AMPLITUDE MODULATION REDUCING CIRCUIT

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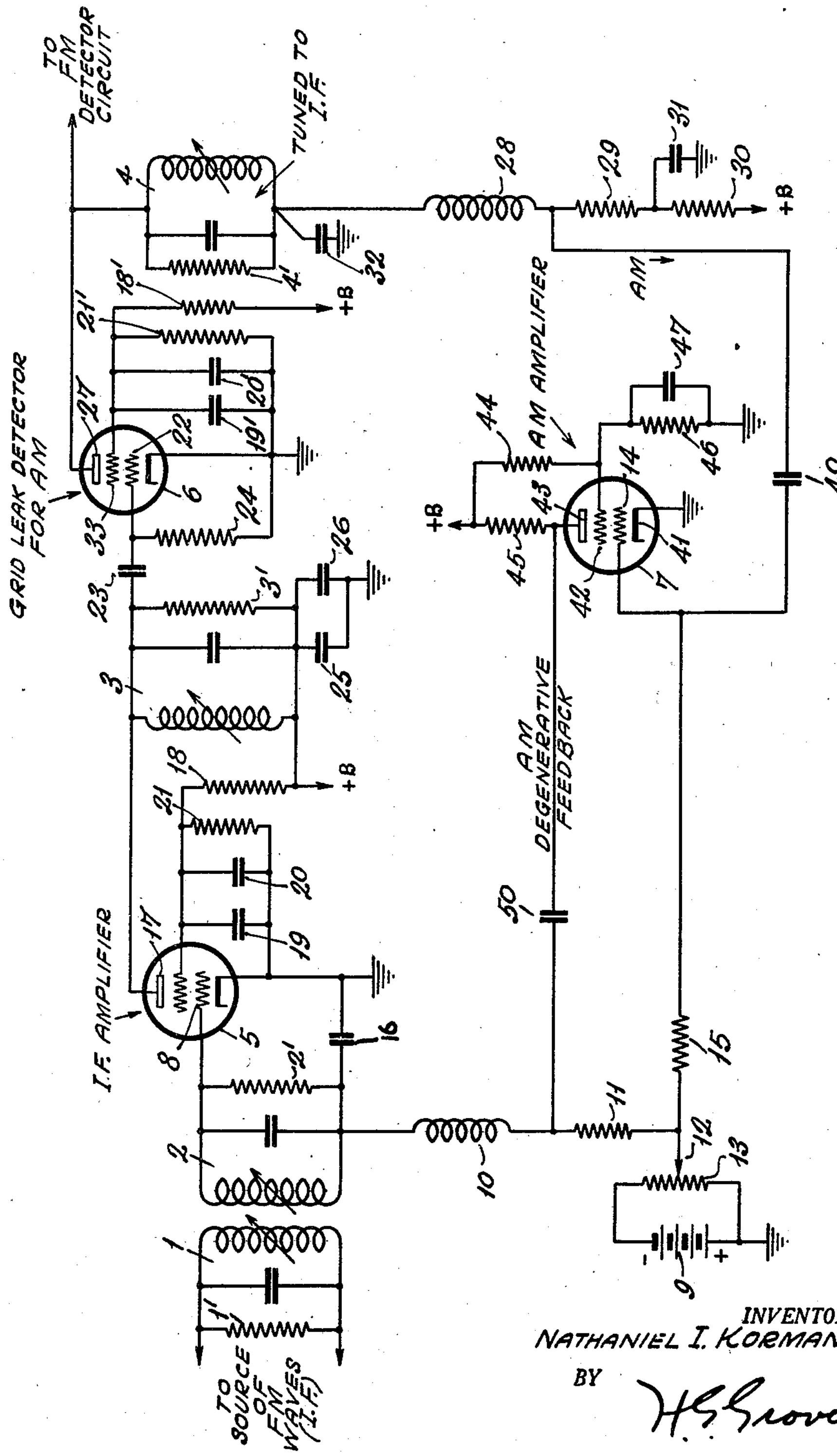

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AMPLITUDE MODULATION REDUCING CIRCUIT

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My present invention relates generally to a novel and improved system for substantially reducing undesired wave amplitude variations in a signalling system employing angle modulated carrier waves.

