

Nov. 30, 1948.

D. G. C. LUCK
FREQUENCY MODULATION

2,454,933

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2 Sheets-Sheet 1

Fig. 1.

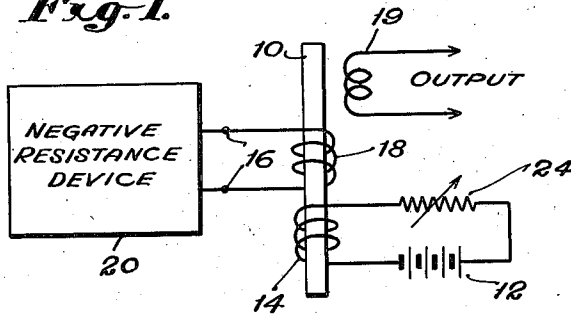
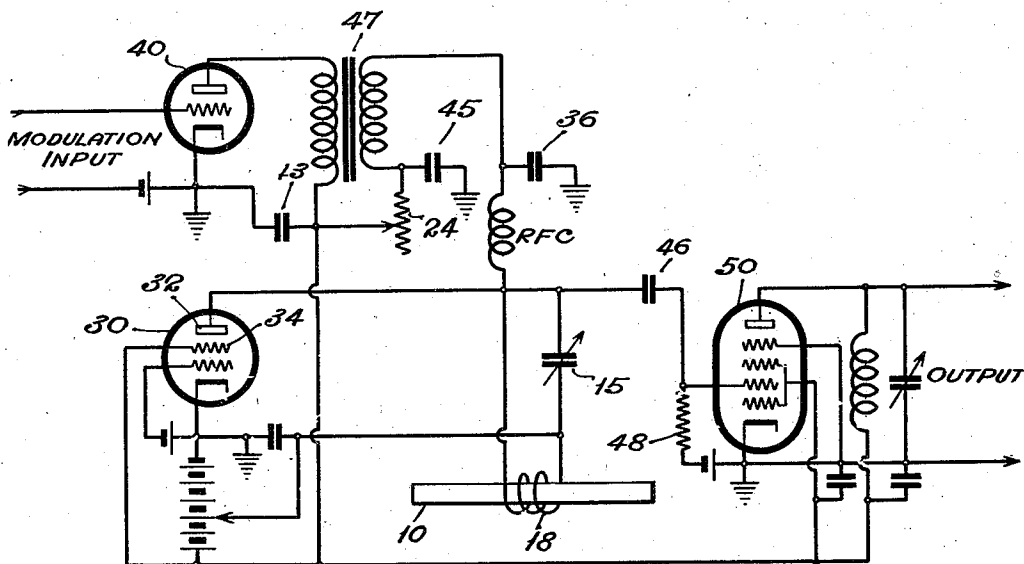


Fig. 2.



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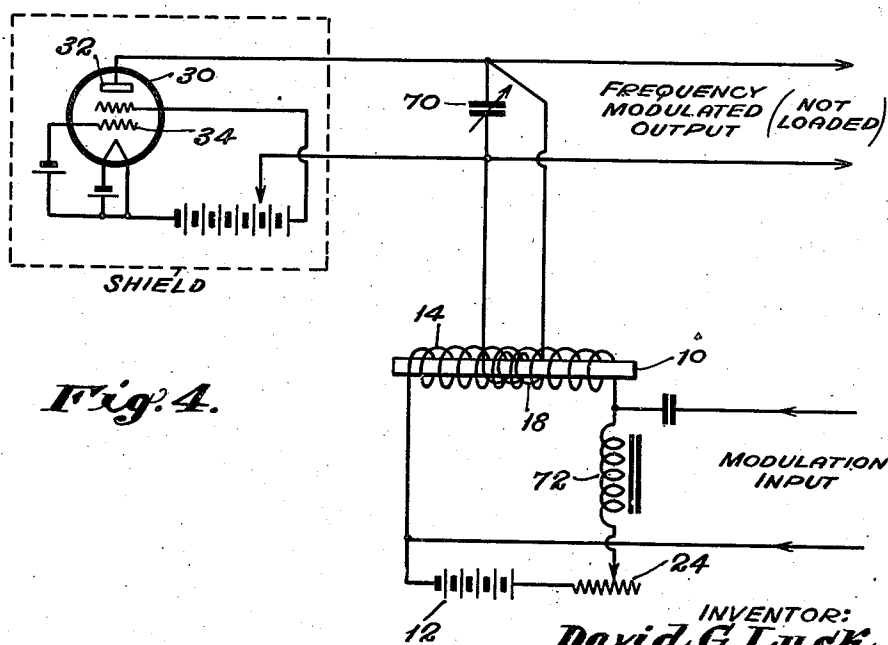
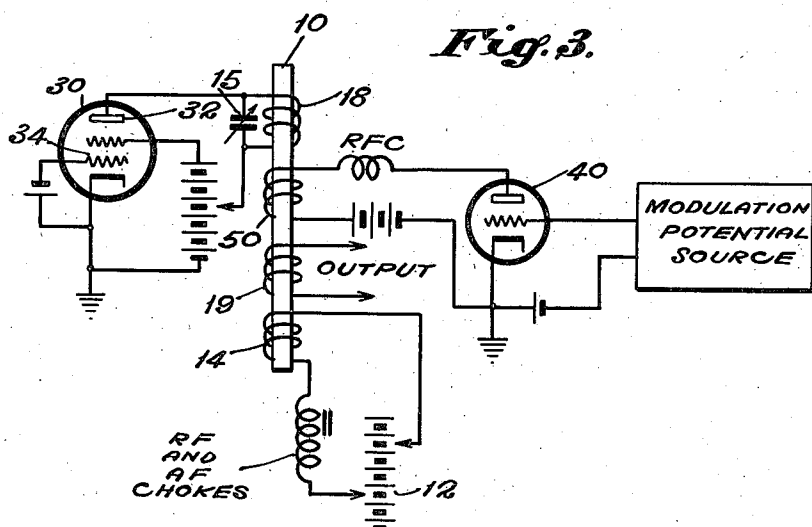
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FREQUENCY MODULATION

