Aug. 16, 1927. 1,639,045

W. A. MARRISON

HARMONIC FREQUENCY PRODUCER

Filed May 3, 1923 2 Sheets-Sheet 1

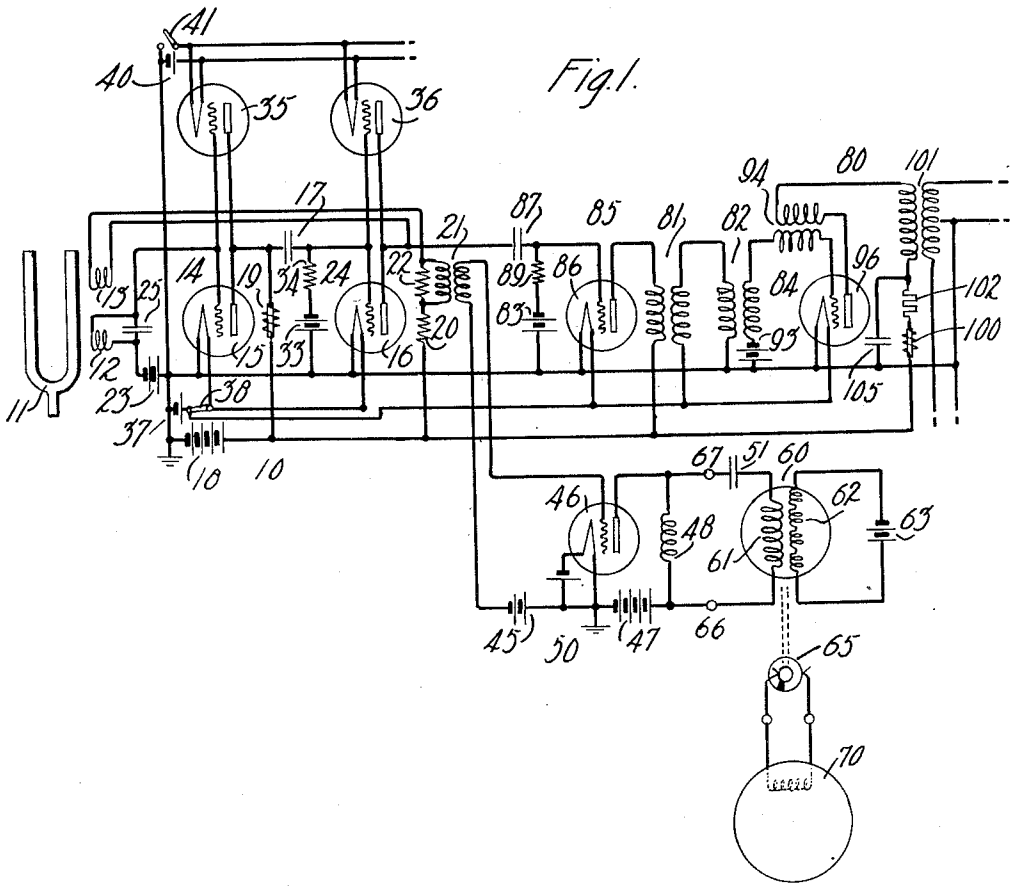


Fig. 1.

Inventor:
Warren A. Marrison
by W. W. Griggs Atty.

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Fig. 2.

