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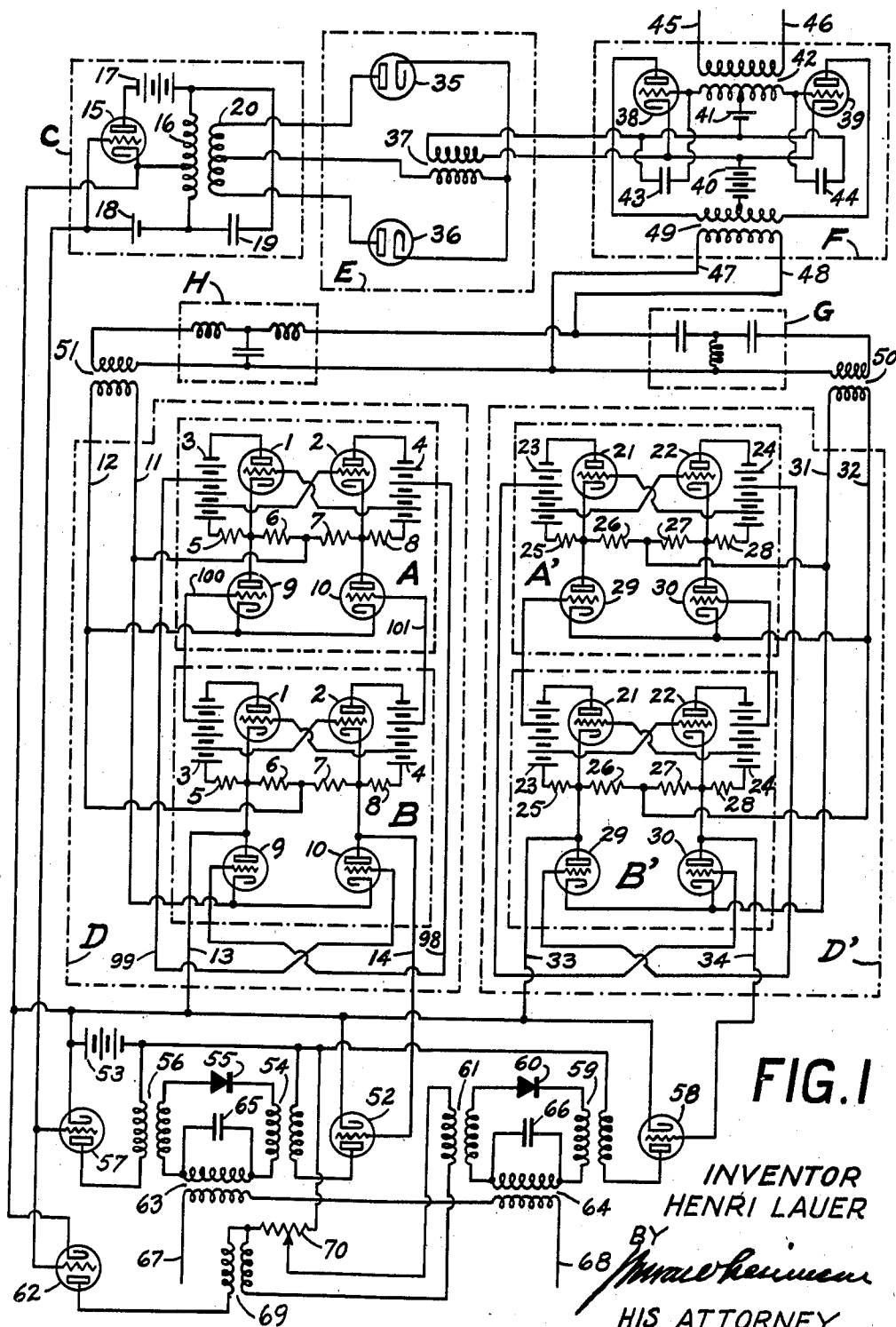
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FREQUENCY DIVIDING SYSTEM FOR ELECTRIC ALTERNATING CURRENTS

