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V. J. DUKE

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FREQUENCY DISCRIMINATOR CIRCUIT

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Fig. 1

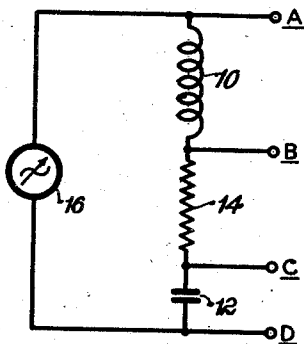


Fig. 2.

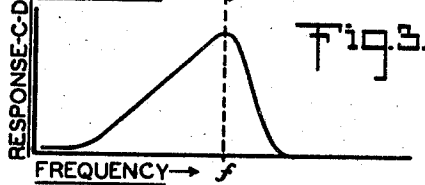
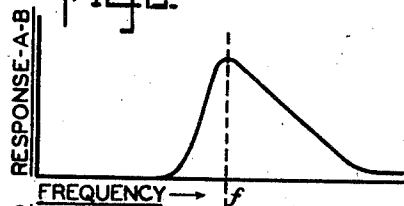


Fig. 4.

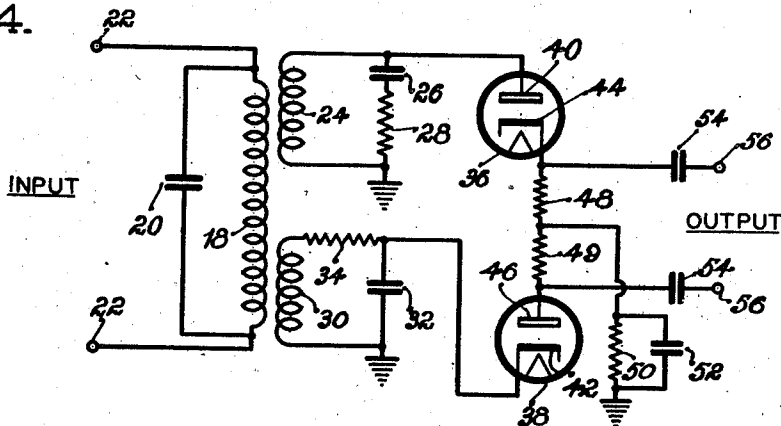
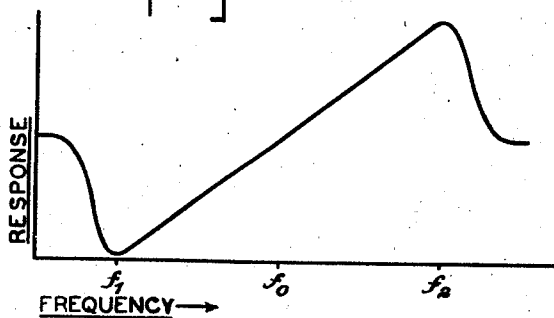


Fig. 5.



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FREQUENCY DISCRIMINATOR CIRCUIT

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1

This invention relates to an improvement in radio and television receivers, and more particularly, to a receiver circuit for receiving a frequency modulated carrier.

When sound signals are used to frequency modulate a radio frequency carrier, the frequency of the carrier is caused to deviate between two defined limits, the deviation being a function of the amplitude of the modulating signals, and the rate of deviation being a function of the frequency of the modulated signals. When these signals are transmitted and received at a radio receiver, a frequency discriminator network is used which responds to the frequency modulations to detect, in effect, the transmitted signals so as to reproduce the modulating signals. Inasmuch as audio signals do not normally exceed the order of about 15,000 cycles per second, an excessively wide deviation of the carrier is not necessary, and discrimination in the receiver becomes relatively simple.

In present television transmitting or relay stations, the picture signals are used to amplitude modulate one particular radio frequency carrier, whereas the related sound signals are used to frequency modulate another relatively adjacent radio frequency carrier. In actual practice, these two carriers are spaced 4.5 megacycles apart, the frequency modulated sound carrier being normally located above the amplitude modulated picture signal carrier.

