

Dec. 21, 1948.

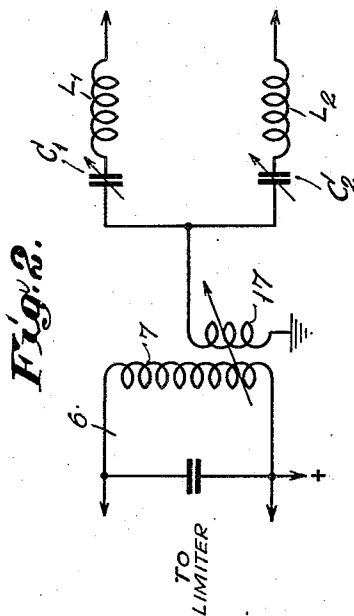
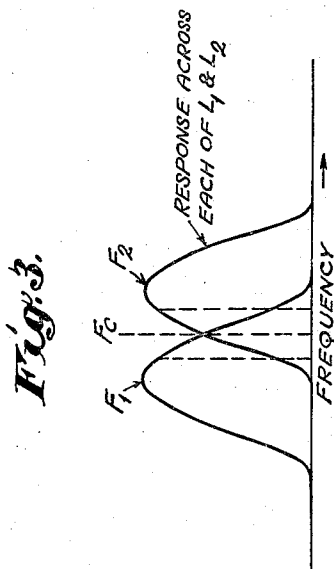
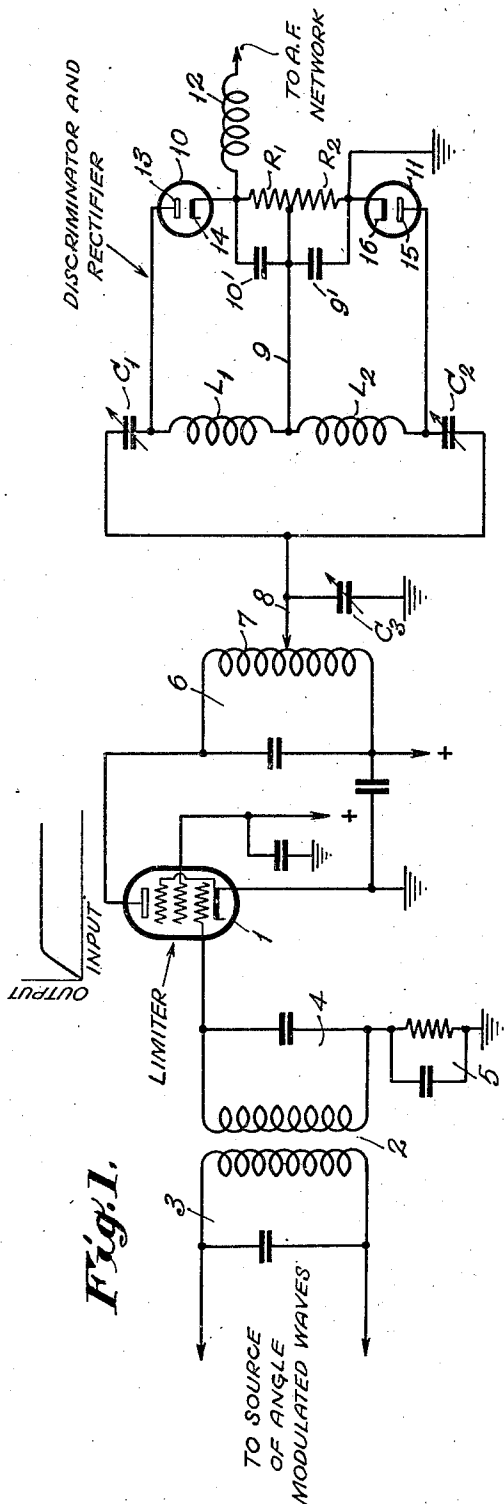
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2,457,013