Filed June 3, 1942

2 Sheets-Sheet 1



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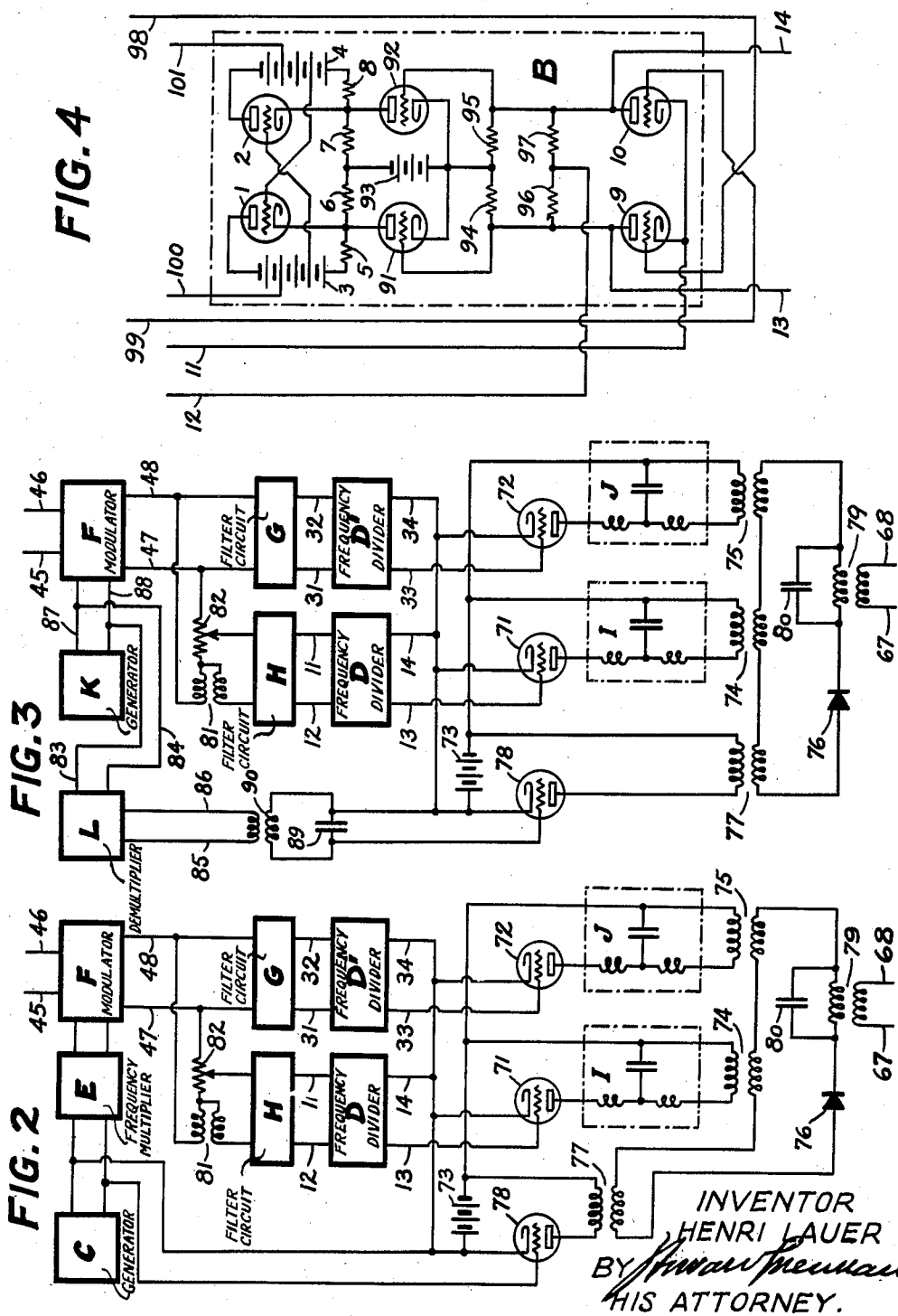
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,331,986

FREQUENCY DIVIDING SYSTEM FOR
ELECTRIC ALTERNATING CURRENTS

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Application June 3, 1942, Serial No. 445,622

12 Claims. (Cl. 250—36)

The present invention relates to a frequency dividing system for electric alternating currents permitting to obtain, from a single phase alternating input voltage, an alternating output voltage of sub-multiple frequency.