As is well known to those skilled in the art, the frequency range encountered in a high fidelity television transmitter is from zero to 4 or 5 megacycles per second, or even higher. When these signals are used to amplitude modulate a radio frequency carrier, side bands of the same frequency order are produced, and in normal practice, in order to reduce the width of the transmission band for transmitting side bands of this order, one side band of the amplitude modulated picture signal carrier is suppressed or partially suppressed, leaving the other complete set of side bands. Generally, the lower side band frequencies are suppressed, and the upper side band frequencies, positioned between the picture and sound carriers, are transmitted.

It has been proposed to transmit not only the sound signals by frequency modulation, but also the picture signals, in order that the advantages of frequency modulation may be utilized. This proposal is particularly adaptable in television relay stations where relatively high radio frequency carriers are used.

When a radio frequency carrier is frequency

2

modulated by television picture signals having a very wide frequency range, considerable difficulty is encountered at the receiver since normal discriminator circuits are not capable of detecting the signals with the proper degree of fidelity and linearity. Certain proposals have heretofore been made for increasing the discriminator frequency range of frequency modulation receivers by broadening the tuning of frequency modulation receiver discriminators through the use of damping resistances connected in parallel with the tuned circuits in the discriminator. Under normal conditions and where the deviation of frequencies is not excessive, this may be done, yet where a deviation frequency of the order of 10 megacycles is to be detected, normal resistance damping means cannot be used since the response of the discriminator is not linear, and, furthermore, when the tuned circuits of the discriminator are broadened by parallel resistance damping means, the discriminator is also made responsive to frequencies lying outside the region of interest.

The present invention, therefore, relates to an improvement in frequency modulation discriminators wherein the discriminator may be made responsive to a frequency deviation of the order of 10 megacycles without causing unnecessary and undesirable response in regions beyond the frequency deviation region, and without introducing distortion in the detected picture signals. Naturally, in television receivers it is desirable to have linear discrimination, since the fidelity of the reproduced pictures depends upon the efficiency and linearity of the frequency modulation discriminator.

One purpose of the present invention, therefore, resides in the provision of means, in a frequency modulation receiver, whereby frequency deviations of the order of 10 megacycles may be detected.

Another purpose of the present invention resides in the provision of means in a frequency modulation receiver discriminator whereby substantially linear discrimination is made possible throughout a frequency deviation of the order of 10 megacycles.

A still further purpose of the present invention resides in the provision of a discriminator in a frequency modulation receiver whereby the discriminator will respond to a deviation band of the order of 10 megacycles without appreciably responding to signals above or below the deviation band.

Still another purpose of the present invention

resides in the provision of means connected in the load circuit of a frequency discriminator whereby a balanced condition may be substantially maintained at all times at the input to the discriminator.

Another purpose of the present invention resides in the provision of a frequency discriminator whereby unbalanced conditions at the input of the discriminator will be compensated for in the discriminator through biasing of the discriminator diodes.

Still other purposes and advantages of the present invention will become more apparent to those skilled in the art from the following detailed description, particularly when considered in connection with the drawing wherein

Figure 1 shows a resonant circuit and a series resistance to assist in explaining the theory of the present invention;

Figures 2 and 3 show response curves for the tuned circuit shown in Figure 1;

Figure 4 shows an adaptation of the tuned circuit of Figure 1 to a frequency discriminator; and

Figure 5 shows a response curve of the discriminator circuit shown in Figure 4.

Referring to the drawing, and particularly to Figure 1 thereof, there is shown a series resonant circuit including inductance 10 and capacitance 12. Between these two elements is included a resistance 14. The inductance 10 and capacitance 12 are tuned to a predetermined frequency, and a source of potential 16 of variable frequency is connected across the series resonant circuit. Naturally, the frequency of the oscillations available from the source 16 should lie within the range immediately above and below the resonant frequency of the inductance 10 and capacitance 12. Output terminals A, B, C, and D are associated with the resonant circuit, the terminals A and B being connected across the inductance 10, and the terminals C and D being connected across the capacitance 12.

The response of the resonant circuit is indicated in Figures 2 and 3, the curve shown in Figure 2 being the response across the terminals A—B, and the curve shown in Figure 3 being the response across the terminals C—D. As the frequency supplied by the source 16 is gradually increased from a minimum value, substantially no response potential will be derived from the terminals A—B since the inductance 10 will have relatively low impedance at the lower applied frequency. As the frequency is increased to the resonant frequency f_0 , peak or maximum response will be derived from the terminals A—B, as indicated in Figure 2. As the frequency is further increased, the response across the terminals A—B will reduce gradually, and will finally approach a value corresponding to the potential of the applied frequency source.