One of the important objects of my invention is to provide an improved means for eliminating, or at least substantially reducing, undesired amplitude variations or modulation of angle modulated carrier waves by deriving from the latter any amplitude variation component which may exist on the waves, and then applying the derived component to a wave amplifier in a sense to inversely modulate, or degenerate, the amplifier with respect to the amplitude variation component of the modulated carrier waves whereby the undesired amplitude variations are effectively reduced.

Another important object of my present invention is to provide a circuit arrangement for a frequency modulation (FM) receiver, wherein amplitude modulation (AM) existing on the FM carrier wave is detected in a grid leak type of detector whose output circuit concurrently feeds FM wave energy to a following FM demodulator network, the detected AM voltage being amplified and applied to an amplifier stage preceding the demodulator in such a phase as degeneratively to decrease the amplitude modulation on the FM carrier wave.

Another object of my invention is to provide an improved system for removing amplitude variations from FM carrier waves which is efficient and effective for ultra-high frequencies as high as 100 megacycles (mc.) or higher, and which is not dependent upon a relatively high level of input signal energy as is the case with the various known forms of limiters of the readily-saturable amplifier type.

While my present invention is described herein as embodied in the intermediate frequency (I. F.) amplifier section of a receiver of the superheterodyne type, it is to be understood that such an embodiment is purely illustrative. My invention is readily applicable to any signalling system employing angle modulated carrier waves, be the system a receiver or a transmitter. The generic term "angle modulated carrier wave" includes an FM carrier wave or a phase modulated (PM) carrier wave, or carrier waves modulated by hybrid, or mixed, FM and PM characteristics. As those skilled in the art of radio communication well know, an FM wave is one whose carrier frequency is varied or deviated from the normal or center frequency value in accordance with the

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amplitude of modulating signals at the transmitter, the rate of deviation or variation being dependent on the modulation frequencies per se. A PM carrier wave essentially differs from an FM wave in that the extent of deviation is greater for higher modulating signal frequencies than for lower. In other words, a PM wave is a pre-emphasized FM wave. Hence, an FM receiver may receive a PM wave by employing suitable de-emphasis or correction networks at the modulation signal amplifier of the receiver.

Assuming for the purposes of this application that the system described is an FM receiver of the superheterodyne type, only so much of the receiver as includes the I. F. amplifier is shown in the drawing since my invention is applicable to that portion of the system. However, the invention is equally applicable to any other part of the system prior to the I. F. networks, in that the carrier frequency range and the frequency variation range of each received modulated carrier wave are not critical so far as the operation of my invention is concerned. For example, my improved limiting circuit will function in a satisfactory manner in the presently-assigned 42 to 50 megacycles (mc.) FM broadcast band where each transmitter is permitted an overall frequency swing of 150 kilocycles (kc.). The present limiting circuit has advantages for the very high radio frequencies, those for example in the range of 3000 to 30,000 mc. The I. F. value of the receiver could suitably be chosen from a range of 2 to the order of 120 mc., and the overall frequency swing can be over relatively narrow ranges below 150 kc. or over wide ranges as high as 12 mc. or above. The modulating signals may be in the audio frequency range, or in the video frequency range. In the latter case the overall frequency swing of the transmitter carrier will be relatively high.

The drawing shows a schematic diagram of the invention disclosed.

Before describing the details of construction of my invention, it is pointed out that it is assumed that the operating I. F. value is 72 mc., and that the selector circuits are constructed to accommodate and pass an overall frequency swing of 12 mc. In such case each of I. F. selector circuits 1, 2, 3 and 4 will be tuned to the operating I. F. value of 72 mc., with sufficient damping being introduced by respective shunt damping resistors 1', 2', 3' and 4' to impart a pass band width of about 12 mc. to each selector circuit. Each resonant selector circuit prior to circuit 1 will, also, have a suitable pass band width of the order of 12 mc. The selector circuit 1 may be coupled to the output electrodes of a suitable converter tube (not shown), or to the output electrodes of a preceding I. F. amplifier tube. The coils of selector circuits 1 to 4 inclusive are schematically indicated by arrows as being of the adjustable inductance type, more particularly of the adjustable iron core type.