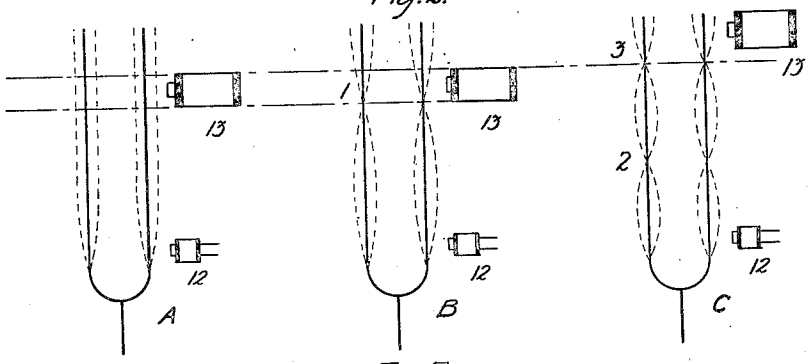


Fig. 3

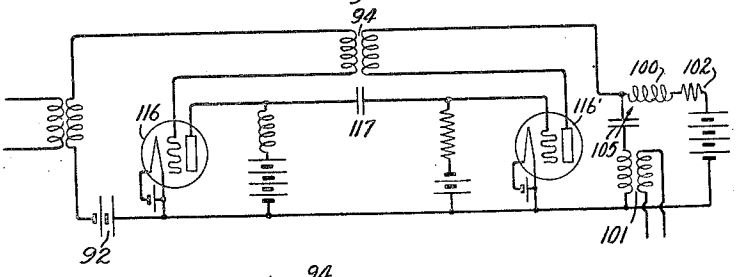


Fig. 4

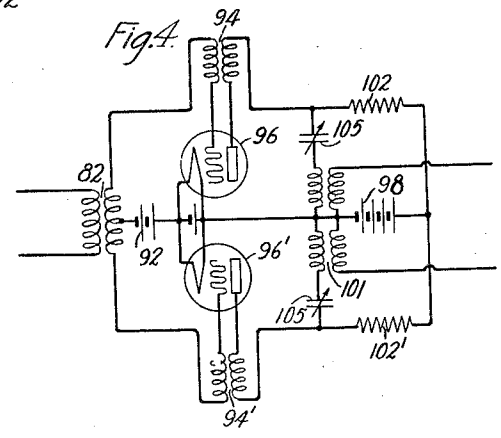
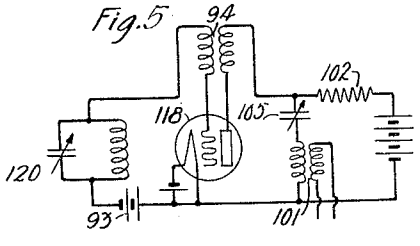


Fig. 5



Inventor
Warren A. Marrison,
by E. W. Griggs
Atty.

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UNITED STATES PATENT OFFICE.

WARREN A. MARRISON, OF BLOOMFIELD, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

HARMONIC FREQUENCY PRODUCER.

Application filed May 3, 1923. Serial No. 636,364.

This invention relates to a source of waves of constant frequency.

The art of electrical communication has at its disposal such a wide variety of methods for the transmission of intelligence that it now employs alternating currents having frequencies which cover the entire range between a few cycles per second and several million. Refinements in these methods have reached a point where it is imperative that determinations of the frequency of any of these alternating currents may be made with an accuracy considerably higher than has been possible hitherto.

For example, in the field of radio broadcasting, it has already become necessary to establish a carefully planned assignment of wave-lengths for the many stations now operating throughout the country. Great care must be exercised in maintaining these stations at their allotted frequency in order that the general scheme may be effective in preventing undue interference.

Recently introduced methods for multiplex telephony and telegraphy by means of carrier currents over wires have placed exceedingly rigorous limits on the frequency adjustment of certain types of apparatus. It is sometimes necessary to hold such circuits as oscillators and filters to within 0.1 percent of a given value under commercial operating conditions. It is, therefore, apparent that the calibrating devices used in the manufacture and maintenance of such circuits must be reliable to 0.01 percent and that the primary standard should be good to 0.001 percent.

An object of this invention relates to the provision of means under the control of a mechanically vibrating device whereby single frequency electrical oscillations may be generated and measured and from which harmonics of a higher order may be produced.

A feature of this invention concerns the arrangement of a tuning fork oscillator, whereby the tuning fork may be maintained in uniform and constant vibration, in its fundamental mode, and whereby said tuning fork may be made to control the generation of electrical oscillations.

Another feature of this invention concerns the provision of means associated with a tuning fork oscillator whereby vacuum tubes forming a portion of the oscillating circuit may be replaced without substantial variation in the characteristics or phase of the electrical oscillations.

Another feature relates to a harmonic producer in which waves of a plurality of frequencies that are integral multiples of a fundamental frequency are derived therefrom by the periodic discharge of a condenser energized by a battery connected thereto through a high resistance, said discharge taking place in the plate circuit of a three element vacuum tube having the single frequency oscillations applied to its input circuit.

Considered broadly, this invention comprises mechanically vibrating means controlling the frequency of electrical oscillations generated in a vacuum tube device whereby electrical energy of a constant fundamental frequency without harmonics is obtained. This energy is supplied to an amplifier in which it is augmented by a local source of energy and caused to produce synchronous motion in an electro-mechanical device, for example a clock whereby the constancy of the frequency of the waves generated may be determined or the device calibrated as an independent time integrating means. In addition, the fundamental frequency energy may be utilized to derive energy having a plurality of frequencies which are integral multiples thereof, and which may be practically utilized for comparison with commercial frequencies higher than the fundamental.

