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RECEIVER SELECTIVITY CONTROL

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Fig. 6

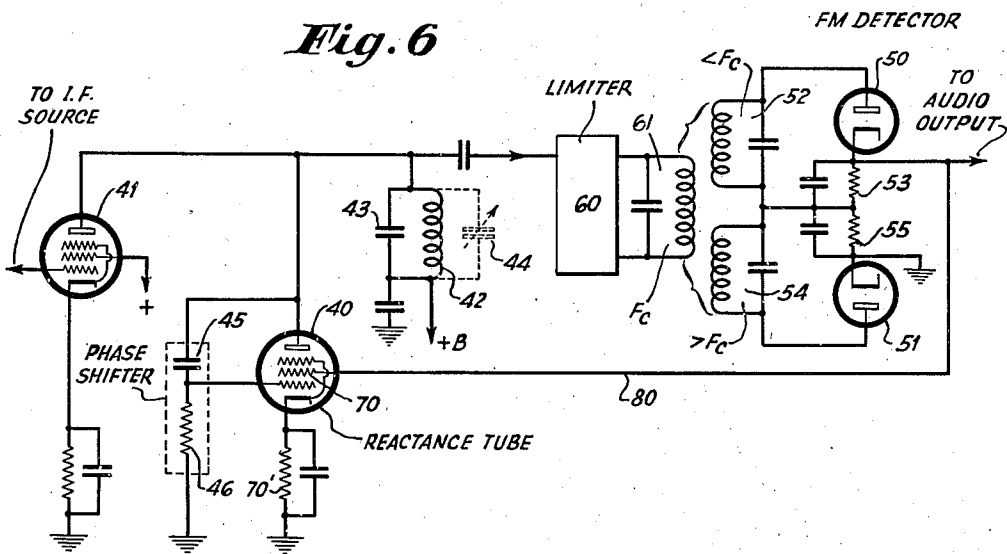
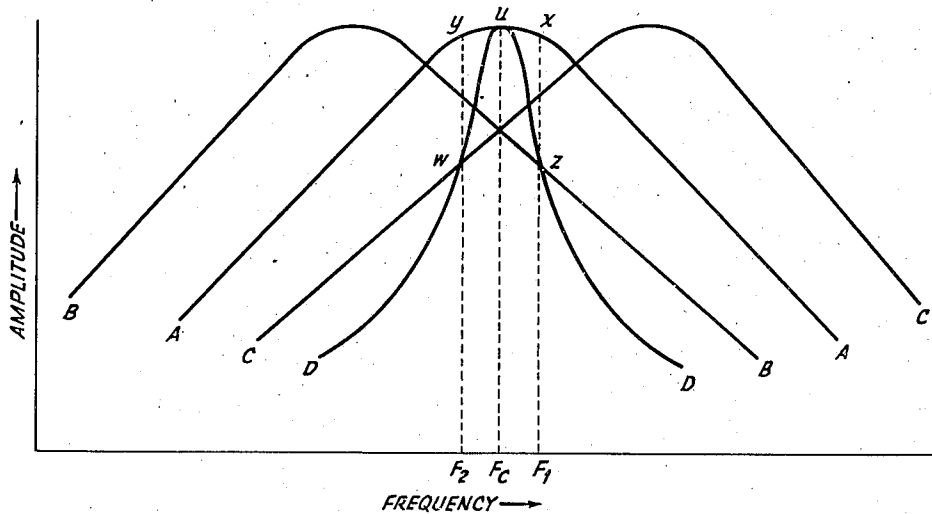


Fig. 5



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RECEIVER SELECTIVITY CONTROL

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My present invention relates to reactance tube control circuits for radio receivers, and more particularly to self-adjusting selectivity control circuits for angle modulated carrier wave receivers.

An important object of my invention is to provide a resonant reactance tube circuit capable of automatically shifting the frequency of a selector network of a receiver of angle modulated carrier wave energy so as to pass efficiently all frequency components in the received band of signal energy.

Another important object of my invention is to provide a novel method of frequency-shifting a tuned selector circuit of a receiver of frequency modulated carrier wave energy.