The I. F. amplifier tubes 5 and 6, which for example may be 6AK5 type tubes, are cascaded. Selector circuit 3 couples the output electrodes of tube 5 to the input electrodes of tube 6.

The use of a single selector circuit 3 between tubes 5 and 6 tends to provide less phase shift than would be the case with a double-tuned circuit. Hence, in the present degenerative circuit the use of the single selector circuit 3 tends to minimize phase shift and to insure against the circuits going into oscillation. However, the increased gain resulting from the use of double-tuned selector circuits may be considered as more than compensating for the increase of phase shift, and, therefore, the single selector circuit 3 may be replaced by a pair of coupled selector circuits, if desired. After the desired amplification by tubes 5 and 6 the I. F. signal energy is transmitted to any suitable FM detector circuit. In other words the amplified I. F. signal voltage developed across the tuned selector circuit 4, arranged in the plate circuit of tube 6, is demodulated to provide the modulation signals which originally were applied to the carrier at the transmitter.

The FM detector circuit is not shown, but may be of any well-known type. For example, it may be constructed in the manner shown by S. W. Seeley in his U. S. Patent No. 2,121,103, granted June 21, 1938, it may follow the teachings disclosed by G. L. Usselman in his U. S. Patent No. 1,794,932, granted March 3, 1931, or it may be constructed along the lines of the detector circuit shown by J. D. Reid in his U. S. Patent No. 2,341,240, granted February 8, 1944. The Seeley detector circuit is preferred since, as widely used, it utilizes a discriminator input circuit tuned to the I. F. value thereby facilitating alignment with the prior selector circuits. Whatever the nature of the FM detector circuit, there should be developed across selector circuit 4 signal energy which varies in frequency and not in amplitude. Any AM component or effect which may exist on the FM carrier wave will be evidenced in the FM discriminator-detector output as a distortion product since it is not desired that any amplitude variation exist at the transmitter.

However, there are many reasons why AM components may appear on the FM wave during the passage of the energy from the transmitter to the circuit 4. Noise impulses, selective fading, curvature of receiver selector response curves, tube noise, power supply ripples; these are but a few sources of amplitude modulation of the FM carrier. In the past there has been employed as an amplitude limiting device an amplifier tube whose characteristics were chosen to provide ready saturation of the tube for signals above a desired amplitude. Such a limiter device requires a relatively high signal level at the input thereof. Further, at the very high radio frequencies the usual limiters of the prior art do not function satisfactorily.

My present invention overcomes these objections to the prior limiters, and provides a reliable and quick-acting means for substantially eliminating AM components on the FM wave prior to frequency discrimination. According to my

method the AM component of the FM wave is subjected to detection, but without interfering with the normal I. F. amplification of the FM wave. This detection is secured in the circuit of tube 6. The detected AM voltage is then applied, after amplification by tube 7, to prior amplifier tube 5 in a sense to degenerate the gain thereof for the AM component. Specifically, these functions are accomplished by virtue of the following circuit connections. Amplifier tube 5 has its control grid 8 connected to a source 9 of suitable negative bias through a path consisting of the coil of selector circuit 2, choke coil 10, resistor 11 and slidable tap 12. The direct current source 9 is shunted by resistor 13 of the potentiometer 12, 13. The tap 12 also determines the fixed operating bias for amplifier 7, since control grid 14 of tube 7 is connected to tap 12 through resistor 15. The cathodes of both tubes 5 and 7 are grounded.

The low potential side of selector circuit 2 is returned to ground for I. F. currents by condenser 16. The plate 17 of amplifier tube 5 is connected to the +B voltage supply terminal through resistor 3′, while the screen grid of the tube is operated at a suitable lower positive potential by virtue of voltage-reducing resistor 18. The screen grid is shunted to ground by condenser 19, which may be a 20 microfarad electrolytic condenser and which bypasses any detected AM voltage component (the degenerating voltage), and by condenser 20 which may be a paper condenser of 1500 micromicrofarads and which bypasses the I. F. currents. The reason for using both condensers 19 and 20 is that the relatively large electrolytic condenser 19 may nevertheless have substantial impedance to the I. F. currents. Resistors 21 and 18 comprise a voltage divider for deriving the correct tube voltages.