In order that a more comprehensive understanding of the nature of this invention may be obtained, reference should be made to the following detailed description considered in connection with the drawings in which Fig. 1 is a schematic circuit, illustrating in detail one form of the invention. Fig. 2 is a diagram which illustrates the principle used in adjusting the tuning fork oscillator. Figs. 3, 4 and 5 show alternative forms of the harmonic producer circuit.

Referring to Fig. 1, a tuning fork oscillator 10 comprises a tuning fork 11 positioned adjacent to electromagnets 12 and 13 connected respectively to the input circuit of vacuum tube 15 and the output circuit of vacuum tube 16. The output circuit of vacuum tube 15 is connected to the input circuit of the vacuum tube 16 by way of condenser 17. The output circuit of tube 15 is

supplied with energy from battery 18 through series impedance 19. The output circuit of tube 16 is also supplied with energy from battery 18 through resistance 20, the primary of transformer 21 and resistance 22 in parallel and winding of electromagnet 13.

Electromagnet 12 is connected in series with the polarizing battery 23 to the input circuit 14 of vacuum tube 15 and is shunted by a low capacity condenser 25. Input circuit 24 of vacuum tube 16 is polarized by battery 33 in series with resistance 34.

Reserve electron tubes 35 and 36 have their plate and grid electrodes connected respectively to the plate and grid electrodes of tubes 15 and 16. A battery 37 in series with switch 38 supplies energy for heating the filaments of tubes 15 and 16. Battery 40 may supply current for heating the filaments of tubes 35 and 36 by way of switch 41. Tubes 35 and 36 may be substituted for tubes 15 and 16 without affecting the character of the oscillations generated in the tuning fork oscillator by first closing switch 41 and subsequently opening switch 38.

The substitution of tubes 35 and 36 for tubes 15 and 16 is required when one or both of the latter tubes deteriorate or when the batteries associated therewith require to be changed.

An amplifier 50 comprises a space discharge tube 46 which is supplied with waves from the secondary of transformer 21 which is connected in series with a grid polarizing battery 45 in the input circuit of tube 46. The output circuit of tube 46 is supplied with direct current energy from battery 47 through impedance coil 48, and alternating current energy is supplied from the output circuit of vacuum tube 46 to the synchronous motor 60, by leads connected to the terminals of coil 48 at points 66 and 67.

Synchronous motor 60 comprises a rotor winding 61 which derives energy from a circuit containing condenser 51 connected across the terminals of coil 48. The stator of the winding 62 of motor 60 is supplied with direct current energy from battery 63. The commutator 65 is driven by motor 60 and has its brushes forming a portion of the circuit of an electromagnetic device 70 which may be, for example, an electric clock.

A harmonic generator 80 derives energy from tuning fork oscillator 10 by way of a second amplifier 85, the input circuit of which is directly connected to the plate and filament of tube 16 by way of condenser 87. Amplifier 85 comprises a three element vacuum tube 86 having its grid electrode polarized by a battery 83 connected in series with resistance 89. The output circuit of amplifier 85 which is connected to the plate electrode of tube 86 is also supplied with energy from battery 18 in series with the primary winding of transformer 81, the secondary of which is connected in series with the primary of transformer 82.

Harmonic generator 80 comprises an input circuit 84 between the grid and filament of tube 96. The input circuit 84 comprises the filament of tube 96, battery 93, secondary winding of transformer 82 and one winding of transformer 94 and grid of tube 96. The output circuit of harmonic generator 80 includes in series the cathode and plate of tube 96 and is supplied with energy from battery 18 in series with impedance coil 100, high resistance 102, primary of transformer 101 and secondary winding of transformer 94. A condenser 105 is connected in shunt about resistance 102, impedance 100 and battery 18. Energy may be derived from the output circuit of harmonic producer 80 through the secondary winding of transformer 101.

In the operation of this system, tuning fork 11 is set into vibration in any desired manner and continues in vibration under the action of driving magnet 13. The vibration of the tuning fork 11 causes the reluctance of the magnetic path of receiver magnet 12 to be varied. This variation introduces a variation in the potential applied to the grid of vacuum tube 15. Condenser 25 is connected in shunt to the winding of electromagnet 12 to compensate for small phase displacement in the remainder of the system. The capacity of condenser 25 should be of such value that the circuit formed by coil 12 and condenser 25 will not be resonant at a frequency in the neighborhood of that of the tuning fork 11. This varying potential results in the production of a similar variation in the current in the output circuit of tube 15. A consequent variation in the potential across the input electrodes of tube 16 is produced whereby the output current in the plate circuit of tube 16, which includes the winding of magnet 13, undergoes a corresponding variation.