Another object of my present invention is to accommodate automatically, and with simple and few elements, the pass band of a tuned acceptor circuit for angle modulated carrier waves to the frequency swing of the waves.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawings, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows one embodiment of the invention, as applied to the intermediate frequency (I. F.) amplifier of a frequency modulation receiver of the superheterodyne type.

Fig. 2 shows in idealized form the phase shifting characteristic of the tuned transformer of the reactance tube.

Fig. 3 illustrates ideally the effect of the reactance tube circuit on the controlled selector circuit characteristic.

Fig. 4 shows a modification of the invention.

Fig. 5 shows graphically the ideal functioning of the circuit of Fig. 4.

Fig. 6 illustrates still another modification of the invention.

In considering the embodiment of the invention shown in Fig. 1, it is to be assumed that the tube 1 is an I. F. amplifier tube of a superheterodyne receiver adapted to receive angle modulated carrier wave energy. The latter term "angle modulated carrier wave energy" is generic, and includes frequency modulated (FM hereinafter for brevity) carrier wave energy, phase modulated carrier wave energy and even

hybrids thereof. By way of specific example, it is assumed that the I. F. amplifier stage shown in Fig. 1 is utilized in a superheterodyne receiver of FM waves. The receiver may be tunable through the assigned FM band of 42-50 megacycles (mc.). However, the invention is not restricted to this particular frequency band. In the 42-50 mc. band each station carrier, or mean, frequency F_c has a maximum deviation of substantially 75 kilocycles (kc.) to each side of F_c . The frequency deviation of the mean frequency is proportional to the amplitude of the modulation signals, while the rate of frequency deviation is representative of the modulation frequencies per se.

As is well known to those skilled in the art, the conventional superheterodyne receiver includes tunable selector circuits arranged in the amplifier stages preceding the converter network. The function of the converter is to reduce the mean frequency of the selected and amplified FM signal energy to the operating I. F. value. The latter may be chosen from a range of frequencies covering 4 to 25 mc., and preferably a value of 8.33 mc. is employed as a satisfactory compromise value. The various selector circuits up to and including the input transformer 2 of tube 1 have each a pass band width such as efficiently to pass the overall frequency swing of the selected FM signal energy. Of course, each selector circuit prior to tube 1 may be replaced by a controlled selector circuit of the type forming the subject matter of my present invention. Each of the primary and secondary circuits of input transformer 2 is tuned to the operating I. F. value. The tube 1 may be of any conventional form, and the circuit details thereof are well known and need not be described in further detail.

The plate circuit of tube 1 includes a resonant circuit which consists of coil 3 shunted by condenser 4. The resonant circuit 3-4 is tuned to the operating I. F. value, and has a resonance curve or characteristic which has a single peak. The FM signal energy developed across the resonant circuit 3-4 is transmitted through the coupling condenser 5 to the following I. F. amplifier stage. The latter may be a stage similar to the one shown in Fig. 1, or it may be the amplitude limiter employed prior to the FM detector circuit. The function of the limiter is substantially to remove any amplitude modulation on the modulated carrier energy. The FM detector circuit derives the modulation signal energy from the limited signal energy fed to the detector.

According to my invention, the selector circuit 3—4 is automatically shifted in frequency to accommodate the frequency swing of the received frequency modulated carrier wave energy. It is, again, emphasized that my present explanation is restricted to the selector circuit 3—4 merely by way of illustration, and that the same functions may be performed in connection with other selector circuits of the receiving system prior to the FM detector circuit. In accordance with my invention, I utilize an electron discharge tube 6, which is termed a reactance tube since it functions to simulate a reactive effect across the tuned selector circuit 3—4.

The plate 7 of tube 6 is connected to the plate of amplifier 1. Hence, the +B terminal of the direct current voltage supply (not shown) is connected not only to the plate of the I. F. amplifier tube 1, but also to the plate 7 of the reactance tube. The cathode of tube 6 is connected to ground through a carrier-bypassed biasing resistor 3. It will, therefore, be seen that the plate to cathode impedance of tube 6 is connected in shunt with the selector circuit 3—4. The reactive sign and magnitude of the plate to cathode impedance of tube 6 determine the direction and extent of frequency shifting of selector circuit 3—4. The reactive sign and magnitude of the plate to cathode impedance of tube 6 are determined by the circuits now to be described.