ANGLE MODULATED WAVE DISCRIMINATOR

Filed July 28, 1944

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

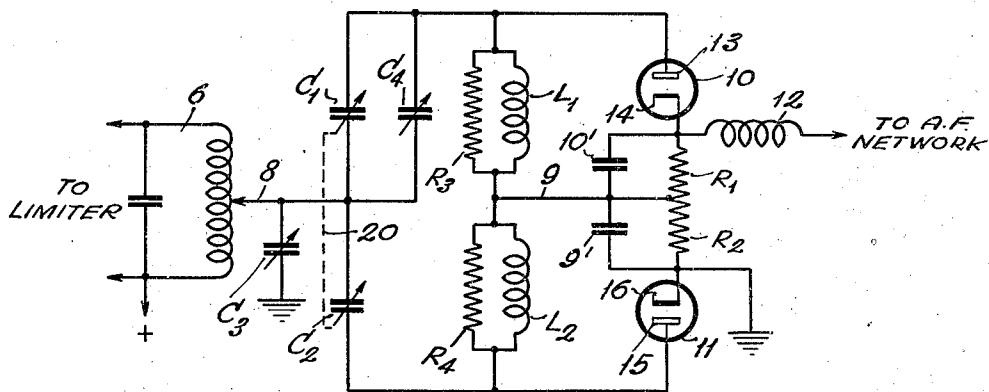


Fig. 5.

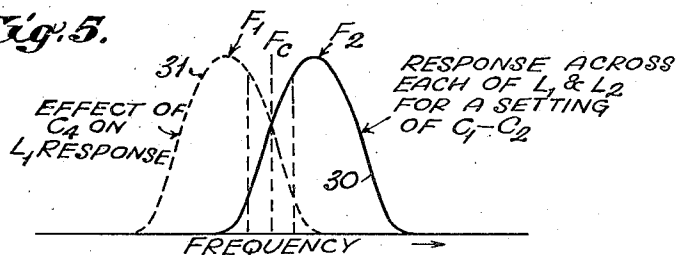


Fig. 6.

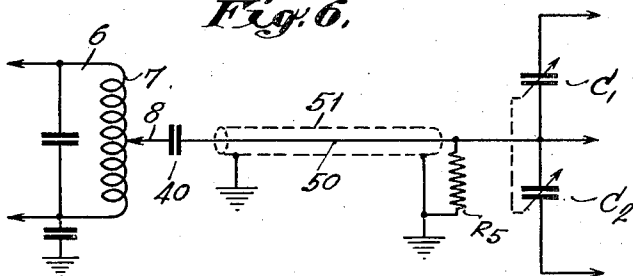
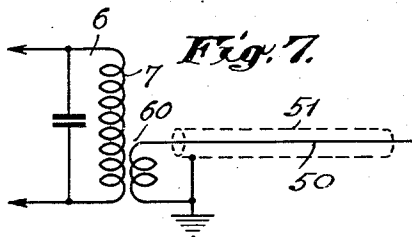


Fig. 7.



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ANGLE MODULATED WAVE DISCRIMINATOR

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1 Claim. (Cl. 250-27)

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My present invention relates generally to improved circuits for translating angle modulated carrier waves into amplitude modulated (AM) carrier waves, and more particularly to improved frequency discriminator circuits.

In my U. S. Patent No. 1,794,932, granted March 3, 1931, I have shown a system for translating angle modulated waves into AM wave energy. In that patent the specific embodiment was that of a frequency discriminator for frequency modulated (FM) carrier waves. Generally, the patent disclosed the use of a pair of resonant circuits tuned to frequencies located on opposite sides of a predetermined reference frequency, and the difference between the peak frequencies of the pair of circuits substantially exceeded the maximum frequency variations of the FM waves. In employing this form of discriminator the usual practice has been to use high impedance coupling devices, such as coupling tubes, to feed the discriminator circuits. The coupling devices were subject to interference from stray electric fields.

It is one of the important objects of this invention to feed an improved frequency discriminator by means of low impedance coupling which is not easily affected by stray fields.

Another important object of my invention is to provide a discriminator network for use with opposed rectifiers, wherein the discriminator consists of a pair of series-resonant circuits tuned to respectively different sides of a predetermined reference center frequency, the voltages across the inductive elements of the series-resonant circuits being applied to respective ones of said rectifiers.

Another important object of my invention is to provide a novel and improved method of, and means for, adjusting the frequency spacing of the frequency discriminator circuits.

