noise level are also suppressed which otherwise could be received at the expense of tuning through objectionable off-station noise. In other words, the level is set where the weakest desired stations are received satisfactorily and the noise between stations is determined by the setting of

resistor 41 or the value of capacitance 39. In a receiver which develops noise peaks equivalent to a 4 microvolt signal on the antenna, a signal of 7 microvolts is sufficient to completely stop the multivibrator and provide essentially noiseless reception.

It will of course be apparent to those skilled in the art that many modifications within the scope of my invention may be made. For example, instead of varying resistance 41, the signal level at which multivibrator operation starts may be adjusted by varying capacitor 39 or any other element whose value is not determined by other considerations, such as the operation of the cascade limiter. Also, although the invention has been described as employed in conjunction with a cascade limiter circuit, it is not to be construed as being limited thereto since it may be used with any two amplifiers connected in cascade, either in the radio frequency or the intermediate frequency stages, the amplifiers being so connected that in the absence of a signal they operate as a multivibrator and, since for substantially the complete time of such operation at least one of the tubes is biased to cutoff, noises in the preceding portion of the receiver circuits are not translated through this multivibrator circuit to subsequent stages of the receiver. In such a case, instead of developing signal voltages across resistor 26 to stop operation of the multivibrator circuit, conventional automatic volume control voltages may be employed for this purpose.

Hence, while I have shown particular embodiments of my invention, it will be understood that I do not wish to be limited thereto since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. The combination, in a noise suppression device for a signal channel, of an electron discharge device connected in said channel to translate signals transmitted through said channel, and means effective when signals in said channel are below a predetermined amplitude to render said device alternately saturated and non-conducting at a super audible rate thereby to prevent translation by said device of noise current in said channel.

2. The combination, in a noise suppression device for a signal channel, of an electron discharge device connected in said channel to translate signals transmitted through said channel, and means effective when signals in said channel are below a predetermined amplitude to render said device alternately saturated and non-conducting at a super audible rate thereby to prevent translation by said device of noise current in said channel, and means responsive to desired signals in said channel to interrupt operation of said last means.

3. The combination, in a noise suppression device for a signal channel, of an electron discharge device having an anode, a cathode, and a control electrode, means to supply signals in said channel between said control electrode and cathode and to supply signals reproduced between said anode and cathode to said channel, a second electron discharge device having an anode, a cathode, and a control electrode, a multivibrator circuit including said two devices whereby oscillations of multivibrator type are produced, and said first device is prevented thereby from translating noise currents appearing in said channel, and means responsive to desired signals to interrupt operation of said multivibrator whereby said first device translates said desired signals.

4. In combination with a source of signal modulated carrier waves subject to undesired noise impulses, an amplifier comprising a pair of electron discharge devices connected in cascade, input and output circuits connected to said amplifier, said input circuit being connected to said source, and means for supplying a positive feedback voltage from said output circuit to said input circuit, said feedback means being effective in the absence of a wave to be amplified in said input circuit to cause said devices to regenerate and produce therein oscillations of a frequency intermediate audibility and the frequency of said wave whereby, in alternation, one of said devices is biased to cutoff and translation of noise impulses to said output circuit is prevented.

5. In combination with a source of signal modulated carrier waves subject to undesired noise impulses, an amplifier comprising a pair of electron discharge devices connected in cascade, input and output circuits connected to said amplifier, said input circuit being connected to said source, means for supplying a positive feedback voltage from said output circuit to said input circuit, said feedback means being effective in the absence of a wave to be amplified in said input circuit to cause said devices to regenerate and produce therein oscillations of a frequency intermediate audibility and the frequency of said wave whereby, in alternation, one of said devices is biased to cutoff and translation of noise impulses to said output circuit is prevented, and means for preventing said amplifier from producing said oscillations when a signal is being amplified thereby.

6. A noise suppression circuit for a signal translating channel comprising a pair of electron discharge devices connected in cascade in said channel, input and output electrodes connected to said devices, positive feedback means connected to supply voltages from said output electrode to said input electrode, said feedback means being effective to cause said devices to regenerate and produce therein oscillations of a frequency intermediate audibility and the frequency of said signals, whereby, in alternation, one of said devices is biased to cutoff and translation of noise by said channel is prevented, and means for interrupting said oscillations when a signal is being translated by said channel, said means comprising a resistance connected between said input electrode and a point of fixed potential and arranged to have developed thereacross signal voltages having a polarity opposite to the voltage supplied to said input electrode by said feedback means.

7. In a receiver for radio signals the combination of an amplifier having an input circuit and an output circuit, means supplying a feedback voltage from said output circuit to said input circuit, said feedback means being effective when signals to be amplified in said input circuit are below a predetermined amplitude to cause said amplifier to regenerate and produce oscillations of a frequency intermediate audibility and the frequency of said signals, whereby noise currents are eliminated when said signal currents are below said predetermined level, and means in said input circuit for eliminating any audio frequency currents produced in said circuits by said oscillations.

8. The combination in a radio receiver for frequency modulated waves, of means for limiting the intensity of said waves to a predetermined value to remove noise currents therefrom, said means comprising an electron discharge amplifier having an input circuit and an output circuit, means for impressing a wave to be amplified on said input circuit, and feedback means connected between said circuits and effective when said waves in said input circuit are below a predetermined amplitude for causing said amplifier to regenerate at a super audible rate and produce oscillations having an intensity of at least said value to remove noise currents from said output circuit.

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