A transformer 9 is provided for coupling the plate 7 to the control grid 10 of tube 6. The primary circuit of transformer 9 is designated by numeral 11. The circuit 11 is tuned to the mean frequency of the applied FM wave energy, this mean frequency, indicated by the symbol F_c , is the operating I. F. value. The low potential side of circuit 11 is grounded, while the ungrounded side is connected to plate 7 by the coupling condenser 12. The reactance of condenser 12 is adjusted to be high in comparison to the input resistance of transformer 9. The secondary circuit 13 of transformer 9 is likewise tuned to F_c , and its ungrounded side is connected directly to the control grid 10. The circuits 11 and 13 are indicated as being magnetically coupled, and each of them is shunted by a damping resistor in order to provide a normal band-pass characteristic for selector circuit 11—13 at the mean frequency F_c . The numerals 11' and 13' designate the damping resistors of circuits 11 and 13 respectively.

The alternating voltage between plate 7 and ground is represented by the symbol E_1 ; the alternating voltage developed across the primary circuit 11 is represented by the symbol E_2 ; and the alternating voltage between control grid 10 and ground is represented by the symbol E_3 . At the mean frequency F_c the plate to cathode impedance of tube 6 functions in the manner of a resistive impedance which provides a predetermined degree of damping for the selector circuit 3—4. In Fig. 3 I have indicated by the central resonance curve, shown in solid line, the relative appearance of the selector resonance characteristic at the instantaneous mean frequency F_c . In Fig. 2 I have depicted the manner in which the reactance tube circuit has its reactive sign varied as the instantaneous frequency of the applied FM signal energy changes.

Since coupling condenser 12 is high in reactance compared to the input resistance of transformer 9, the voltage fed from plate 7 to primary circuit 11 is phase shifted approximately 90 degrees. This phase shift takes place since the current through the coupling condenser 12 and the

transformer primary is determined by the coupling condenser so that the current leads the applied voltage. The voltage drop across the transformer primary will be in phase with the current, since the transformer primary is resistive. This voltage drop will, therefore, lead the voltage applied from plate 7. An additional phase shift is imparted to the feedback voltage of the reactance tube by means of the transformer 9. It is well known that such a tuned transformer imparts a phase shift of 90 degrees at the midband frequency. This results in voltage E_3 being approximately in phase with the voltage E_1 applied from plate 7. The overall phase shift characteristic of the coupling condenser and transformer is as shown ideally in Fig. 2. At the carrier, or midband, frequency the phase shift is zero, while deviations from the carrier frequency produce leading or lagging phase shifts depending on the direction of the deviation. The change of phase with frequency is caused by the inherent characteristic of the tuned transformer. Since the feedback of the reactance tube is resistive at the mean frequency F_c , the reactance tube presents a resistive plate circuit across selector circuit 3—4. This produces a damping action which broadens the selectivity of the selector circuit, as shown by the solid line central curve of Fig. 3. Adjusting the voltage of an electrode of tube 6, for example the screen, gives a measure of control over the band width of circuit 3—4.

As the instantaneous frequency of the applied FM signal energy shifts in an increasing direction towards the maximum frequency point, the plate to cathode impedance of tube 6 has an inductive reactance which increases in magnitude in accordance with the extent of the frequency deviation from mean frequency. At the same time the shunt resistance component is increased so as to reduce the degree of damping. This follows from the fact that if the resistance component across circuit 3—4 increases, the equivalent series resistance in circuit 3—4 decreases. Hence, the resonance curve of circuit 3—4 will be relatively sharper at such times. Conversely, the plate to cathode impedance of tube 6 simulates a capacitive reactance as the instantaneous frequency shifts to frequencies less than the mean frequency, while the shunt resistance component is likewise increased.