The tube 6 has its control grid 22 coupled to the high alternating potential side of circuit 3 by condenser 23. The resistor 24 connects grid 22 to the grounded cathode of tube 6. Condensers 25 and 26 connected from the low potential side of selector circuit 3 may correspond respectively to condensers 19 and 20 and bypass to ground respectively the degenerative AM voltage and the I. F. voltage. The condenser 23 and grid leak resistor 24 cooperate to provide the usual leaky grid condenser network for an amplitude modulation detector operating on the principle of grid circuit rectification. The plate 27 of the tube 6 is connected to the +B voltage supply terminal through a path consisting of the coil of selector circuit 4, choke coil 28, resistor 29 and resistor 30. Condenser 31 bypasses to ground the detected AM component, while condenser 32 returns the low potential side of circuit 4 to the grounded cathode of tube 6 for I. F. currents. Condenser 31 assists in getting the correct relation between phase shift and gain in the feedback loop.

The screen grid 33 of tube 6 is bypassed to ground by condensers 19′ and 20′ which act respectively to bypass the degenerative AM component and the I. F. current, as in the case of the screen grid circuit of tube 5. The resistors 21′ and 18′ function to obtain correct screen grid voltage, as in the case of resistors 21 and 18. The grid leak detector tube circuit concurrently detects any AM variations on the FM carrier wave and amplifies the FM wave per se. Since the detector input circuit 3 is tuned to the operating I. F. value, and since no frequency discrimination takes place at circuit 3 so as to translate the FM wave into a corresponding AM wave, the grid leak detector action will not affect the reproduction by the FM detector circuit of the frequency variations of the FM carrier wave. In other words the tube 6 will act in the manner of an I. F. amplifier for the FM carrier wave energy.

However, any AM components existing on the FM carrier wave will be rectified by the well-known grid rectification action of the grid leak detector tube. The grid circuit of tube 6 effectively functions like a diode circuit, the cathode and grid 22 functioning as the diode, and provides rectified voltage of amplitude modulation frequency across resistor 24. This rectified voltage is applied to the control grid 22 of the tube which acts also as a screen grid amplifier tube for the detected AM voltage. The amplified AM voltage output of tube 6 is transmitted to the grid 14 of amplifier tube 7. This is accomplished by connecting grid 14 through the coupling condenser 40 to the lower end of choke coil 28. The cathode 41 of tube 7 is grounded, while the control grid 14 is established at a desired negative bias by virtue of the adjustment of potentiometer tap 12. The screen grid 42 of tube 7 is connected through resistor 44 to the +B terminal which supplies the plate 43, the resistor 45 functioning as the output load resistor of the amplifier tube 7. Screen grid 42 is, furthermore, returned to ground through a resistor 46 bypassed by condenser 47. Resistors 44 and 46 provide a voltage divider for obtaining correct screen voltage for tube 7.

The voltage developed across resistor 45 is amplified voltage of amplitude modulation frequency, and it is applied to the control grid 8 of the I. F. amplifier tube 5. The voltage is applied to the control grid 8 in a degenerative sense. In other words the path including condenser 50 and choke coil 10, which has a relatively low impedance for the AM voltage but a relatively high impedance for I. F. currents, is a degenerative AM feedback path. The condenser 50 is connected from the plate end of resistor 45 to the junction of resistor 11 and choke coil 10. Hence, the AM voltage is employed inversely to modulate the FM wave energy applied to the control grid 8 by the selector circuits 1 and 2. This inverse modulation of the FM wave energy is actually a degenerative control of the gain of amplifier tube 5. In other words the gain control of tube 5 is in accordance with the AM envelope of the detected AM voltage output of tube 6. It may, also, be said that the tube 6, including the amplifier 7, and its connection back to the control grid circuit of tube 5 functions as a fast-acting gain control circuit which acts to reduce the gain of tube 5 in proportion to the tendency of the AM effects on the FM carrier wave to increase.