It will be observed that the curve shown in Figure 2 is asymmetric, the rate of change of response being considerably greater for frequencies below resonant frequency than the rate of change of response for frequencies above the resonant frequency.

If the same variation in frequencies is again applied to the series resonant circuit, a different response may be derived from the terminals C—D. The curve shown in Figure 3 represents the response obtainable at these terminals, and it will be noted that at relatively low frequencies the potential across the terminals C—D corresponds substantially to the potential of the applied frequency source, since at the lower fre-

quencies the condenser offers relatively high impedance. As the frequency is increased, the response increases gradually and reaches a maximum when the resonant frequency is applied to the tuned circuit. Further increases in the applied frequency cause a relatively rapid decrease of the response at the terminals C—D, the response finally reaching zero, since at the higher frequencies the impedance offered by the condenser 12 is relatively low. It will be noticed that the response curve taken across terminals C—D, as shown in Figure 3, is also asymmetrical, and is enantiomorphic with respect to the curve of Figure 2.

The asymmetry of the curve shown in Figures 2 and 3 are the result of the inclusion of the series resistance 14 in the tuned circuit. Without the resistance, the curves would be substantially symmetrical and similar. If a resistance were placed in parallel with the tuned circuit, as is the usual method for broadening the response curve, then the response curves shown in Figures 2 and 3 would be broadened, and, naturally, their resonant peaks decreased, but the curves would still remain substantially symmetrical. When the resistance 14 is inserted in series with the resonant circuit, the response curves across the inductance per se or the capacitance per se will no longer be symmetrical, the response being broadened in the higher frequency range across the inductance, and in the lower frequency range across the capacitance.

The inclusion of the resistance 14 also performs another function other than merely producing asymmetry and broadening the response, the additional function being that of increasing the linearity of response in the broadened region. It will, therefore, be observed that the curve shown in Figure 2, for example, is substantially linear from the resonant frequency to some considerably higher frequency, and likewise that the response of the curve shown in Figure 3 is substantially linear from a relatively low frequency to substantially the resonant frequency.

The circuit arrangement shown in Figure 1 and described above is used in connection with a frequency discriminator where the frequency deviation is of the order of 10 megacycles. The particular resonant frequency is naturally immaterial, but in various tests the resonant frequency was chosen at 21 megacycles, with a frequency deviation range of from 16 to 26 megacycles.

A preferred form of the present invention is shown in Figure 4, which includes the primary 18 of the frequency discriminator transformer. The primary is tuned to substantially resonant frequency by means of the parallel tuning condenser 20, and frequency modulated radio frequency signals are applied to the input terminals 22, which are connected to the primary winding 18. These signals may naturally be derived from a preceding amplifier tube.

The secondary of the discriminator transformer includes two tuned circuits, one of which comprises the inductance 24 and the capacitance 26. One end of the inductance is connected to ground, whereas the other end of the inductance is connected to one plate of the capacitance 26. The other plate of the capacitance is connected to ground by way of resistance 28. The other tuned circuit includes an inductance 30 and a capacitance 32. One end of the inductance and one plate of the capacitance are connected together and to ground, whereas the other end of

the inductance and the other plate of the capacitance are connected together by means of the resistance 34.

As is conventional practice in frequency discriminators, two diode rectifiers 36 and 38 are provided, and these rectifiers are supplied with energy from the two tuned secondary circuits of the frequency discriminator transformer. Input to the diode 36 is effectively derived from potential developed across the inductance 24, whereas the input to the diode 38 is effectively derived from across the capacitance 32.

The anode 40 of the diode 36 is connected to the ungrounded end of the inductance 24, while the cathode 42 of the diode 38 is connected to the ungrounded plate of the capacitance 32. The cathode 44 of the diode 36 and the anode 46 of the diode 42 are connected together by means of resistances 48 and 49, the junction of these resistances being connected to ground by means of resistance 50. This latter resistance is by-passed by a condenser 52. The output from the discriminator is then derived from the cathode 44 of diode 36, and from the anode 46 of diode 38 by way of coupling condensers 54 and output terminals 56.