In Fig. 3 there is shown the effect of the inductive reactance X_L on the resonance curve configuration and frequency location of selector circuit 3—4. Similarly, Fig. 3 shows the effect of the capacitive reactance X_C on the selector circuit 3—4. These effects are shown in Fig. 3 by the dotted line resonance curves located on opposite sides of the central solid line curve. It will be seen that the effect of each of the inductive reactance and capacitive reactance is to shift the resonance curve in respectively opposite directions relative to the mean frequency. Further, the configuration of the shifted resonance curve is relatively sharper than at the mean frequency for the reasons explained in the preceding paragraph. Hence, there is produced an overall relatively wide acceptance curve for the selector circuit 3—4, and this widening of the acceptance curve permits the selector circuit 3—4 automatically to be accommodated to the extent of the overall frequency swing of the FM signal energy. The resultant wide acceptance curve in Fig. 3 is represented by the dotted line between the peaks of the extreme sharpened resonance curves. Furthermore, since the shifting of the resonance curve is

performed in response to the instantaneous value of the applied FM signal energy, it will be realized that the accommodation occurs at a very rapid rate.

It will be noted that the overall wide response curve shown in Fig. 3 is not flat-topped, but dips at the carrier frequency due to the variable damping action of the resistive component of the reactance tube. It will be apparent to those skilled in the art that the overall response may be adjusted to a flat-topped characteristic by adjusting any other selector in the system, for instance transformer 2, to be round-topped to a compensating degree.

It will now be appreciated that instead of the usual wide band-pass transformers provided in the various selector circuits prior to the FM detector there may be used the controlled selector circuits of the present invention. When the frequency swing of the applied FM signal energy is relatively narrow, the selector circuit 3-4 will have its frequency shifted to a relatively small extent. On the other hand, when the frequency swing of the applied signal energy is very wide the accommodation of the selector circuit 3-4 will be correspondingly increased. Furthermore, it is apparent that this frequency-following effect is not present for the case of amplitude modulation which is undesired in angle modulation reception. Consequently, such a receiver has the property of rejecting undesired amplitude modulation.

My invention is not limited to the utilization of a double-tuned, phase-shifting transformer such as is represented by transformer 9 in Fig. 1. In Fig. 4 I have shown a different form of tuned phase-shifter circuit. In Fig. 4 the amplifier tube 1 has its input circuit tuned to the mean frequency F_c of the applied signal energy. Its output circuit 3-4 is tuned to the same mean frequency F_c . The reactance tube 6 has its plate to cathode impedance connected in shunt across the output circuit 3-4. There is, also, connected in shunt across the output circuit 3-4 a phase shifter network which includes a series resonant circuit tuned to the mean frequency F_c . The phase shifter network is indicated within the dotted rectangle, and consists of the series resonant circuit 20-21. The lower end of coil 21 is grounded, while the upper terminal of condenser 20 is connected directly to the control grid 10 of tube 6. The grid 10 is returned to ground through a direct current return resistor 22 whereby normal negative bias, developed across biasing resistor 8, is applied to grid 10.

The plate 7 of the reactance tube is connected to the phase shifter network by the direct current blocking condenser 23 and the series resistor 24. The type of reactance tube network shown in Fig. 4 functions to sharpen the tuning of output circuit 3-4. If the instantaneous frequency of the applied signal energy at input transformer 2 increases above the mean frequency F_c , then the series resonant circuit 20-21 has an inductive effect. At the mean frequency F_c , of course, the series resonant circuit is essentially resistive. Where the instantaneous frequency of the applied signal energy drops below the mean frequency F_c , the series resonant circuit appears as a capacitive reactance. The result is that the effective frequency of circuit 3-4 is tuned in a direction opposite to the signal frequency deviation.

Fig. 5 shows how the selectivity is made greater by this self-tuning action. Curve A-A is the selectivity curve of tuned circuit 3-4 in the ab-

sence of reactance tube 6. The operation of the reactance tube is such as to shift the tuning of 3-4 towards a higher frequency, such as is shown by curve C-C, when the frequency of the applied signal instantaneously shifts towards a lower frequency. Likewise, the tuning shifts lower when the signal frequency shifts higher. This opposite-direction self-tuning action is brought about by using a tuned phase-shifter circuit between the plate and cathode of the reactance tube such that the reactance tube gives a capacity effect for frequencies higher than the carrier or mean frequency, and an inductive effect for frequencies lower than the mean frequency. Thus, when the carrier frequency shifts from the frequency F_c to the frequency F_1 , the amplitude changes from the point u on curve A-A to point z on curve B-B. When the frequency shifts lower to F_2 , the amplitude drops from u on A-A to w on curve C-C. It is thus apparent that the resulting selectivity curve will follow the curve D-D, which is considerably sharper than the original characteristic which existed in the absence of the reactance tube.