Another object of my invention is to provide a low impedance cable coupling between a source of angle modulated waves and a discriminator therefor, wherein a resistor is used as the input impedance to the frequency discriminator circuit so that the discriminator may be operated at a considerable distance from the said source of modulated waves.

Still more specific objects of this invention are to provide a discriminator with a low impedance input for a simple monitor receiver to test and observe the angle modulation character of signals in a transmitter; or to provide a low impedance input discriminator capable of being located at some distance from the intermediate

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frequency amplifier stages of a superheterodyne receiver, as for example where the discriminator is to be located on a different shelf of a cabinet.

Still other objects of my invention are to improve the efficiency, reliability and stability of FM discriminator-rectifier systems.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claim; 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 several circuit organizations whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit diagram of one embodiment of my invention;

Fig. 2 shows a modified coupling means to the discriminator circuits;

Fig. 3 shows idealized response curves for the discriminator circuits;

Fig. 4 shows a modification of the discriminator circuits;

Fig. 5 graphically illustrates the manner of adjusting the discriminator of Fig. 4;

Fig. 6 shows a modification in the coupling means to the discriminator circuits; and

Fig. 7 shows a modification of the input end of the coupling means of Fig. 6.

Referring now to the accompanying drawings, wherein like reference numerals in the different figures designate similar elements, I have shown my invention embodied by way of specific illustration in an FM receiver system. Only such networks of the FM receiver system are shown as are necessary to a proper understanding of my invention. The generic term "angle modulation" used in this application is to be understood as being equally applicable to FM or phase modulated (PM) waves, or to hybrid modulations having characteristics common to FM or PM. Whereas in an FM wave the extent of frequency deviation of the carrier from its normal or center frequency is dependent on the amplitude of the modulating signal and the rate of deviation is determined by the modulating frequencies per se, in a PM wave the deviation is relatively greater for the higher modulation frequencies. Hence, my improved detector is readily adapted to detect a PM wave (considered as a relatively narrow band FM wave), a de-emphasis network being employed subsequent to detection to com-

pensate for the inherent pre-emphasis of the higher modulating frequencies.

Further, it is to be understood that the modulating signals may be of the kind used in telegraphy or in telephony, and that the invention is not limited to any particular frequency band or frequency deviation range. Merely by way of specific illustration, let it be assumed that FM waves are to be received from a transmitter whose carrier frequency is located in the 42-50 megacycle (mc.) band, the latter band being the presently-assigned FM broadcast band. Of course, the FM waves could be received from a transmitter operating in any other of the megacycle ranges. Where PM waves are being received the present invention is readily adapted for reception of PM waves whose carrier frequency would be located in any of the known megacycle bands. So far as the frequency deviation range of the received FM signals is concerned, there is employed a 150 kilocycle (kc.) maximum deviation range in the 42-50 FM band. Here, again, the invention is not limited to that relatively wide deviation band, but may be employed for FM or PM waves with a relatively narrow transmission channel.

Referring to Fig. 1, let it be assumed that the improved detector circuit is embodied in a superheterodyne receiving system. While my invention is in no way restricted to any particular form of receiving system, it is preferred to specify the superheterodyne receiving system since the latter is most widely employed at the present time in the reception of angle modulated carrier waves. As is well-known to those skilled in the art of radio communication, the received FM carrier waves of a desired carrier frequency in the 42-50 mc. band are reduced to an intermediate frequency (I. F.). The I. F. value may be one best suited for the operating conditions at the point of reception, and a value of 4.3 mc. has been found suitable for the reception of FM waves in the 42-50 mc. band. The I. F. energy is usually subjected to I. F. amplification in one or more amplifier stages. In order to prevent any amplitude variations which may develop on the received modulated carrier energy prior to the discriminator circuits from affecting the subsequent detector, it has been the practice to provide an amplitude limiting device between the source of angle modulated wave energy and the discriminator section of the discriminator-detector circuit. Limiter devices are well-known, and generally take the form of amplifiers whose output above a predetermined input amplitude is substantially uniform.