It will be evident from a consideration of Fig. 2 that by varying the position of magnet 13 with respect to the prongs of tuning fork 11 and by varying the phase relation between the current in receiver 12 and in magnet 13, the mode of vibration of tuning fork 11 may be altered. Tuning fork 11 may be caused to vibrate in its fundamental mode only as indicated in A, Fig. 2, or may be caused to vibrate in other modes such as indicated at B and C, Fig. 2. According to this invention the position of magnet 13 is preferably so adjusted with respect to the prongs of tuning fork 11 and the phase of the current in its winding likewise so adjusted with respect to the current in the receiver magnet 12, that the tuning fork 11 will be caused to vibrate in its fundamental mode only, that is, without the production of extraneous vibrations.

Diagram A of Fig. 2 shows the normal mode and the arrangement of the control and driving magnets respectively at 12 and 13. By proper connection the electrical input to the fork at 13 may be made to be in phase with the energy picked up at 12, thereby maintaining the fork in vibration. It will be observed from the diagram B, Fig. 2, that a reversal in the connection of the coils would cause the fork to be vibrated in its second mode. Again, from diagram C, Fig. 2, it will be observed that, if the driving magnet is above the node 3, the amplifier must produce no phase change if the fork is to be driven in its third mode, whereas, if the magnet is between nodes 2 and 3 the phase must be reversed. In diagram A, the driving magnet is shown positioned between node 1 of the second mode and the node 3 of the third mode. In this position there is little tendency for the fork to vibrate in these modes, that is, to produce these overtones when the phase is correct for the fundamental since for such overtones the driving coil 13 applies force close to the nodal point and hence is ineffective to producing motion.

The tuning fork 11 is the only resonant element and the frequency of the vibrations in the output current of tube 16 is controlled entirely by the vibration of the tuning fork. In order that constant frequency energy may be supplied from the tuning fork oscillator without reaction from the load circuits tending to cause a change in the frequency of vibrations, tubes 86 and 46 are provided. The input circuit of tube 46 is coupled to the output circuit of the tuning fork oscillator by transformer 21. The input circuit of tube 86 is connected to the output circuit of the tuning fork oscillator by a direct capacity coupling. Constant frequency oscillations from the tuning fork oscillator are consequently transmitted to amplifier 50 and from it to the rotor winding 61 of synchronous motor 60. A direct current is supplied to the stator winding 62 by battery 63.

The commutator or interrupter 65 is driven by the shaft of synchronous motor 60 and may serve to interrupt the circuit of the electric clock 70 or similar mechanism which may be utilized as an indicator of time intervals. Amplifier 85 supplies constant frequency oscillations to harmonic generator 80 through transformers 81 and 82.

In harmonic generator 80, the coupling between the windings of transformer 94 is so arranged that when current in the output circuit tube 96 is increasing, a voltage is produced, in the secondary winding of transformer 94, that increasingly tends to make the grid less negative or more positive. The battery 93 which may be adapted to supply from 4.5 to 20 volts is provided in the grid circuit to furnish a sufficient negative potential to prevent a flow of current in the plate circuit under conditions when no varying current is supplied to the input circuit by transformer 82.

Resistance 102 is provided of such value as to permit condenser 105 to be charged during one cycle of the input wave. This resistance may be variable from 1000 to 10000 ohms.

Normally, no currrnt is flowing in the plate circuit and so condenser 105, which may have a capacity from .01 to .001 microfarads, is charged through the high resistance 102 to the potential of the battery 18. When the input wave becomes sufficiently positive the potential impressed upon the grid becomes so positive that plate current flows. This action takes place suddenly. The increased current flowing through the winding of the transformer 94 serves to further increase the positive potential impressed upon the grid and hence causes more plate current to flow. This action is cumulative so that the charge which has been stored in the condenser 105 is suddenly discharged. When the potential between the plates of condenser 105 has fallen to such an extent that the space discharge thru tube 96 cannot be maintained at the amplitude to which it has attained, the decrease in space current causes an electromotive force to be set up in the secondary winding of transformer 94 in such direction as to thereby further reduce the space current in an exceedingly abrupt manner. The values of the resistances 102 and capacity 105 are so chosen that the condenser C becomes charged during the time the grid potential is below the value required to cause a flow of space current.