The selectivity of circuit 3-4 can then be varied, if desired, by varying the mutual conductance of reactance tube 6. As is well known to those skilled in the art, variation of the bias of control grid 10 will result in variation of the gain of the reactance tube. Accordingly, the effective magnitude of the simulated capacitative or inductive reactance can be controlled.

In Fig. 6 I have shown a modification of the invention wherein the phase shifter network which is operatively associated with the reactance tube 40 is aperiodic. The tube 40 is controlled in sense of effect and magnitude of effect by means of the usual form of discriminator-rectifier employed in frequency modulation receivers. Let it be assumed that numeral 41 denotes the usual and conventional form of I. F. amplifier used in a superheterodyne receiver of frequency modulated carrier waves. The plate circuit of the amplifier 41 includes the parallel resonant circuit 42-43 which is tuned to the operating I. F. value. The plate to cathode impedance of reactance tube 40 is connected effectively in shunt across the resonant output circuit 43-42 of the I. F. amplifier 41. The reactance tube 40 is made to simulate a variable capacitative reactance, as is indicated by the dotted condenser 44 shown in shunt across coil 42.

This simulated reactance effect is produced by the phase shifter shown in the dotted rectangle. The phase shifter in this modification is aperiodic, since it consists of condenser 45 connected in series with resistor 46 between the plate of tube 40 and ground. The ungrounded end of the resistor 46 is connected to the control grid 47. By making the resistive impedance of resistor 46 small compared to the capacitative reactance of condenser 45 the alternating voltage applied to the control grid 47 will be in phase quadrature relative to the alternating potential at the plate of reactance tube 40. With these relations the plate to cathode impedance of tube 40 appears as if it were a capacitative reactance across the output circuit 43-42.

Of course, the capacitative reactance has a normal predetermined magnitude at the mean frequency F_c of the applied signal energy. In order to vary the magnitude of this reactive effect instantaneous frequency deviations from the mean frequency are translated into control voltages whose polarity and magnitude are a function

respectively of the direction and amount of instantaneous frequency deviation. This is done by employing a conventional FM detector circuit which may include a pair of opposed diode rectifiers 50 and 51. The resonant input circuit 52 is connected between the anode and cathode of rectifier 50, and the carrier-bypassed resistor 53 acts as the load resistor of the rectifier 50. In the same way, the input circuit 54 is connected between the anode and cathode of rectifier 51. The carrier-bypassed resistor 55 acts as the load resistor of rectifier 51. The junction of resistors 53 and 55 is connected to the common junction of the two input circuits 52 and 54.

The cathode of diode 51 is grounded. The differential voltage developed across resistors 53 and 55 in series is taken off from the cathode end of resistor 53. Input circuits 52 and 54 are oppositely and equally mistuned with respect to the operating I. F. value, as is well known to those skilled in the art, with the result that the desired discriminator characteristic is provided for the opposed rectifiers. A limiter 60 is interposed between the resonant output circuit 43—42 and the common signal input circuit 61 which feeds the discriminator circuits. The function of the limiter is substantially to eliminate any amplitude modulation effects which may appear on the carrier wave. The input circuit 61 will be tuned to the mean frequency of the applied signal energy, and is, therefore, tuned to a frequency which is midway between the spaced resonant frequencies of circuits 52 and 54. The circuit 61 is magnetically coupled to each of the off-tuned circuits 52 and 54.

The audio modulation voltage developed at the cathode end of resistor 53 is transmitted to an audio utilization circuit. On the other hand, the direct current voltage developed across the series related resistors 53 and 55 is fed to a control grid 70 of tube 40. The control grid 70 is an intermediate grid of the tube, and it is given a normal negative bias determined by the voltage drop across the cathode biasing resistor 70 arranged in the cathode circuit of the reactance tube 40. At the instant when the frequency of the signal energy applied to circuit 61 is equal to the mean frequency F_c , the rectified voltage across resistors 53 and 55 will be substantially zero. This follows from the fact that the opposed rectifiers will have equal outputs developed across their respective load resistors. However, as the instantaneous frequency of the signal energy at circuit 61 deviates from the mean frequency, the fact that the input circuits 52 and 54 are oppositely and equally mistuned relative to the mean frequency will cause the potential at the cathode end of resistor 53 to follow in polarity and magnitude the direction and extent of instantaneous frequency deviations from the mean frequency. The rectified voltages developed across each of resistors 53 and 55 are, in other words, combined differentially, and the differential voltage is applied over lead 80 to the grid 70 of reactance tube 40.