Since it is desired that the frequency discriminator be effective for a wide range of frequencies, the two tuned secondaries of the discriminator transformer are tuned to different frequencies. The resonant circuit including inductance 24 and capacitance 26 is, therefore, tuned to the lower deviation frequency indicated as f_1 in Figure 5, whereas the tuned circuit including inductance 30 and capacitance 32 is tuned to the upper deviation frequency corresponding to f_2 in Figure 5. When frequency variations between f_1 and f_2 are impressed upon the input terminals 22 of the frequency discriminator transformer, response voltages will be applied to the rectifier tubes 36 and 38 in accordance with the response of the two tuned secondaries. Inasmuch as the diode 36 is effectively connected across the inductance 24, the frequency response of this resonant circuit will be similar to the response shown in Figure 2. The other tuned circuit including inductance 30 and capacitance 32, as stated above, is tuned to resonate at frequency f_2 , and since the diode 38 is effectively connected across the capacitance 32 of this tuned circuit, the frequency response of this tuned circuit will be similar to that shown by the curve in Figure 3. When these two response curves are combined, and the signals rectified by the diodes 36 and 38, an overall response will be produced at the output terminals 56 such as shown in Figure 5.

It will be noticed that the resistances 28 and 34 in the two tuned secondaries of the intermediate frequency discriminator transformers are not located in corresponding points in the tuned circuits. Inasmuch as it is necessary that the input to the diode 36 be derived from across the inductance of the secondary tuned to the lower frequency deviation, the resistance 28 is connected in series with the capacitance 26 and these two elements are then connected in parallel with the inductance 24. A series resonant path results, with the output from the tuned circuit available from the inductance 24. Similarly, the output from the other tuned circuit should be derived from across the capacitance 32 inasmuch as this tuned circuit is tuned to resonate at the upper frequency deviation. Accordingly, the resistance 34 is in effect connected in series with the inductance, with the resistance 34 and in-

ductance 30 connected in parallel with the capacitance 32.

The direct current path from the tuned circuit including inductance 24 and capacitance 26 is from the anode 40 to the cathode 44, and through the resistances 48 and 50 to ground. Similarly, the direct current path for the other tuned circuit is from ground through the resistances 50 and 49, and from anode 46 to cathode 42. It will be noticed that the resistance 50 is, therefore, common to both direct current paths, and that the current flows through this resistance in opposite directions depending upon the differential magnitude of the direct currents. The bypass condenser 52 is connected across the resistance 50 in order to afford a low impedance path for relatively high frequency detected signals, since if the circuit is to be used in a television receiver, frequencies of the order of several megacycles will be encountered. As stated above, the output from the discriminator and the detectors is derived from the anode 46 and the cathode 44.

Since the input to the diodes is applied in reverse order, no inversion of the signal from the one or the other of the diodes is necessary, and a directly usable output voltage may be derived from the terminals 56. The resistances 48 and 49 function as load resistances, and the signals available at the output terminals are developed across these resistances. The signals available at the output terminals 56 should not, however, be directly combined since this would effectively place the two load resistances 48 and 49 in parallel. This would result in having the disadvantage of causing one diode to load the other and vice-versa. To avoid such an undesirable result, the output signals from terminals 56 are preferably supplied to the control electrodes of two separate amplifier tubes or electron streams in order to isolate the two diodes and prevent one from loading the other. The output signals from the two amplifier tubes can, however, be directly combined without introducing any undesired results.

Under normal conditions, when a balanced signal is applied to the frequency discriminator network, the differential current in resistance 50 will be zero since the same amount of direct current flows in both of the direct current paths. If, however, an unbalanced condition exists, then the direct currents will not be balanced, and a differential current will be caused to flow through the resistance 50. This automatically biases the diode supplying the greater amount of current to assist in re-establishing a balanced condition. If, for example, an excessive amount of current is passed by the diode 36 as compared with the amount of current passed by the diode 38, then a positive potential will be developed at the ungrounded end of resistance 50 which biases diode 36 against conduction, and assists diode 38 in conducting. Therefore, by properly regulating the size of resistance 50 and by sufficiently by-passing the resistance by a condenser, a substantially balanced condition may be maintained at all times.