Hence, in Fig. 1 I have shown a limiter tube of well-known form located between the source of angle modulated wave energy and the discriminator network. The limiter tube 1 is shown specifically as of the pentode type, although it may be of any other well-known construction. The input transformer 2 has its primary circuit 3 and secondary circuit 4 each tuned to the operating I. F. value, 4.3 mc. in the example given. Of course, the passband width of transformer 2 will be substantially in excess of the maximum frequency swing of the received FM waves. It is the usual practice to make the passband of each of the selector circuits of the receiving system of an FM receiver substantially in excess of the maximum frequency swing, as taught in my aforesaid patent. By way of example it is pointed out that the passband width of transformer 2 may be of the order of 200 kc. The grid circuit of tube 1

includes the usual resistor-shunt condenser network 5 to provide the limiting action. It is, also, desirable to adjust the operating direct current voltages of the screen and plate of tube 1 so that on the negative half-cycle of the waves applied to tube 1 the amplifier 1 will be readily cut off thereby to augment the limiting action. Above the tube 1 I have depicted an idealized limiting characteristic for the limiter tube, and it will be seen that amplitude variations of the FM signals applied to the discriminator will be inhibited. Of course, my invention is in no way restricted to the tube 1 being a limiter tube, since it may be desired to dispense with limiting action and to have tube 1 function as an I. F. amplifier.

Regardless of the function of tube 1, the resonant plate circuit 6 thereof will be tuned to the operating I. F. value. The plate of tube 1 is connected through the coil 7 of resonant output circuit 6 to a point of suitable positive potential. In accordance with one of the objects of my invention the tapping point of the signal voltage to be applied to the subsequent discriminator circuit is at a relatively low potential point of the coil 7. The tapping point may be made adjustable by providing a sliding contactor 8 which is connected to the junction of the condensers C₁ and C₂. The adjustable condenser C₃ connects the contactor 8 to ground, and adjustment of condenser C₃ may be employed to regulate the coupling impedance between circuit 6 and the discriminator circuit. If desired, the condenser C₃ may be chosen to have a fixed value. The condenser C₁ has connected in series therewith a coil L₁, while the condenser C₂ has connected in series therewith a coil L₂. The junction of coils L₁ and L₂ is effectively connected to ground for signal potentials through a lead 9 and the bypass condenser 9' across resistor R₂, which will be further described hereinafter.

Condenser C₁ and coil L₁ provide a first series-resonant circuit tuned to a frequency located on one side of the operating I. F. value and spaced therefrom by a predetermined frequency value. Condenser C₂ and coil L₂ provide a second series-resonant circuit tuned to a second frequency which is located on the opposite side of the operating I. F. value and spaced therefrom by the same predetermined frequency value.

In Fig. 3 I have shown the frequency response curves of each of coils L₁ and L₂. It is seen that the response across each coil is a maximum at the resonant frequency F₁ or F₂ of its respective series-resonant circuit C₁, L₁ or C₂, L₂, although the voltage drop across each entire series-resonant circuit is, of course, substantially zero at its respective tuned frequency. Hence, the signal voltages developed across each of coils L₁ and L₂ are used for rectification by the opposed rectifiers 10 and 11. The spacing between the peak frequencies F₁ and F₂ in Fig. 3 is about 200 kc., and the crossover, center or balance frequency is designated F₀. The peak frequencies F₁ and F₂ are shown located beyond the dotted vertical lines representing the maximum frequency swing. The diode rectifier 10 is provided with a load resistor R₁, whereas R₂ is the load resistor for diode rectifier 11. Each of the load resistors R₁ and R₂ is bypassed for I. F. currents by a respective I. F. bypass condenser 10' or 9'. Since the cathode end of resistor R₂ is grounded, the rectified voltages across resistors R₁ and R₂ are combined in polarity opposition. The differential resultant voltage of the opposed rectified voltages is taken

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off through I. F. choke coil 12 from the cathode end of resistor R₁.

It will be noted that the anode 13 of rectifier diode 10 is connected to the upper end of coil L₁, while cathode 14 is connected to the lower end of coil L₁ through load resistor R₁ and lead 9. In the same manner diode anode 15 is connected to the junction of coil L₂ and condenser C₂, while cathode 16 is connected to the junction of coils L₁ and L₂ through resistor R₂ and lead 9. Hence, each of the coils L₁ and L₂ acts as the signal input element of its respective diode 10 or 11. At the instant when the I. F. energy is at a frequency F_c the voltages across each of coils L₁ and L₂ are equal, and, therefore, the rectified signal voltages across each of resistors R₁ and R₂ will be equal. Being of opposite polarity the voltages across resistors R₁ and R₂ will cancel each other, and the output will be zero. However, frequency variations or deviations from F_c will result in relative variations of magnitude of the rectified voltages across coils L₁ and L₂ depending on the sense and amount of frequency deviation. The differential voltage taken off at the cathode end of resistor R₁ will vary in correspondence with the aforesaid frequency variations in a manner known to those skilled in the art.