Hence, it will be seen that the mutual conductance of tube 40 will be varied in response to the potential of the cathode end of 53. This potential will be negative or positive relative to ground depending upon whether the instantaneous frequency of the signal energy at circuit 61 deviates toward the frequency of circuit 54 or deviates toward the frequency of circuit 52 respectively. By way of specific example, assume circuit 52 is tuned below F_c while circuit 54 is tuned above F_c .

Since it is desired to vary the resonance curve characteristic of circuit 43—42 in response to the instantaneous changes of the frequency of the received signal energy, it is important that there be omitted from lead 80 any filtering of the rectified modulation voltage. It is this modulation signal voltage which causes the simulated reactance effect 44 to follow the frequency deviations of the received signal energy.

While I have indicated and described several systems 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 organizations 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 with a source of angle modulated carrier wave energy, a resonant selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least a cathode, a control grid and an anode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, a resonant phase shifter network connected between the anode and cathode of said tube, said phase shifter being normally tuned to said mean frequency, and means for applying the alternating voltage across said shifter network between the control grid and cathode.

2. In combination with a source of angle modulated carrier wave energy, a resonant selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least a cathode, a control grid and an anode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, a resonant phase shifter network connected between the anode and cathode of said tube, said phase shifter being normally tuned to said mean frequency, said resonant phase shifter consisting of a pair of reactively coupled tuned circuits arranged in cascade between said anode and control grid.

3. In combination with a source of angle modulated carrier wave energy, a resonant selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least a cathode, a control grid and an anode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, and a resonant phase shifter network connected between the anode and cathode of said tube, said phase shifter being normally tuned to said mean frequency, said phase shifter consisting of a series resonant circuit connected between said control grid and a point at ground potential.

4. In combination with a source of angle modulated carrier wave energy, a resonant selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least a cathode, a control grid and an anode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, a phase shifter normally tuned to said mean frequency, means for applying alternating voltage at said anode to said phase shifter, said tuned phase shifter consisting of a resonant circuit tuned to said mean frequency and connected between said control grid and a point at ground potential.

5. In combination, in a frequency modulation receiver, an amplifier tube having a selective input

circuit tuned to the mean frequency of applied frequency modulation signal energy, a selector circuit connected to the output electrodes of said amplifier tube, said selector circuit being tuned to said mean frequency, an electron discharge tube having its anode to cathode impedance operatively associated with said selector circuit, a resonant phase shifter network tuned to said mean frequency, said phase shifter network being connected in shunt with said impedance, and means responsive to signal voltage developed across said phase shifter for controlling said impedance for automatically varying the tuning of said selector circuit in accordance with the instantaneous frequency deviations of the signal energy with respect to said mean frequency.

6. In combination with a source of angle modulated carrier wave energy, a selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least an anode, cathode and control grid electrode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, a resonant phase shifter network connected between

the anode and cathode of said tube, means for applying the alternating voltage across the phase shifter network to said control grid, said phase shifter being normally tuned to said mean frequency, and means for varying an electrode voltage of said tube to adjust the effect of said impedance.

7. In combination with a source of angle modulated carrier wave energy, a resonant selector circuit tuned normally to the mean frequency of the angle modulated wave energy, an electron discharge tube provided with at least a cathode, a control grid and an anode, means connecting the anode to cathode impedance of said tube in shunt with said selector circuit, a resonant phase shifter network connected between the anode and cathode of said tube, said resonant phase shifter consisting of a pair of reactively coupled tuned circuits arranged in cascade between said anode and control grid, each of the pair of circuits being tuned to the mean frequency thereby to cause the impedance to be capacitative or inductive for frequency deviations of the energy.

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