As pointed out above in connection with Figures 1, 2 and 3, the response of the two tuned secondaries shown in Figure 4 will be asymmetrical and opposite in effect. The inclusion of the resistances 28 and 34 bring about this result, and also produce substantially linear deviation response between the frequencies f_1 and f_2 , as indicated by the curve shown in Figure 5. This is highly desirable in a television receiver, since linear response is necessary if high fidelity pictures are to be reproduced. Furthermore, due to the

asymmetry of the response curves, the discriminator is relatively unresponsive to frequencies below f_1 , and likewise to frequencies above f_2 .

From the above it may be seen that the circuit arrangement shown in Figure 4 is well adapted for use in the detection of frequency modulated carriers where a wide deviation of frequencies is used, and where linear response over the entire deviation range is desirable. This is particularly the case in the transmission of television picture signals by frequency modulation, and when such a discriminator is used in a frequency modulation television receiver, the receiver will respond substantially linearly to all frequencies within the deviation range, while at the same time the receiver will be substantially insensitive to frequencies outside the deviation range. Furthermore, it will be appreciated that through the use of the present invention, a substantially balanced condition will be maintained at all times, and any unbalanced condition will be substantially compensated for through the action of a common impedance member.

Although the present invention is described somewhat in detail, it will be appreciated that various alterations and modifications may be made therein without departing from the spirit and scope of the invention, and it is desirable that all such alterations and modifications shall be considered within the purview of this invention except as limited by the hereinafter appended claims.

Having now described my invention, what I claim is:

1. A discriminator circuit for detecting a frequency modulated carrier comprising a pair of resonant circuits each including an inductance, a capacitance and a resistance, a pair of uni-directional current paths, means for effectively coupling one of the uni-directional current paths in parallel with the inductance element of one of the resonant circuits, means for effectively coupling the other of the uni-directional current paths in parallel with the capacitance element of the other of the resonant circuits, means for applying a frequency modulated carrier to the two resonant circuits, and an output circuit associated with said unidirectional current paths.

2. A discriminator circuit for detecting a frequency modulated carrier comprising a pair of resonant circuits each including an inductance, a capacitance and a resistance connected in series, a pair of uni-directional current paths associated with the resonant circuits, means for effectively coupling one of the uni-directional current paths in parallel with the inductance element of one of the resonant circuits, means for effectively coupling the other of the uni-directional current paths in parallel with the capacitance element of the other of the resonant circuits, means for applying a frequency modulated carrier to the two resonant circuits, a load impedance associated with each of the uni-directional current paths, and an output circuit coupled to the load impedances.

3. A discriminator circuit for detecting a frequency modulated carrier comprising a pair of tuned circuits each including a series connected inductance, capacitance and resistance, a pair of uni-directional current paths associated with the resonant circuits, means including a first load impedance for effectively coupling one of the uni-directional current paths across the inductance element of one of the tuned circuits, means in-

cluding a second load impedance for effectively coupling the other of the uni-directional current paths across the capacitance element of the other of the tuned circuits, a portion of said first and second load impedances being common, means for applying a frequency modulated carrier to the two tuned circuits, and an output circuit associated with said first and second load impedances.

4. A frequency discriminator for detecting a frequency modulated carrier having widely separated deviation limits comprising a pair of tuned circuits each including an inductance, a capacitance and a series resistance, the tuned circuits being tuned to resonate at the widely separated deviation limits of the frequency modulated carrier, a pair of diodes, means for effectively connecting one of the diodes in parallel with the inductance element of one of the tuned circuits, means for effectively connecting the other of the diodes in parallel with the capacitance element of the other of the tuned circuits, a load resistance associated with each of the diodes, means for applying a wide deviation frequency modulated carrier to the tuned circuits whereby substantially linear discrimination of the wide deviation frequency modulated carrier is possible between the widely separated deviation limits and whereby the discriminator will be substantially insensitive to frequency deviations lying outside the widely separated deviation limits, and an output circuit coupled to the load resistances.

5. A frequency discriminator for detecting a frequency modulated carrier having widely separated deviation limits comprising a pair of resonant circuits each having an inductance and a capacitance and each including a series resistance, the resonant circuits being tuned to resonate approximately at the widely separated deviation limits of the frequency modulated carrier, a pair of diodes, means for effectively connecting one of the diodes across the inductance element of one of the resonant circuits, means for effectively connecting the other diode across the capacitance element of the other resonant circuit, a load resistance associated with each of the diodes, a portion of the load resistance being common to both of the diodes, means for applying a wide deviation frequency modulated carrier to the resonant circuits, and an output circuit connected across said load resistances.