Prior discriminators have usually required high impedance coupling means between circuit 6 and the discriminator circuits. Such high impedance coupling means were subject to stray pick-up of interfering potentials. In my present invention a low impedance coupling element is used, as for example the condenser C₃ tapped down (i. e., toward the low alternating current potential end) on coil 7. Such a low impedance coupling device is not easily affected by stray fields. There may be used an inductive form of low impedance coupling element in place of condenser C₃. Thus, in Fig. 2 the junction of condensers C₁ and C₂ is connected to the upper end of coupling coil 17 whose lower end is grounded. The coil 7 of resonant circuit 6 and the coupling coil 17 are magnetically coupled. If desired, there may be employed adjustable magnetic coupling between the two coils. The diodes 10 and 11 may be embodied in a common tube envelope, as in a 6H6 type tube. It is noted that each of the bypass condensers 10' and 9' across resistors R₁ and R₂ will have a sufficiently large impedance value at all useful audio frequencies so as not to interfere with the transmission of the highest modulation frequency.

The magnitude of the low impedance coupling in either of Figs. 1 and 2 is preferably maintained below 1000 ohms. When a coupling coil is used, as in Fig. 2, the coil 17 may be from one to several turns. In the cases where it is desirable to employ the capacity coupling C₃, the value of the capacitance C₃ may be chosen to make its impedance at the operating frequency, for example 4.3 mc., of some relatively low value between 50 and 1000 ohms. It will be noted that the condenser C₃ furnishes a circuit to ground for the input of the discriminator circuits. That is, oscillating currents in the discriminator series-tuned circuits flow to ground through the bypass condenser 9' around resistor R₂, and from ground back through capacitive impedance C₃ to the series-tuned circuits again. The same would apply to an inductive impedance or a resistance (see Fig. 6) used in place of condenser C₃. The input power is, also, coupled to the discriminator through the impedance of condenser C₃. The advantage of a low impedance at condenser C₃ is that it must be comparatively low in order for the series-tuned

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circuit scheme to be effective. Otherwise too much radio frequency voltage would be used up in condenser C₃, and not enough would be left for the series-tuned circuits. Further, a low impedance at condenser C₃ permits the use of an ordinary insulated wire for lead 8, such as a low-voltage, insulated switchboard wire laid close to the metal panel. This permits easy shielding of the discriminator elements from other radio frequency sources. The use of the low impedance condenser C₃ means that the tapping to a relatively low alternating current potential point on coil 7 is necessary, which gets away from high potentials and high electric fields that may cause trouble due to stray capacity couplings, etc.

The modification shown in Fig. 4 is similar to the circuit of Fig. 1, except for the manner of securing the response characteristics of Fig. 3. The condensers C₁ and C₂ are constructed in the form of a variable condenser having two groups of stator plates, each group having its corresponding group of rotor plates. A common rotor shaft 20 has all the rotor plates affixed thereto. Hence, adjustment of shaft 20 results in simultaneous tuning of the series-resonant circuits C₁, L₁ and C₂, L₂ to a common desired frequency. The "frequency split" or displacement of the response characteristics of the pair of tuned circuits on opposite sides of the mean frequency F_c is provided by adjustable condenser C₄. The latter is shown in shunt with condenser C₁. Alternatively, it may be shunted across condenser C₂, if desired.

Each of coils L₁ and L₂ is shunted by a respective resistor R₃ or R₄. The magnitude of each resistor R₃ or R₄ is selected to give the desired slope or decrement to the tuning characteristic of the series-resonant circuits. In Fig. 5 I have shown a solid line frequency response curve 30 denoting the response across each of coils L₁ and L₂ for a selected setting of the rotor shaft 20. The rotor shaft, with condenser C₄ effectively out of the circuit, is adjusted to tune each of circuits C₁, L₁ and C₂, L₂ to the common off-center frequency F₂; which is higher than F_c. The condenser C₄ is now adjusted so as to tune circuits C₁, L₁ to the frequency F₁ which is located on the opposite, low-frequency side of F_c, and is spaced from the latter by a frequency value equal to the frequency difference between F_c and F₂. The curves in Fig. 5, of course, are the response curves across each of coils L₁ and L₂.

