

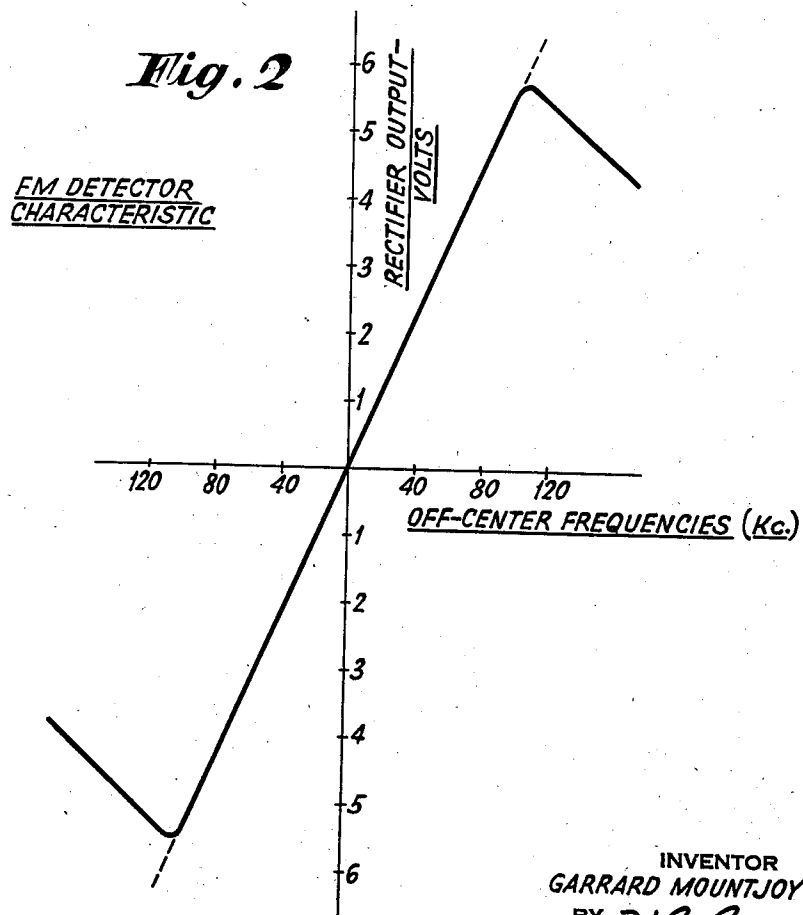
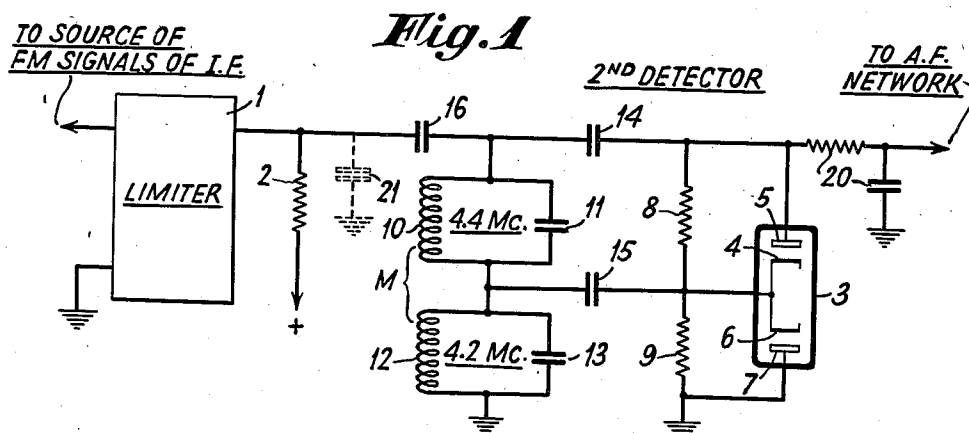
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FREQUENCY MODULATED WAVE DETECTOR

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FREQUENCY MODULATED WAVE DETECTOR

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My present invention relates to frequency modulated (FM) wave detectors, and more particularly to FM detectors of the oppositely mistuned type.