6. A discriminator for detecting a frequency modulated carrier having an extremely wide frequency deviation comprising a pair of tuned circuits each including an inductance, a capacitance and a resistance, the capacitance and inductance elements of one tuned circuit being tuned to resonate at one frequency deviation limit and the capacitance and inductance element of the other tuned circuit being tuned to resonate at the other frequency deviation limit, a pair of diodes associated with the tuned circuits, a load circuit associated with each diode, means for effectively coupling one diode in parallel with the inductance element of one of the tuned circuits, means for effectively coupling the other diode in parallel with the capacitance element of the other tuned circuit, means for impressing upon the two tuned circuits a frequency modulated carrier having deviation limits lying between the resonant frequencies of the two tuned circuits whereby the discriminator will respond substantially linearly to frequency modulations occurring between the two resonant frequencies and will be substantially unresponsive to frequency variations lying out-

side the deviation limits, and an output circuit coupled to said load circuits.

7. A discriminator for detecting a frequency modulated carrier having an extremely wide frequency deviation comprising a pair of tuned circuits each including a series connected inductance, capacitance and resistance, the capacitance and inductance elements of one tuned circuit being tuned to resonate at approximately one frequency deviation limit and the capacitance and inductance element of the other tuned circuit being tuned to resonate at approximately the other frequency deviation limit, a pair of diodes associated with the tuned circuits, a load circuit associated with each diode, means for coupling one diode across the inductance element of one of the tuned circuits, means for coupling the other diode across the capacitance element of the other tuned circuit, means for impressing a frequency modulated carrier upon the two tuned circuits whereby the discriminator will respond substantially linearly to frequency deviations between the two resonant frequencies and will be substantially unresponsive to frequency deviations lying outside the two resonant frequencies, and an output circuit connected across said load circuits.

8. A frequency discriminator for detecting a frequency modulated carrier comprising a first tuned circuit including an inductance, a capacitance and a resistance, a first uni-directional current path including a cathode and an anode, means for connecting the anode of the first uni-directional current path to one end of the inductance of the first tuned circuit, means including a load resistance for connecting the cathode of the first uni-directional current path to the other end of the inductance of the first tuned circuit, a second tuned circuit including an inductance, a resistance and a capacitance, a second uni-directional current path including a cathode and an anode, means for connecting the cathode of the second uni-directional current path to one terminal of the capacitance of the second tuned circuit, means including a second load resistance for connecting the anode of the second uni-directional current path to the other

terminal of the capacitance of the second tuned circuit, means for applying a frequency modulated carrier to the two tuned circuits, the two tuned circuits being tuned to resonate at spaced frequencies and the deviation limits of the applied frequency modulated carrier lying between the resonant frequencies whereby substantially linear discrimination of the frequency modulated carrier will result, and an output circuit coupled to the cathode of the first uni-directional current path and to the anode of the second uni-directional current path.

9. A frequency discriminator for detecting a frequency modulated carrier comprising a first tuned circuit including a series connected inductance, capacitance and resistance, a first uni-directional current path including a cathode and an anode, means for connecting the anode of the first uni-directional current path to one end of the inductance of the first tuned circuit, means including a first load resistance for connecting the cathode of the first uni-directional current path to the other end of the inductance of the first tuned circuit, a second tuned circuit including an inductance, a resistance and a capacitance, a second uni-directional current path including a cathode and an anode, means for connecting the cathode of the second uni-directional current path to one terminal of the capacitance of the second tuned circuit, means including a second load resistance for connecting the anode of the second uni-directional current path to the other terminal of the capacitance of the second tuned circuit, a portion of the first and second load resistance being common, means for applying a frequency modulated carrier to the two tuned circuits, the two tuned circuits being tuned to resonate at widely spaced frequencies and the deviation limits of the applied frequency modulated carrier lying between the resonant frequencies whereby substantially linear discrimination of the frequency modulated carrier will result, and an output circuit coupled to the cathode of the first uni-directional current path and to the anode of the second uni-directional current path.

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