Aug. 15, 1933. C. W. HANSELL 1,922,290

DETECTION OF FREQUENCY MODULATED SIGNALS

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Fig. 1

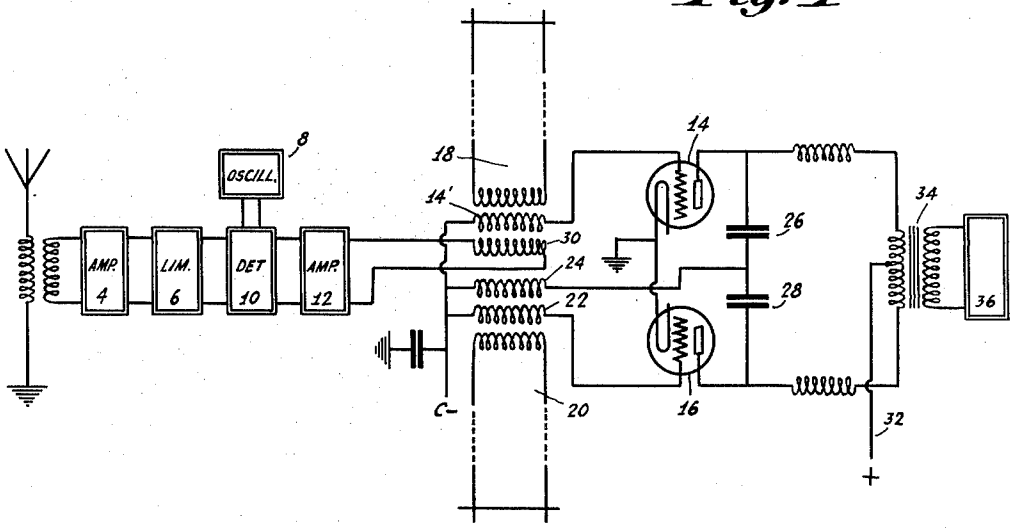
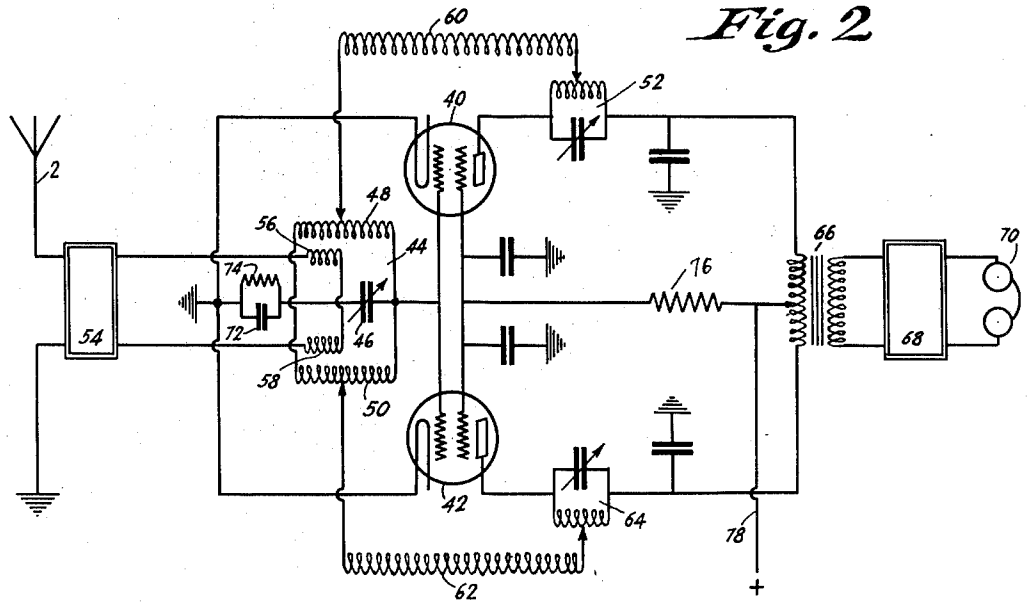


Fig. 2



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DETECTION OF FREQUENCY MODULATED SIGNALS

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3 Claims. (Cl. 250—33)

This invention relates to means for securing a response dependent upon the frequency of alternating electrical energy, and more particularly to means for detecting frequency modulated signals.