One of the main objects of my present invention is to provide an FM detector of the "back to back" type, the signal input circuits of the rectifiers being oppositely and equally mistuned from the center frequency of the applied FM waves, and perfect symmetry being provided in the detection characteristic by utilizing mutual inductance between the input circuits to cancel the effects of any capacitance coupling thereto from prior networks.

Another important object of this invention is to provide in an FM detector network a pair of diode rectifiers whose outputs are in phase opposition, while the input circuits thereof are in series relation across the prior network, and the input circuits being mistuned from a center frequency by equal frequency values in opposite senses.

Another object of my invention is to provide an FM detector of minimum component parts having good linearity and easily adjusted, the detector having, furthermore, a low impedance with consequent low contribution to intermediate frequency (I. F.) regeneration in the prior cascaded amplifier.

Still other objects of my invention are to provide an FM detector of perfect symmetry and high efficiency, and more especially to provide an FM detector capable of economical manufacture and assembly in a receiver.

The novel features which I believe to be characteristic of my invention are set forth in 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 drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a detector network embodying the invention,

Fig. 2 graphically shows the detection characteristic of the network of Fig. 1.

Referring now to the accompanying drawing, there are shown the limiter and second detector stages of an FM receiver of the superheterodyne type. Such receivers are so well known at the present time that a general description thereof should suffice. The FM band at this time is 42 to 50 megacycles (mc.). The signal collector,

usually a dipole, would feed collected signals to one or more tunable radio frequency amplifiers. The amplified signals would then be applied to a converter stage to reduce the center frequency of the FM signals to an I. F. value. It is the general practice at the present time to use an I. F. (intermediate frequency) value of 4.3 mc. If wide band frequency deviation is employed in the production of the FM signals, the over-all frequency deviation will be 200 kilocycles (kc.). Hence, the tuned circuits, whether of radio frequency or I. F., will have a band width of 200 kc. On the other hand if narrow band FM signals are used, the frequency swing could be of the order of 30 or 40 kc.

Assuming, for the purposes of illustrating this invention, that the FM carrier is swung up to 100 kc. on either side by the modulating signals, then the I. F. amplifiers will feed to the limiter stage FM signals whose carrier is at the I. F. value of 4.3 mc., while the over-all frequency deviation is 200 kc. Of course, the modulation, whether of audio frequency or higher, is represented in the I. F. energy as carrier frequency deviations. The amplitude of the audio modulation corresponds to the extent of frequency deviation of the carrier, while the modulation frequency corresponds to the rate of carrier frequency deviation.

Since the amplified FM signals of I. F. value must be applied to the FM detector with uniform carrier amplitude, a limiter stage is interposed prior to the detector input circuits. The limiter is schematically represented in Fig. 1. Those skilled in the art are fully aware of its construction and functions. For example, the limiter tube may be a 6J7 pentode whose input electrodes are coupled to the last I. F.-tuned circuit, while the plate is connected to a source of positive voltage through resistor 2. The limiter tube is designed, and has its constants chosen, to produce an amplifier which is very easily overloaded. That is, grid current is caused to flow, and plate current saturation is produced on one half of the signal cycle and plate cut-off is created on the other half of the cycle. The primary purpose of the tube is to wipe out all amplitude variations present in the output of the I. F. network prior to the limiter, and to transmit to the detector a constant amplitude-variable frequency signal.

The limited FM signals are applied to the second detector stage which comprises the 6HG type tube 3. The latter is a double diode tube, and consists of diodes 5—4 and 6—7. The cathodes

4 and 6 are connected in common to the junction of resistors 8 and 9. Anode 5 connects to the upper end of resistor 8, while anode 7 is connected to the grounded end of resistor 9. Resistors 8 and 9 function as the load impedances of diodes 5-4 and 6-7 respectively. The resonant input circuit for diode rectifier 5-4 consists of coil 10 shunted by condenser 11. The circuit 10-11 is tuned to one side of the center frequency of 4.3 mc. The frequency value is 4.4 mc. That is, the circuit 10-11 is resonated to a frequency 100 kc. above the FM center frequency.