Let it be assumed, in explaining the operation of the circuit more fully, that for one reason or another the FM carrier wave energy at the receiving system becomes amplitude modulated. There will then be developed across the resistor 24 rectified voltage of amplitude modulation frequency whose wave form follows that of the amplitude modulation of the FM carrier wave. This means that the grid end of resistor 24 will become increasingly negative as the amplitude of the FM carrier wave increases, and thus will reduce the plate current flow through resistors 29 and 30. As a result the plate end of resistor 29 will become increasingly positive in potential with the result that the control grid voltage of tube

7 will increase. This causes the space current flow through resistor 45 to increase thereby rendering the plate end of resistor 45 less positive. The plate end of resistor 45 being connected back to the grid of tube 5, this grid will become more negative and thus act to decrease the gain of tube 5 for the FM wave. Thus, the action of the circuit is to oppose any change in the amplitude of the FM wave.

Since the modulation component of voltage drop across resistor 24 depends upon the existence of amplitude modulation on the FM carrier wave, it necessarily follows that when the amplitude modulation on the carrier wave disappears the voltage across resistor 24 will also disappear. As a result the tube 6 will operate with its normal space current flow, and tube 7 will not have any alternating voltage applied to its grid. It should be noted that the gain of tube 7 is not changed by the presence of amplitude modulation. In the same way the disappearance of the AM component of the FM carrier wave will result in tube 5 functioning as a normal I. F. amplifier. It will, therefore, be seen that the control action is automatic, and responds at once to the appearance of any AM component on the FM carrier wave. In this way there is delivered to the FM detector circuit modulated carrier wave energy which is frequency-variable and is substantially free of any amplitude modulation.

It may be desirable in some instances to eliminate the source of negative bias 9 and the common potentiometer 12, 13 for the control grids 8 and 14. In such case the cathode circuit of each of tubes 5 and 7 will include respective cathode bias resistors of suitable value. Furthermore, in the case where the operating frequency in the system is sufficiently high, the capacitance in each of the selector circuits may be provided by the inherent control grid to cathode capacity of each of the amplifier tubes. Such inherent capacitance may be sufficient to provide the necessary tuning capacity for each selector circuit.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In combination, a source of angle modulated carrier waves, an amplifier for the modulated waves, a second amplifier for the amplified modulated waves, means operatively associated with said second amplifier to render it operative as a detector of undesired amplitude variations in the amplified angle modulated carrier waves applied thereto, means for deriving from the output of said second amplifier voltage representative of detected undesired amplitude variations, and a circuit for applying said derived voltage to said first amplifier in a sense substantially to reduce said undesired amplitude variations.

2. In combination, a pair of cascaded amplifier tubes, a source of angle modulated carrier waves coupled to the input electrodes of the first amplifier tube, at least one selector circuit tuned to a desired operating frequency coupling the output electrodes of the first amplifier tube and the input electrodes of the second amplifier tube, a leaky grid condenser network connected to the input electrodes of the second amplifier tube thereby rendering the latter operative as a grid leak detector for undesired amplitude variations

which may exist on said angle modulated carrier waves, a resonant selector circuit coupled to the output electrodes of the second amplifier tube across which is developed said angle modulated carrier waves in amplified form, means in circuit with the output electrodes of the second amplifier tube for deriving therefrom detected amplitude variation voltage, and means for applying such detected voltage to the input electrodes of said first amplifier tube in a degenerative sense thereby substantially to reduce said undesired amplitude variations.

3. In combination, a source of phase or frequency modulated carrier waves, an amplifier for amplifying said waves, said amplifier producing undesired amplitude variations in the amplified waves, a grid leak detector tube circuit having input electrodes coupled to said amplifier, means in the output circuit of the grid leak detector tube for developing amplified phase or frequency modulated waves, and means responsive to detected amplitude variation voltage in the output circuit of said grid leak detector tube for controlling the gain of said amplifier in such a way as to balance or neutralize substantially all of said undesired amplitude variations.