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11 Claims. (Cl. 179—171.5)

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This application discloses a new and improved means for producing frequency modulation of a carrier of stable frequency.

In my improved system I modulate the wave length of oscillations generated by an oscillation generator of the type in which the frequency of oscillations produced is controlled by means of a magnetostrictive body. To do so I supply a polarizing force to the magnetostrictive element which varies in accordance with signal variations to thereby vary the period of vibration of the said element and as a consequence the frequency of the oscillations generated.

The signals may be of any type providing their highest frequency does not exceed the frequency of the generated carrier in turn limited by self-resonances of magnetizing windings on the magnetostrictive body.

In describing the invention reference is made to frequency modulation of the oscillations. The modulations may be as to frequency-or-phase or variations of either or both depending on the treatment of the modulation before it is used to modulate the generated oscillations. The term instantaneous frequency modulation is used to cover these various types of modulation.

Various forms of my invention are illustrated in the drawings wherein Figure 1 is a simplified showing of a magnetostriction generator with connections for varying the frequency of the generated wave. Figures 2, 3 and 4 are more complete showings of the arrangement of Figure 1 and modifications thereof.

If an element 10 having magnetostrictive properties (polarized permanently by a source 12 connected with windings 14) is vibrated mechanically it will feed voltage to leads 16 connected with windings 18 also associated with the magnetostrictive member 10. These voltages will be of a frequency determined by the elasticity and the dimensions of the element 10. If the generated oscillations are fed into a negative conductance or resistance device 20 sustained oscillations are generated in the device 20 and winding 18 due to the fact that the negative resistance device 20 feeds power back to the winding 18 to drive the element 10 at its natural frequency.

By properly arranging the mechanical resonator system a very stable oscillation generator is obtained.

The magnetic field strength influences the frequency at which the magnetostrictive oscillator operates and I make use of this property to modulate the frequency of the generated oscillations.

I vary the voltage in the polarizing winding 14

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by control means such as a variable resistance 24 to thereby vary the polarization of the magnetostrictive element 10 and correspondingly vary the period of the oscillations generated. Since the polarizing field of the winding 14 varies in direct proportion to the current therein producing it the system is well suited to the production of oscillations the frequency of which is modulated by varying the current in the field producing winding. The frequency deviation possible is limited because the oscillator is highly stabilized. However, since the oscillator is stable the modulated oscillations can be multiplied to increase the deviation the desired extent. If the oscillator was of an unstable type such multiplication could not be used.

The negative conductance device may, as illustrated in Figure 2, comprise a tube 30 having an anode 32 operating at less potential than its screen grid 34 to obtain the dynatron or negative resistance effect. The plate direct current circuit is completed to source 11 by the winding 18. A tuning condenser 15 shunts the winding 18 and the plate impedance of the negative resistance driver tube 30. This tuning condenser is necessary for efficient loading of the negative resistance driver tube 30.