This frequency dividing system utilizes the properties of such frequency reducing devices as are described in my United States patent application, Serial Number 369,725 of December 12, 1940, Patent No. 2,305,625, dated Dec. 22, 1942, or of certain other frequency reducing devices of odd or of even frequency transformation ratio. Without therefore limiting the present system to the use of the device disclosed in my said patent application, this system is, however, described in relation therewith, for the convenience of explanation. For greater simplicity of language, this device, as well as other devices which may be used in its place to perform a similar function, is designated here as a frequency divider.

Referring to my aforesaid patent application, when an alternately reversed voltage is applied to the input terminals of the device disclosed therein, a voltage is developed at the output terminals of said device, which reverses alternately at a sub-multiple frequency. If therefore, the applied input voltage reverses once during every cycle, as is the case, in particular, when this input voltage is of sinusoidal wave shape, the output voltage has a fundamental frequency which is a sub-multiple of that said input voltage. But if the input alternating voltage is of non-sinusoidal wave shape and, say, has a polarity which reverses several times during every cycle of its fundamental frequency component, the frequency components of the output voltage of the device may or may not be in the same frequency relations to each other as those of the input voltage, depending in particular on the frequency transformation ratio of the device and on the frequency composition of the input voltage. In other words, the simultaneous frequency division, in a same ratio, of several frequency components of the input voltage is achieved by means of this device for only certain particular frequency, amplitude and phase relations of the input voltage components. And the system described in my said patent application for eliminating or reducing certain harmonics developed by the operation of the device and not present in the original input voltage does not lift this limitation of the field of application of said device.

The object of the system forming the present invention is to permit the frequency division of not only a sinusoidal alternating input voltage,

but also the frequency division, in a same ratio, of two simultaneously applied alternating input voltages of different frequencies and, in particular, of equal or approximately equal amplitudes, irrespective of the relative values of said frequencies, and in certain cases of more than two simultaneously applied alternating input voltages of different frequencies and of suitable relative phases and amplitudes.

In this system, the alternating input voltage, the component frequencies of which are to be divided, is not applied directly to the input terminals of the frequency divider, but is made to modulate an alternating "carrier" current or voltage of higher frequency. The invention then consists, after separating the frequency components of the thus modulated current or voltage into upper or lower side frequency component bands and suppressing the carrier frequency component, in applying the components of the upper side frequency band to the input terminals of a frequency divider as defined above and the components of the lower side frequency band to the input terminals of another frequency divider of equal input-output frequency transformation ratio, demodulating the output voltages of both of these two dividers with a substantially sinusoidal alternating voltage having a frequency which is a sub-multiple of the frequency of the said carrier current in the same ratio as the frequency transformation ratio of the two dividers, and applying the thus demodulated voltages of the two dividers upon a common circuit, in which the low frequency component currents or voltages constitute the output currents or voltages of the frequency dividing system, means being furthermore provided to give such suitable phase relations to said currents or voltages as may be required.

When two frequency dividers of equal ratios are thus differently actuated, and their output voltages demodulated as described, I have found that, save in certain particular instances, the respective resulting demodulated voltages of the two dividers differ from each other in their respective frequency composition, or in the relative amplitudes of their various frequency components, and that the algebraic sum of these voltages, as obtained when they are applied to a common circuit, constitutes a voltage which is a more complete and closer sub-multiple frequency reproduction of the input voltage, than the demodulated output voltage of either divider taken individually.

The invention will be better understood from

the following description, when considered in relation to the accompanying drawings, in which

Figure 1 is a wiring diagram of a frequency halving system according to the present invention, that is to say a frequency dividing system having an input-output frequency ratio of two to one. For simplicity, triode relays are shown in the drawing, but other suitable types of relays may be used in place of these; the filament heating circuits of all electron tubes are omitted, for greater clearness of the drawing; and certain of the tube circuits may be altered to use common energizing and common biasing batteries or voltage sources, as is frequently done in practice.

Figure 2 is a schematic wiring diagram of the system, illustrating a different arrangement of the demodulating circuits.

Figure 3 is a schematic wiring diagram of the system, illustrating a different arrangement of the sources of the carrier frequency alternating voltage and of the sub-multiple frequency sinusoidal alternating voltage.

Figure 4 is a wiring diagram of one of the circuit systems of a frequency divider similar to one of those used in the arrangement of Figure 1, but incorporating an additional amplification stage, as explained further below.