In order to detect frequency modulated signals it has heretofore been proposed to first change the frequency modulation to amplitude modulation by impressing the received signals on a resonant circuit tuned to a frequency lying outside the operating range of frequency, and thereafter to detect the resulting amplitude modulated signals in order to obtain signal frequency energy for use in a translating device. Such a method is difficult to free from distortion, and is limited in usefulness by the fact that the resonance characteristic of a tuned circuit may differ under dynamic conditions, such as exist when the frequency of the energy applied thereto is rapidly varying, from what it is under static conditions, when each frequency applied thereto is kept constant for a considerable period of time.

It is a further object of my invention to provide a frequency modulation detector which is sensitive and free from distortion. My invention includes means for converting direct energy to alternating energy in an electron emission tube oscillator having long line means for fixing its frequency to a value lying outside the range of frequency modulation, applying the frequency modulated energy to the local oscillator in order to force the latter to similarly vary in frequency, and providing means for utilizing the consequent variations in the direct energy supplied to the oscillator for translation.

Frequency modulated energy, ideally, possesses no amplitude variation, and this condition is desirable for correct operation of my arrangement, lest the consumption of direct energy vary with variations in the strength of the received signal. Close limiting is not essential, but there must be sufficient limiting so that the signal energy will maintain control over the frequency of oscillation of the oscillator. To meet the desired condition I propose to limit the amplitude of the frequency modulated energy before applying it to the oscillator, thereby eliminating changes in amplitude caused by fading and other transmission phenomena.

The degree of variation of the direct energy is enhanced if the percentage frequency modulation is increased, and according to my invention the relatively slight modulation of the received carrier is increased by heterodyning the received energy with locally generated energy of constant frequency. The resulting beat energy has a variation in frequency equal to that of the received carrier, but the modulation being impressed on a lower carrier, the percentage modulation is greatly increased.

In order to obtain symmetrical operation and so further reduce the possibility of distortion, I propose to use two local oscillators, one having long line means for fixing its frequency to a value lying outside one extreme of the working range and the other having long line means for fixing its frequency to a value lying outside the other extreme of the working frequency range. The received energy is applied to both of the oscillators while the translating device is coupled in series with the anodes of the oscillator tubes, with respect to the direct energy, so that it is made responsive to the differential of the anode currents.

In order to insure the oscillator following the received energy in frequency, I prefer to couple the oscillators together so that they are forced to oscillate at a common, compromise, frequency lying intermediate their natural frequencies, fixed by the long line means, and I use the received frequency modulated energy to force the said common frequency to vary with the frequency modulation. Such an arrangement, when properly adjusted, balances the tendency for the oscillators to oscillate at their own frequencies in such a way that the energy required from the incoming signal may be greatly reduced. That is, the sensitivity is greatly increased.

By long line control means, I mean the type of control for an oscillation generator of the electron emission tube type wherein a long resonant transmission line preferably in coiled form to occupy small space, is coupled to the oscillator and forces it, by virtue of standing waves thereon, to oscillate at a frequency corresponding to the wave length of the standing waves on the line. An oscillator of this type is described more fully in my copending application on an oscillator, filed October 18, 1929, Serial Number 400,489. Or, the long line control may be of the type disclosed by James L. Finch and James W. Conklin in their copending application, Serial Number 363,660, filed May 16, 1929, wherein an aperiodic line transfers energy from the output circuit to the input circuit of an electron emission tube oscillator and maintains the frequency of oscillations generated to a value corresponding to that for which the line is a whole number of half wave lengths long.

Long lines are used for frequency control of the local oscillators, according to the present invention, for the reason that the fixed frequency of each oscillator, and consequently the intermediate frequency at which they are forced to oscillate together, and their balance is more constant because the lines prevent undesired changes in tuning due to variations in power voltage, load, tuning, temperature and other factors which influence undesirably ordinary oscillators of the tuned circuit variety. Moreover, the lines cause an equivalent increase in the sharpness of tuning of the oscillators so that a smaller percentage variation in the frequency of the input energy can cause a greater response in the receiver output.

My invention is more fully described in connection with the accompanying drawing, in which

Figure 1 illustrates a frequency modulation receiver wherein resonant long lines are used for frequency control of local oscillators, and

Figure 2 discloses a similar arrangement wherein aperiodic long lines are used for frequency control of the local oscillators.