The winding 18 is also included in a direct current polarizing circuit including the choke RFC, the secondary winding of modulation transformer 47, adjustable resistor 24 and source 11. Condenser 36 outside (with respect to the generating circuit) the radio choke RFC by-passes residual radio frequency around the modulator including the secondary winding of transformer 47.

The modulator tube 40 has its input excited by modulation currents and its anode connected through the primary winding of transformer 47 and source 11 to its cathode. The source 11 is shunted by modulation frequency by-pass condenser 43. As stated above the secondary winding of transformer 47 is in the polarizing circuit of winding 18 and modulation frequency by-pass condenser 45 passes the modulation around the polarizing source 11. An impedance matching transformer is used at 47 to properly load the modulator tube 40.

The generated and timing modulated carrier is fed by coupling condenser 46 and bias impedance 48 to an amplifier stage tube 50 the anode of which supplies the output to additional stages such as frequency dividers or heterodyne frequency changers to lower its frequency or to frequency multipliers or heterodyne frequency changers to increase its frequency.

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In this modification it will be noted that the single winding 18 serves to produce the polarizing field, modulate the same and supply the output, whereas in Figure 1 separate windings performed these functions.

In operation the source 11 and winding 18 polarize element 10 to a point giving best compromise between modulation capability and operating efficiency. The field producing current is modulated by tube 40 to vary the field in accordance with the modulation. Negative conductance tube 30 and winding 18 operate to maintain the element 10 in oscillation at its natural frequency but modified some by the field variations. The modulation source is prevented from unduly loading the bar by the choke RFC and the output is so arranged so that it does not load the system. The dimensions of winding 18 are suitable to the generated frequency and for producing the polarizing field and varying the same in accordance with the control potentials. The generated oscillations are modulated as to timing in accordance with the current fed to the input of tube 40.

In the modification of Figure 3 a separate winding 50 is provided for modulation of the polarization of the magnetostrictive element 10 and the direct current for the tube 40 is permitted to flow in this winding. The direct plate current of tube 30 also flows in winding 18. An advantage obtained by use of the separate windings is that each coil may be constructed and arranged for optimum operation. The high frequency coils should be concentrated on regions of maximum oscillating strain of the magnetostrictive bar 10 and should be magnetically snug on the bar (but not touching mechanically). The low frequency coil geometry is less important.

In Figure 3 the battery 12 and winding 14 polarize rod 10 to a point giving best compromise between modulation capability and operating efficiency, the chokes preventing this circuit from loading down others coupled to it. The modulating tube 40 and winding 50 swing the polarizing field in accordance with the output of the modulating source. Coil 18 and negative transconductance device ("dynatron" or "transitron") 30 enable energy from the plate battery to maintain bar 10 in oscillation at its own natural resonant frequency, by virtue of the coupling provided by the magnetostrictive properties of the bar. The output coil 19 permits utilization of flux variations in the bar, but the utilization circuit must not load the bar markedly or oscillation may stop. When flux change due to changing strain in the magnetostrictive bar 10 induces voltage in coil 18, the function of device 30 is to produce current in coil 18 tending to aid the original flux change. The non-linearity of device 30 limits swings so produced, permitting oscillation.

In the modification of Figure 4 the winding 18 is shunted by a tuning condenser 70 which with the winding 18 provides a circuit tuned substantially to the mean frequency of operation of the generator. The output is supplied by connections across this tuned circuit and the output circuits are such that they do not load the generator and prevent operation thereof due to damping.

Modulation is supplied across a modulation reactor 72 in series with winding 14 and source 12.

The operation of this modification is essentially as described hereinbefore.

In the arrangements of Figures 1, 2, 3, and 4 timing modulated voltages for external use are derived inductively from the rod, either directly through winding 18 or through a separate cou-

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pling coil 19 as shown, but they may instead be derived from an impedance inserted in the lead to an electrode in tube 30, so long as this impedance can be prevented from spoiling the operation of the negative transconductance.

In the prior figures an oscillation generator of the negative resistance or dynatron type has been shown and a single winding 18 is connected with this negative resistance tube 30. It will be understood, however, that I may make use of an oscillation generator of the regenerative type in which case there is a grid winding on the element 10 as well as a plate winding 18. The generated voltage polarity is such with respect to the windings and element 10 that the grid winding is excited by change in the flux caused by physical disturbance of the element 10 and this results in variable current in the plate winding to further stimulate the element to alter its dimensions. This distortion acts through the element and flux to further excite the grid and thus to develop sustained oscillations.