The system illustrated in Figure 1 comprises a generator of substantially sinusoidal alternating voltage, the circuits of which are enclosed in the dot-and-dash line frame C; a frequency multiplier, enclosed within the frame E; a modulator, shown within the frame F; two filter circuits passing respectively the upper and lower side frequency band components of the modulated voltage and shown respectively within the frames G, H; two frequency dividers D and D' of same input-output frequency ratio as the output-input frequency ratio of the frequency multiplier E; and demodulating, phase-adjusting, and output circuits shown in the lower part of the drawing. These various components of the frequency dividing system are briefly described below, before describing the operation of the system.

The circuits enclosed in the frame C represent a generator of alternating voltage of substantially sinusoidal wave shape. In the particular instance illustrated here, this is a usual form of triode oscillator, the triode 15 having its grid and plate electrodes respectively connected to the ends of an inductance 16 and its filament connected to a suitable intermediate point of said inductance. The plate and grid of the triode 15 being given suitable positive and negative potentials, respectively, by means of the batteries 17, 18, and the inductance 16 being shunted by a condenser 19, continuous oscillations are sustained in the circuit formed by the inductance 16 and condenser 19, the frequency of which is a function of the dimensions of said inductance and condenser.

Coupled to the inductance 16 is a coil 20, through which the oscillations generated in the circuit 16-19 energize a frequency multiplier, which is a frequency doubler in the present instance, constituted by the circuits enclosed in the frame E. This comprises two diodes 35, 36 having their filaments connected to each other, and their plate electrodes connected respectively to the ends of the coupling coil 20. A connection is also provided between the filaments and the middle point of the coil 20, which connection includes the primary winding of a transformer 37. As known, under the action of the alternating voltage induced in the coil 20 by the oscillating current flowing in the circuit 16-19, a

pulsating current of double frequency flows in the circuit branch comprising said primary winding of the transformer 37. The alternating voltage induced in the secondary winding of this transformer 37, which thus has a frequency equal to twice the frequency of the alternating current produced by the generator C, constitutes the carrier voltage mentioned in the earlier paragraphs of this specification.

This carrier voltage is impressed upon a modulator, the circuits of which are shown within the frame F. This is a conventional balanced modulator, which comprises two parallel-connected triodes 38, 39, the plate circuits of which are energized by the battery 40, and the grids of which are given a suitable biasing potential by the battery 41. The secondary winding of the transformer 37 is connected in the common branch of the grid circuits of the triodes 38, 39, so that the carrier voltage generated in this secondary winding through the operation of the frequency doubler E produces simultaneous and in-phase variations of the grid potentials of said triodes 38, 39. The grid circuits of these triodes also comprise the secondary winding of a transformer 42, shunted by the usual high frequency by-pass condensers 43, 44, and so connected that an alternating current flowing in the primary winding of said transformer 42 produces oppositely directed alternating voltage variations of the grids of said triodes, which modulate in opposite directions the alternating plate current components of these tubes developed under the action of the carrier voltage. The terminals 45, 46 of the primary winding of the transformer 42 constitute the input terminals of the frequency dividing system, and it is the object of the operation of said system, as described further below, to produce an alternating voltage across its output terminals 67, 68, the largest components of which have frequencies which are respectively sub-multiples (in the present instance one-half) of those of the components of the alternating voltage impressed upon said input terminals 45, 46.

Connected to the secondary terminals 47, 48 of the differential output transformer 49 of the modulator F are two filter circuits G, H, schematically represented as composed of condensers and inductance coils so disposed and connected that the filters G, H, pass respectively the upper and lower side frequency band components of the output voltage of the modulator F, that is to say those frequency components of said output voltage which have respectively greater and smaller frequencies than the carrier voltage produced by the multiplier E. Any other suitable arrangement may of course be used in place of those shown as G, H, for performing the same function. Through these filter circuits G, H, and through transformers 50, 51, the actuating terminals 31, 32 and 11, 12 of two frequency dividers D', D are connected respectively to the output terminals 47, 48 of the modulator F. The divider D' is thus actuated by the upper side frequency band voltage components of the modulated output of the modulator F, while the divider D is actuated by the lower side frequency band voltage components of said modulator output.