In the arrangement shown in Figure 1, an antenna system 2 supplies collected energy to an amplifier 4 in turn feeding a limiting device 6 which amplifies the collected energy to energy variable in frequency but constant in amplitude. The limited energy is preferably reduced in frequency in order to increase the percentage frequency modulation, by heterodyning it with energy from a local oscillator 8 in a heterodyne detector 10. Local oscillator 8 is preferably of the long line controlled type such as disclosed in my copending application Serial Number 400,489, filed October 18, 1929, or of the type disclosed by James L. Finch and James W. Conklin in their copending application 363,660 filed May 16, 1929. The limiter 6 may be located after the detector 10 as well as ahead of it and, of course, a further stage of amplification 12 may be provided which itself may be made to act as a limiter.

The oscillating system used as a detector comprises two electron emission tube oscillators 14, 16 having resonant long line controlling means 18, 20 for fixing the natural frequencies of each of the oscillators to lie outside different extremes of the applied frequency range. The input circuit to oscillator 14 includes inductance coil 14' to which resonant long line 18 is coupled. In the line there are produced, dependent upon its physical length, standing waves which act to pull oscillator 14 into step therewith. Similar remarks apply to oscillator tube 16 and resonant long line 20 coupled to inductor 22 in the input circuit thereof. For a more complete description of the action of the resonant long line for frequency control, reference is made to my copending application, Serial Number 400,489, filed October 18, 1929.

If desired regeneration may be accomplished solely through the interelectrode capacities of the tubes, which may be increased by parallel capacity, but I prefer to establish a feed back by means of coil or inductor 24 coupled to the input coils 14', 22 and to the anode circuits of tubes 14, 16 through capacitors 26, 28. The input inductors and feed back coil are closely coupled together whereby the entire system is forced to oscillate at some common frequency which is a compromise or floating frequency intermediate the natural frequencies of the oscillators fixed by the resonant long lines.

Not only are the oscillators coupled together as described, but they are also coupled to coil 30 so that the common frequency of the oscillators follows the frequency of the applied energy. The direct energy or anode potential and anode current is fed from a lead 32 preferably to the mid-point of a transformer 34 arranged in series between the anodes of tubes 14, 16. The translating device 36 is coupled to the secondary of transformer 34.

Accordingly, a variation in the received frequency increases the efficiency of one of the oscillators at the same time that it decreases the efficiency of the other of the oscillators, thereby causing an effective pushpull operation, with respect to the supplied direct anode energy, whereby the translating device 36 becomes responsive to the differential of the anode currents of the two oscillators.

It is not essential that the oscillators be combined into a single oscillator of floating frequency, for, coils 14' and 22 need not be so closely coupled that the oscillators oscillate; but they may be separated or arranged so together that the two oscillators oscillate independently of each other. In that case, however, coil 30 should be coupled to both coils 22, 14' so that each oscillator is varied in frequency independently by the input energy.

Figure 2 indicates a receiving system similar to that disclosed in Figure 1 utilizing aperiodic long lines for frequency control of the oscillators. This type of line is more fully described in the copending application of James L. Finch and James W. Conklin, Serial Number 363,660, filed May 16, 1929.

In the arrangement shown in Figure 2, electron emission tube oscillators 40, 42 are preferably of the screen grid tube type and have a common tuned input circuit 44 which, for the convenience of coupling, is formed of a capacitor 46 paralleled by two separate inductors 48, 50. Feed back from the output side of tube 40 occurs through tuned circuit 52 tuned approximately to a frequency slightly higher than the frequency of the highest frequency applied to the input of the tubes, from antenna system 2 and receiving apparatus 54 which may be an amplifier or an amplifier and limiter, or, the arrangement shown in Figure 1, namely, amplifying, limiting and heterodyning means, through inductors 56, 58 coupled to the tuned input circuit 44 of the oscillators.

Long line 60 coupling the output and input circuits of oscillator 40 is made an odd number of half wave lengths long, the wave length taken being that corresponding to the frequency lying on one side of the band of frequencies at which it is desired oscillator 40 to oscillate. Similar remarks are applicable with reference to aperiodic long line 62 and tuned circuit 64 which, however, are adjusted for the opposite extreme frequency or beyond the lower extreme frequency of the band received.

By virtue of the coupling to the common input circuit 44 which is tuned to some intermediate frequency, the entire system including oscillators 40, 42 oscillates at some common floating intermediate frequency and, adjustments are made so that the energies supplied by each oscillator are so well balanced that a very small additional amount of energy can

modify their resultant frequency to any frequency within the band supplied by inductors 56, 58. Consequently, wobbling in frequency of currents applied by inductors 56, 58 to the tuned input circuit 44 causes wobbling of the frequency of the system as a whole, which because of differential variations in the efficiency and consumed plate currents of each of electron discharge device 40, 42, causes differential variations in plate current through output transformer 66 at a frequency corresponding to the modulation frequency of the energy collected by antenna 2.