The tuned input circuit 12-13 of the other diode rectifier 6-7 is resonated to 4.2 mc., or 100 kc. below the center frequency. The upper end of coil 10 is coupled to the anode 5 by condenser 14, while condenser 15 connects the junction of coils 10 and 12 to the junction of resistors 8 and 9. The low end of coil 12 is established at ground potential. The direct current blocking condenser 16 connects the upper end of resistor 2 to the upper side of input circuit 10-11.

The modulation signal voltage, audio in the present case, is taken off at the upper end of load resistor 8, and transmitted through de-emphasizing network 20 to the audio amplifier stages. The network 20 reduces the response of the high audio frequencies; it being known that at the transmitter in wide band FM transmission the higher audio frequencies are emphasized. The dotted line capacity 21 designates the capacitance coupling which is due to the plate to ground capacity of the limiter tube plus the attending plate wiring and circuit capacitance to ground. In general, numeral 21 represents the inherent circuit capacity coupling between the prior network and the detector input circuits. The capacity 21 tends to render the detection characteristic unsymmetrical. Proper poling and adjustment of M, the mutual inductance between coil 10 and 12, will cancel out the effect of the undesired capacity 21, and a perfectly symmetrical detection characteristic will result.

In Fig. 2 there is shown the FM detector characteristic. This characteristic is secured by plotting "off-center frequency" as abscissae, and "rectified output" as ordinates. It will be observed that the spaced peaks of the curve occur at 100 kc. off the center frequency. This curve has good linearity and perfect symmetry. The curve was secured with 2.5 R. M. S. volts input to the limiter signal grid at the center frequency of 4.3 mc. The mutual M is so poled and adjusted that the effect of the capacitance coupling 21 is cancelled out. In this way the perfectly symmetrical characteristic shown in Fig. 2 is secured. The choice of the Q of the two circuits 10-11 and 12-13 dictates the linearity of the output voltage. More or less sensitivity may be obtained by proper choice of the values of inductances 10 and 12. Coils 10 and 12 may be made small, since the limiter output may be large.

The input of the detector has a low impedance which is due to the effect of two mistuned circuits in series. These series circuits are tied directly across the limiter plate. The series circuits have a much smaller impedance than the I. F. impedance of a network which relies on primary coupling to the circuits 10-11 and 12-13.

Considering specifically the functioning of the detection network it will be understood that the maximum rectified voltage appears across resistor 8 when the frequency of the FM carrier is sub-

stantially that of the circuit 10-11. Similarly, maximum rectified voltage appears across resistor 9 when the FM carrier frequency is equal to the resonant frequency of circuit 12-13. Between these two frequencies of the FM carrier the rectified voltage across each of resistors 8 and 9 will depend upon the frequency displacement of the carrier frequency with respect to the resonant frequencies of each of the input circuits. Hence, at the center frequency the over-all output voltage taken off at the upper end of resistor 8 will be equal to zero, since the diode output resistors are arranged in phase opposition. This follows from the fact that at the center frequency of the FM carrier the rectified voltages across resistors 8 and 9 are equal. For frequency deviations of the FM carrier the effective output voltage at the upper end of resistor 8 will depend upon the difference between the rectified voltages produced across resistors 8 and 9. The curve in Fig. 2 gives the relation between the rectified output voltage of the detector load 8-9 for the various frequency deviations of the FM carrier. Since the audio frequency voltage components are represented by frequency deviations of the FM carrier, it will be seen that the voltage taken off at the upper end of resistor 8 is the audio modulation voltage.