This process repeats for each cycle of the input wave. Thus at each positive peak of the input wave, we obtain an abrupt discharge of the condenser C giving a wave having a peak very narrow in comparison with the whole cycle. It is well known that such a wave will be made up of a fundamental with a large number of harmonics. Energy of the fundamental and harmonic frequencies may be obtained from the transformer 101 by connection to either pair of leads shown. By means of this invention several hundred harmonics that are integral multiples of the input wave may be obtained.

Fig. 3 shows an alternative form of the harmonic producer 80, wherein an additional vacuum tube 116 is provided, the input circuit of which is coupled to the output circuit of tube 116′ by means of transformer 94. The output circuit of tube 116 is coupled to the input circuit of tube 116′ by a condenser 117. The primary winding of transformer 101 is shown connected in series with condenser 105. The

secondary of transformer 101 has leads from which the fundamental frequency with harmonics may be obtained. The battery 92 in the grid circuit of tube 116 has the same function as battery 93 of harmonic producer 80. The additional tube 116 in this circuit causes a more abrupt discharge of condenser 105 because of the additional amplification obtained.

In Fig. 4, another form of harmonic producer based upon the principle utilized in the harmonic producer 80 is shown, utilizing two electron tubes. Two transformers 94 and 94′ are utilized for coupling the respective output circuits of tubes 96 and 96′ to the input circuits of said tubes. An input transformer 82 is connected in balanced arrangement with the respective input circuits. Transformer 101 is connected in similar manner to the corresponding transformer of Fig. 3. Battery 98 supplies current in common to the plate circuit of tubes 96 and 96′. Series paths each including one of the condensers 105 and 105′ in series with one half of the primary winding of transformer 101 are shunted respectively about the resistance 102 and 102′ and battery 98. The operation of this circuit is identical with that of harmonic producer 80 except that both positive and negative peaks of the input wave are effective to produce sharply peaked waves in the output circuit connected to the secondary of transformer 101.

In Fig. 5 is shown a combination oscillator and harmonic producer utilizing the principle embodied in the harmonic generator 80. By means of a circuit of this kind oscillations of any desired frequency may be generated and harmonics thereof produced in the manner described in connection with harmonic generator 80.

The circuit of Fig. 5 omitting condenser 105 and primary of transformer 101 constitutes a well known form of oscillation generator. The inclusion of condenser 105 and coil 101 causes the circuit to function in a manner similar to that of harmonic generator 80 and thus to produce a peaked wave.

Although this invention has been illustrated and described in connection with certain specific embodiments it is clear that numerous other practical applications may be made. The invention is therefore to be limited only by the scope of the appended claims.

What is claimed is:

1. The combination with a source of electrical oscillations of constant frequency, of a three-electrode space discharge device having an input circuit associated with its grid electrode and an output circuit associated with its plate electrode and a feed back circuit linking said input circuit with said output circuit, and means in said output circuit causing impulsive energy to be fed from said output circuit to said input circuit for producing harmonics.

2. A harmonic generator comprising a space discharge tube, input and output circuits for said tube, means for producing waves in said input circuit, a source of space current for said tube comprising a battery in series with a resistance, and a condenser in direct shunt to said battery and resistance.

3. A harmonic generator comprising a space discharge tube, input and output circuits for said tube, means for coupling said circuits, means for supplying an alternating current wave to said input circuit to control the impedance of the space path of said tube, and means including a source of space current and a condenser in shunt thereto for causing abrupt discharges in said output circuit corresponding to a portion of alternate half cycles of the supplied waves.

4. A harmonic generator comprising a space discharge tube, input and output circuits for said tube, means for producing waves in said input circuit, a path including a source of space current for said tube and a resistance in series therewith, a condenser in shunt to said path, said resistance and condenser being so proportioned that said condenser is completely charged during the time of one-half cycle of the waves in said input circuit.

5. A harmonic producer comprising a space discharge tube having a control electrode, an anode and a cathode, an input circuit connected to said control electrode and cathode, and an output circuit connected to said anode and cathode, said output circuit including a path comprising a source of space current and a resistance in series, and a condenser in shunt to said path, means in said input circuit for supplying waves thereto, and additional means for normally preventing a flow of space current in said tube except during positive half cycles of said waves, said resistance, condenser and space current source being so proportioned as to cause said condenser to discharge through the space path of said tube during each positive half cycle of said waves.

In witness whereof, I hereunto subscribe my name this 2d day of May, A. D. 1923.

WARREN A. MARRISON.