I claim:

1. In a system of the class described, an element having magnetostrictive properties, a direct current polarizing circuit therefor, a tube generator having electrodes coupled to a winding the magnetic field of which includes said element, the arrangement being such that said element vibrates at a frequency determined in part by the polarizing direct current intensity and vibration of said element applies voltages to the said tube electrodes and the tube feeds power back to said winding to develop in the arrangement oscillations of substantially fixed frequency, and a source of modulating current coupled to a winding the magnetic field of which is cut by said element for varying the polarization thereof and correspondingly varying the frequency of the oscillations generated.

2. In a modulation system, an element having magnetostrictive properties, a tube having electrodes, a source of modulation currents, a circuit coupled to said source so that modulation current flows in said circuit, a winding for producing a magnetic field cut by said element for polarizing said element, a source of direct current, connections including said winding, said first mentioned circuit and said source of direct current in series, and other connections coupling said winding to electrodes of said tube, whereby frequency modulated oscillations are produced in said system.

3. In a modulation system, an element having magnetostrictive properties, a direct current polarizing circuit therefor including a magnetic field producing winding and a source of direct current in series therewith, a modulation potential impedance in series in said circuit, means for applying modulating potentials to said impedance, an electron discharge device having output electrodes, a second winding the magnetic field of which is cut by said element, means coupling said second winding with the output electrodes of said device, and an output circuit coupled with said last mentioned winding.

4. In a system as described, a magnetostrictive vibrator, a field winding in a circuit including a source of current for producing a magnetic field wherein said vibrator is located, an oscillation generator circuit the frequency of operation of which is controlled by said magnetostrictive vibrator located in said magnetic field produced by current in said field winding, a variable impedance effectively in the path of said current, and a source of control potentials associated with

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said impedance for varying the strength of the current in said field winding in accordance with said control potentials and correspondingly varying the instantaneous frequency of the oscillations generated.

5. In a system as described, an oscillation generator comprising a tube having electrodes in an oscillation generating circuit, a magnetostrictive element in a polarizing field, at least one winding having a magnetic field cut by said element, means coupling said winding to the tube electrodes to include said winding in the oscillation generating circuit to determine its frequency of operation, means for producing said polarizing field including a source of direct current, and means in series with said source for varying the strength of said polarizing field in accordance with signals to correspondingly vary the frequency of operation of said generator.

6. In a system as described, a resonant magnetostrictive element, a field winding, a source of direct current, connections including said field winding and direct current source in a circuit for producing a polarizing field wherein said element is located, an oscillation generator the frequency of operation of which is controlled by said resonant magnetostrictive element, a variable impedance in said direct current circuit, and a source of signal currents associated with said impedance for varying the current in said direct current circuit and the polarization of said element in accordance with said signal currents to correspondingly vary the frequency of operation of said generator.

7. In a system of the nature described, an oscillation generator circuit the frequency of operation of which is controlled by a resonant magnetostrictive element in a uni-directional magnetic field formed by a winding on said element, said winding being included in said first circuit and connected to a source of direct current and an impedance, on which signal voltages are applied, connected to said direct current source to vary the current flow in said winding and modulate the strength of said field in accordance with signals.

8. In a system of the nature described, a magnetostrictive element included in the magnetic field of a first winding in a circuit with a negative conductance, a second winding connected to a source of direct current for producing a magnetic field in which said element is located, an impedance in series with said last winding, and means for impressing modulating potentials on said impedance for modulating the direct current in said last winding to correspondingly vary said field in accordance with modulating potentials.

9. In a system of the nature described, an oscillation generator circuit of controllable frequency comprising a tube having electrodes, an element having magnetostrictive properties lo-

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cated within the magnetic field of a first winding coupled to electrodes of said tube to determine the frequency of operation of said generator circuit, a magnetic field producing winding on said element, a source of direct current connected to said field winding for producing a magnetic field in which the element is located and an impedance connected with said field winding for modulating the direct current therethrough in accordance with modulating potentials.

10. In a system of the nature described, a tube having electrodes, an element having magnetostrictive properties, at least one winding magnetically coupled to said element and electrically coupled to said tube electrodes, a magnetic field producing winding arranged to produce a magnetic field cut by said element, a source of direct current connected to said field producing winding, a third winding whose magnetic field is cut by said element, a source of potentials representing signals, and connections from said source of potentials to said third winding for causing current characteristic of said signals to flow in said third winding.

11. In a system of the nature described, an element having magnetostrictive properties located in the magnetic field of a first winding, means connecting said first winding in circuit with a negative resistance, a second winding for producing a magnetic field cut by said element, a source of direct current connected to said second winding, a third winding for producing a magnetic field cut by said element, a source of potentials representing signals, and connections from said last source to said third winding for causing current characteristic of said signals to flow in said third winding.

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