The useful output appearing in the secondary of transformer 66 is amplified by any suitable relatively low frequency amplifier 68 and translated by any suitable translating device such as phones 70.

In order to suitably bias the control electrodes of the oscillators, a condenser 72 and grid leak resistance 74 are provided. In order to insure aperiodic transfer of energy from the output circuit to the input circuit of the oscillators, the impedance included between the tapping points on the input circuit 44 and ground should be made equal to the characteristic or surge impedance of lines 60, 62. Long lines having a considerable energy attenuation allow less perfect matching of their terminal impedance without influencing their action in the circuit. Moreover, to preclude transfer of energy through the interelectrode capacity of the tubes 40, 42, screen grids are provided which are suitably biased by a proper choice of resistance 76 in series with them and the anode lead 78 supplying the system with direct anode energy. Of course, shielding is used between the grid and anode circuits to prevent regeneration other than through the long lines.

It is not necessary that the symmetrical arrangements of tubes shown in Figures 1 and 2 be employed although that arrangement is preferable. That is, a single tube oscillator having a natural frequency fixed to one side of a received band of frequencies, could be used, the indicating signal energy being caused to act upon the oscillator in such a fashion as to change its fixed frequency; thereby causing changes in efficiency of the oscillator with accompanying changes in consumption of direct energy supplied thereto.

In addition, cascade oscillators may be used which, in the case of Figure 2, for example, the long lines would be made an even number of half wave lengths long in the event that each oscillator consisted of an even number of cascaded tubes. The reason for this change in length of line is more fully described in the copending application of James L. Finch and James W. Conklin, already alluded to.

It is also possible, according to this invention, and may be desirable to so adjust the regeneration; by proper choice of values for the electrical elements involved, that no oscillations take place until the energy of the incoming signal is added.

Having thus described my invention, what I claim is:

1. A system for detecting frequency modulated waves comprising a pair of electron discharge devices each having an anode a cathode and a control electrode, a reactance connected between the control electrode and cathode of each of said electron discharge devices, a transmission line, long relative to a desired operating wave length, coupled to one of said reactances for causing one of said electron discharge devices to operate at a frequency to one side of a mean desired operating frequency, another long transmission line, long relative to a desired operating wave length, coupled to said other reactance for causing said other electron discharge device to operate at a frequency on the other side of said desired mean operating frequency, means for coupling said electron discharge devices together whereby said electron discharge devices operate at said mean operating frequency, and means for applying frequency modulated energy to electrodes of said devices for rendering said devices relatively more or less conductive in accordance with the frequency of said frequency modulated energy.

2. In apparatus of the character described, a pair of electron discharge devices each having an anode a cathode and a control electrode, an inductance coil connected between the cathode and control electrode of each of said electron discharge devices, a transmission line, long relative to a desired operating wave length, inductively coupled to one of said inductances and tending to cause said electron discharge device to oscillate at a frequency to one side of a mean operating frequency, another transmission line long relative to a desired operating wave length coupled to the other of said inductances and tending to cause said other electron discharge device to oscillate at a frequency on the other side of said mean frequency, means for coupling said inductances together whereby said devices operate at said mean frequency, and means for feeding frequency modulated energy to said devices for varying the mean operating frequency of said electron discharge devices.

3. In apparatus of the character described, a pair of electron discharge devices each having an anode a cathode and a control electrode, a tunable circuit tuned to one side of a mean operating frequency connected to the anode and cathode of one of said devices, a tunable circuit tuned to the other side of said mean operating frequency connected between the anode and cathode of the other of said devices, a common tunable circuit connected between the control electrodes and cathodes of said devices, a long transmission line, long relative to a desired operating wave length, coupling one of said tunable circuits to said common input circuit, another transmission line long relative to a desired operating wave length and coupling said other tunable output circuit to said common tunable circuit, a source of frequency modulated energy, and means for coupling said source to said common tunable input circuit, said transmission lines tending to cause said tubes to operate at frequencies corresponding to the tuning of said circuits connected between said anodes and cathodes, said common tunable input circuit causing said devices to operate at a mean intermediate frequency, and said source coupled to said common tunable input circuit varying the mean operating frequency of said devices in accordance with frequency of the energy applied to said tunable input circuit from said source of frequency modulated energy.

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