The advantage of using an auxiliary condenser C₄ as in Fig. 4 is that it permits the use of a standard split-stator, or balanced, condenser construction for condensers C₁ and C₂. In this case the two stators and the two rotors are alike, and the rotors are fastened rigidly on the same shaft. This permits easy tuning of the two series circuits simultaneously. Also, the condenser C₄ can be adjusted separately to provide the desired phase split or shift in the tuning response of the two series tuned circuits. In wide band FM reception the phase split in the discriminator is made wide, but for narrow band FM, or for PM reception, the phase split is made comparatively small.

Instead of using a reactance as the input impedance to the frequency discriminator circuit, I may use a resistor element. Thus, in Fig. 6 I show resistor R₅ as the input impedance element. Further, a long concentric cable is used between the limiter output circuit 6 and the junction of condensers C₁ and C₂. The resistor R₅ is located at the output end of the cable, between the conductor 50 and ground. The input end of con-

ductor 50 is connected to slidable tap 8 through a direct current blocking condenser 40. The shield 51 of the cable is grounded whereby the resistor R₅ matches the cable impedance and provides a path for the excitation current to the discriminator circuit. If desired, the magnetic coupling 60 may be used from the input end of the cable to circuit 6 in place of the blocking condenser 40. This modification is shown in Fig. 7.

The resistance input impedance for coupling to the discriminator is preferable when it is desired to operate the discriminator at the end of a cable, in which case the resistance is given a value such as to match the cable impedance. The advantage of this is especially evident when the discriminator is used at the end of a long cable. For example, an unmatched cable will discriminate against some frequencies so that some side frequencies may not be transmitted in proper phase and amplitude. This would result in distortion of the signal.

Inductive coupling of the discriminator to the signal source, as shown by coil 60 in Fig. 7, has some advantages over capacitive coupling as constituted by condenser 40 in Fig. 6. The latter is used when the coupling is to be conductive. The coupling by coil 60 can be made variable by moving it mechanically into and out of the magnetic field of coil 7. Coil 60 is convenient to use on a monitor discriminator to pick up modulated radio frequency energy from any desirable location in a transmitter. Sometimes it is more convenient mechanically, as in the case of a plug-in coil, to wind the coil 60 on the same form as coil 7 so that the coupling is of the desired amount for each plug-in coil.

It is to be understood that I may wish to use the discriminator circuit alone as a monitor receiver to test or observe the wave shape and operation of an FM or PM transmitter. In this case the discriminator would preferably be coupled to the transmitter circuits through a relatively long shielded cable. The discriminator may be near, or at a considerable distance from, the transmitter as desired. The output of the discriminator may be a loud speaker, an oscilloscope, or an amplifier with indicating and measuring equipment. When the discriminator is used as a monitor its circuits are usually tuned to the transmitter output frequency.

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:

In combination with a source of angle modulated carrier waves, a resonant circuit tuned to a predetermined reference frequency coupled to said source, a pair of series-resonant circuits tuned to respective peak frequencies equidistantly located on opposite sides of said reference frequency, said pair of series resonant circuits being connected in parallel relation, a relatively low impedance coupling connection from a relatively low potential point on said resonant circuit to a common connection point of said pair of circuits, a pair of opposed rectifiers, each of said rectifiers comprising an anode and a cathode, each series resonant circuit consisting of a condenser and an inductance, said common connection point being the common connection between the condensers of said series resonant circuits, said low impedance coupling connection consisting of a reactive impedance connected between said common connection point and the cathodes of said rectifiers, a connection from the anode of each respective rectifier to the junction of the condenser and inductance of a respective one of said series resonant circuits, and a common connection from the cathodes of said rectifiers to the common connection of said inductances whereby there is applied to each respective one of said rectifiers the voltages developed across the respective inductances of said series-resonant circuits.

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