4. In combination with a source of frequency modulated carrier waves, a first amplifier for the modulated waves, a second amplifier for said modulated waves, means to render said second amplifier operative as a detector of undesired amplitude variations in the amplified angle modulated carrier waves applied thereto, means for deriving from the output of said second amplifier detected undesired amplitude variation voltage, and means for applying said derived voltage to said first amplifier in a degenerative sense thereby to reduce said undesired amplitude variations.

5. A signalling system comprising a source of angle modulated carrier waves coupled to the input electrodes of a first amplifier tube, a selector circuit tuned to a desired operating frequency coupling the output electrodes of the first amplifier tube to the input electrodes of a second amplifier tube, means connected to the input electrodes of the second amplifier tube for rendering the latter operative as a detector for undesired amplitude variations which may exist on said angle modulated carrier waves, means coupled to the output electrodes of the second amplifier tube to utilize angle modulated carrier waves in amplified form, means in circuit with the output electrodes of the second amplifier tube for deriving therefrom detected amplitude variation voltage, and means for applying such detected voltage to the input electrodes of said first amplifier tube in a degenerative sense thereby substantially to reduce said undesired amplitude variations.

6. In combination, a source of phase or frequency modulated carrier waves, an amplifier for amplifying said waves, said amplifier producing undesired amplitude variations in the amplified waves, a detector tube circuit having input electrodes coupled to said amplifier, means in the output circuit of the detector tube for developing amplified phase or frequency modulated waves, and means responsive to detected amplitude variation voltage in the output circuit of said detector tube for controlling the gain of said amplifier in such a way as to reduce substantially all of said undesired amplitude variations.

7. In combination, a source of angle modulated carrier waves, a first tube for transmitting said waves, said tube producing undesired amplitude variations in the amplified waves, a detector tube circuit having input electrodes coupled to said first tube, means in the output circuit of the detector tube for developing angle modulated waves, and means responsive to detected amplitude variation voltage in the output circuit of said detector tube for degeneratively controlling the gain of said first tube in such a way as to neutralize substantially all of said undesired amplitude variations.

8. In combination, a source of angle modulated carrier waves, a transmission network for the modulated waves, an amplifier for the transmitted modulated waves, means operatively associated with said amplifier to render it operative as a detector of undesired amplitude variations in the angle modulated carrier waves applied thereto, means for deriving from the output of said amplifier voltage representative of detected undesired amplitude variations, and a circuit for utilizing said derived voltage to control the transmission of said network in a sense substantially to reduce said undesired amplitude variations.

9. In combination, a pair of cascaded amplifier tubes, a source of frequency modulated carrier waves coupled to the input electrodes of the first amplifier tube, at least one selector circuit tuned to a desired operating frequency of the order of 72 megacycles coupling the output electrodes of the first amplifier tube and the input electrodes of the second amplifier tube, said selector circuit having a pass band width of the order of 12 megacycles, a leaky grid condenser network connected to the input electrodes of the second amplifier tube thereby rendering the latter operative as a grid leak detector for undesired amplitude variations which may exist on said frequency modulated carrier waves, a resonant selector circuit coupled to the output electrodes of the second amplifier tube across which is developed said frequency modulated carrier waves in amplified form, means in circuit with the output electrodes of the second amplifier tube for deriving therefrom detected amplitude variation voltage, and an amplifier for applying such detected voltage in amplified form to the input electrodes of said first amplifier tube in a degenerative sense thereby substantially to reduce said undesired amplitude variations.

10. In combination with a source of frequency modulated carrier waves, a first amplifier for the modulated waves, a second amplifier for said modulated waves, means to render said second amplifier operative as a detector of undesired amplitude variations in the amplified angle modulated carrier waves applied thereto, means for deriving from the output of said second amplifier detected undesired amplitude variation voltage, an amplifier for said detected voltage, and a capacity feedback path for applying said amplified detected voltage to said first amplifier in a degenerative sense thereby to reduce said undesired amplitude variations.

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