For production adjustment of this detector network only one input frequency is required. This is the center frequency. One circuit is initially mistuned. The second circuit is resonated, and the output read on a measuring instrument. It is then detuned until the output becomes a certain predetermined percentage of maximum output. The first circuit is then adjusted to produce zero output. The two input circuits are now equally and oppositely mistuned with respect to the center frequency. The percentage mistuning of the second circuit need only be determined once in the laboratory.

The plate to ground capacitance 21 may also be cancelled by the use of a plate choke coil instead of the load resistor 2. In this case the choke coil is made to resonate with the plate circuit capacitance 21 to the I. F. value. In this case there would be no M between coils 10 and 12, but the latter would be wound further apart. This method is not as desirable as the mutual balance method, since it adds one more complex component.

The following constants are given by way of illustration, and are not to be considered in any way limiting:

R_2	=100,000 ohms
R_8	=50,000 ohms
R_9	=50,000 ohms
R_{20}	=150,000 ohms
$C_{16}=C_{14}=C_{15}$	=500 micro-microfarads (mmf.)
$C_{11}=C_{13}$	=approximately 400 mmf.
$L_{10}=L_{12}$	=3.6 microhenries

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, as set forth in the appended claims. The term "timing modulated" is used in the claims generically to cover frequency modulation and/or phase modulation.

What I claim is:

1. In combination with a network supplying frequency modulated carrier waves, a detection

network comprising a pair of rectifier circuits, each rectifier circuit having a resonant input circuit and an audio output circuit, said rectifier input circuits being oppositely and equally mistuned with respect to the center frequency of said modulated waves, said output circuits being arranged in phase opposition, and said input circuits being arranged in series relation with each other and with the space current paths of the rectifiers, said supply network having capacity coupling to said input circuits, said input circuits being magnetically coupled with each other to provide sufficient mutual inductance to cancel out the effect of said capacity coupling.

2. In combination with a network supplying frequency modulated carrier waves, a detection network comprising a pair of rectifier circuits, each rectifier circuit having a resonant input circuit and an audio output circuit, said rectifier input circuits being oppositely and equally mistuned with respect to the center frequency of said modulated waves, said output circuits being arranged in phase opposition, and said input circuits being arranged in series relation with each other and with the space current paths of the rectifiers, said supply network comprising a limiter stage for eliminating carrier amplitude variation, a resistance-capacity coupling between said limiter stage and said input circuits and said input circuits providing a low impedance load across said limiter stage.

3. In combination with a network supplying frequency modulated carrier waves, a detection network comprising a pair of rectifier circuits, each rectifier circuit having a resonant input circuit and an audio output circuit, said rectifier input circuits being oppositely and equally mistuned with respect to the center frequency of said modulated waves, said output circuits being arranged in phase opposition, and said input circuits being arranged in series relation with each other and with the space current paths of the rectifiers, said supply network being coupled to said input circuits by resistance coupling which has an undesirable capacity component, and said input circuits being magnetically coupled with each other to provide sufficient mutual inductance to cancel out the effect of said capacity component.

4. In combination, a diode rectifier circuit provided with a resonant input circuit and a resistive output load, a second diode rectifier circuit provided with a second resonant input circuit and a second resistive output load, means connecting said resistive loads in phase opposition, a source of frequency modulated carrier waves, said input circuits being oppositely and equally mistuned relative to the center frequency of said waves and arranged in series relation with each other and in series with the space discharge paths of said rectifier diodes, said resistive loads being connected in series between the anodes of said diodes, and said loads being connected directly in shunt with said series-arranged input circuits.

5. In combination, a diode rectifier circuit provided with a resonant input circuit and a resistive output load, a second diode rectifier circuit provided with a second resonant input circuit and a second resistive output load, means connecting said resistive loads in phase opposition, a source of frequency modulated carrier waves, said input circuits being arranged in series relation with each other and in series with the space discharge paths of said rectifier diodes, coupling means between the source and input circuits having un-

desirable capacity to ground, said input circuits being inductively coupled with each other to provide sufficient mutual inductance for cancelling out the effect of said capacity coupling thereby to maintain said rectifier circuits symmetrical in their rectification of the modulated carrier waves.

6. In combination, a diode rectifier circuit provided with a resonant input circuit and a resistive output load, a second diode rectifier circuit provided with a second resonant input circuit and a second resistive output load, means connecting said resistive loads in phase opposition, a source of frequency modulated carrier waves, said input circuits being arranged in series relation with each other and in series with the space discharge paths of said rectifier diodes, one of said rectifier input circuits being mistuned from the carrier wave center frequency by a frequency equal to the permissible frequency swing of the carrier, the other rectifier input circuit being mistuned in the opposite direction by an equal frequency value, coupling means between the source and input circuits having undesirable capacity coupling to said input circuits, and said input circuits being magnetically coupled to provide mutual inductance sufficient to cancel out the effect of said capacity coupling.

7. In combination with a network supplying timing modulated carrier waves, a detection network comprising a pair of diode rectifier circuits, each rectifier circuit having a resonant input circuit and an audio output circuit, said rectifier input circuits being oppositely and equally mistuned with respect to the center frequency of said modulated waves, said output circuits being arranged in phase opposite, and said input circuits being arranged in series relation with each other across said supply network, said supply network having undesirable capacity coupling to said input circuits, and said input circuits being magnetically coupled to provide sufficient mutual inductance to cancel out the effect of said capacity coupling.

8. In combination, a diode rectifier circuit provided with a resonant input circuit and a resistive output load, a second diode rectifier circuit provided with a resonant input circuit and a resistive output load, means connecting said resistive loads in phase opposition, a source of timing modulated carrier waves, said input circuits being arranged in series relation with each other across said source and in series with the space discharge paths of said rectifier diodes, coupling means between the source and input circuits having undesirable capacity coupling to ground, and said input circuits being coupled to provide sufficient mutual inductance for cancelling out the effect of said capacity coupling thereby to maintain said rectifier circuits symmetrical in their rectification of the modulated carrier waves.

9. In combination, a diode rectifier circuit provided with a resonant input circuit and a resistive output load, a second diode rectifier circuit provided with a resonant input circuit and a resistive output load, means connecting said resistive loads in phase opposition, a source of timing modulated carrier waves, said input circuits being arranged in series relation with each other across said source and in series with the space discharge paths of said rectifier diodes, coupling means between the source and input circuits having undesirable capacity coupling to ground, said input circuits being magnetically coupled to provide mutual inductance for cancelling out the effect of said capacity coupling thereby to maintain

said rectifier circuits symmetrical in their rectification of the modulated carrier waves, and each of said input circuits being oppositely mistuned with respect to said modulated carrier wave center frequency by equal frequency amounts.

10. In a detector for timing modulated carrier waves having a predetermined center frequency, a pair of diodes, means establishing the diode cathodes at a common potential, a resistive load connected between the anodes of said diodes, means establishing substantially the midpoint of said load at said potential, a pair of resonant input circuits connected in series relation between the anodes of said diodes, said input circuits being adapted to have said waves impressed thereon, said circuits being oppositely mistuned by substantially equal frequency increments relative to said center frequency, and means connecting the junction of said input circuits to said midpoint.

11. In a detector for timing modulated carrier waves having a predetermined center frequency, a pair of diodes, means establishing the diode cathodes at a common potential, a resistive load connected between the anodes of said diodes, means establishing substantially the midpoint of said load at said potential, a pair of resonant input circuits connected in series relation between the anodes of said diodes, said input circuits being adapted to have said waves impressed thereon, said circuits being oppositely mistuned by substantially equal frequency increments relative to said center frequency, and means connecting the junction of said input circuits to said midpoint, said input circuits being magnetically coupled to provide a predetermined value of mutual inductance, and said last connecting means including a condenser.

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