The two frequency dividers D, D' shown in the drawing are frequency halving devices, that is to say, they have an input-output frequency transformation ratio of two to one which corresponds to the two to one frequency transformation ratio of the frequency multiplier E. These

frequency dividers are similar to each other, and respectively similar to the frequency halving device illustrated in Figure 1 of the drawing appended to the specification of my aforesaid United States Patent application, in which they are described in detail.

The frequency divider D, the various circuit elements of which are designated by the same numerals from 1 to 12 and letters A and B as in said patent application, includes two circuit systems A and B each of which comprises a reversible apparatus composed of two triodes 1, 2 the plate circuits of which are energized, respectively by a battery 3 in series with a resistance 5, and a battery 4 in series with resistance 8. The cathodes of the two tubes are connected to each other by resistances 6, 7 in series, and the grid electrode of each tube is connected to some suitable point of the plate circuit of the other. Each of the systems A, B also comprise two triodes 9, 10 having their filaments connected together, while their plates are respectively connected to the cathodes of tubes 1 and 2. The grids of tubes 9 and 10 of system A are connected respectively to suitable points of the plate circuits of tubes 1 and 2 of system B, while the grids of tubes 9 and 10 of system B are respectively connected to suitable points of the plate circuits of tubes 2 and 1 of system A. Finally, the input terminals 11, 12 which receive the alternating voltage actuating the divider are connected as follows: terminal 11 is connected to the filaments of tubes 9, 10 of system B and to the common point of resistances 6, 7 of system A, while terminal 12 is connected to the filaments of tubes 9, 10 of system A and to the common point of resistances 6, 7 of system B.

A similar description applies to the frequency divider D', the various respective circuit elements of which are designated in corresponding manner by numerals from 21 to 32 and letters A' and B'. Output connections of the frequency divider D are made, through the wires 13, 14, to the plate electrodes of the tubes 9, 10 of its system B, while output connections of the frequency divider D' are made, through the wires 33, 34, to the plates of the tubes 29, 30 of its system B'.

By means of these connections 13, 14, the output voltage of the frequency divider D is applied between the grid and filament of a coupling triode 52, the plate circuit of which is energized by a battery 53 and comprises the primary winding of a transformer 54. The secondary winding of this transformer 54 is included in a circuit comprising an alternating current rectifier 55. On the other hand, the circuit of this rectifier 55 is coupled, through the transformer 56, to the plate circuit of a triode 57 energized by the battery 53, and the grid circuit of which is actuated by a substantially sinusoidal voltage produced by the generator C. For this purpose, the grid and filament of the tube 57 are connected respectively to the grid and filament of the triode 15.

Similarly, by means of the connections 33, 34, the output voltage of the frequency divider D' is applied between the grid and filament of a coupling triode 58, the plate circuit of which is energized by the battery 53, and comprises the primary winding of a transformer 59. The secondary winding of this transformer 59 is included in a circuit comprising an alternating current rectifier 60. The circuit of this rectifier 60 is also coupled, through a transformer 61, to the plate circuit of a triode 62 energized by the battery 53, and the grid and filament of which are connected

respectively to the grid and filament of the triode 15.

However, for purposes explained later, the connection of the transformer 61 to the plate circuit of the triode 62 is made by way of a phase adjusting device composed, in the example illustrated here, of a transformer 69 and the resistance 70. The primary winding of this transformer 69 and the resistance 70 are connected in series in the plate circuit of the tube 62, while one end of the secondary winding of the transformer 69 is connected to a common point of the resistance 70 and the primary winding of said transformer 69. The other end of the secondary winding of this transformer 69 and some suitable point of the resistance 70 are connected respectively to the ends of the primary winding of the transformer 61. In this manner, the alternating current component developed in the plate circuit of the triode 62 under the action of the alternating grid voltage supplied to this triode by the generator C, induces in the circuit of the rectifier 60, an alternating voltage the phase of which may be adjusted by suitably choosing the connection point of the primary winding of the transformer 61 to the resistance 70, and adjusting the coupling of the two windings of the transformer 69, which windings may for this purpose be made to be movable with respect to each other.

Finally, the circuits of the rectifiers 55 and 60 are coupled to a common circuit through transformers 63, 64 respectively, shunted by high frequency by-pass condensers 65, 66. The terminals 67, 68 of this common circuit constitute the output terminals of the frequency dividing system.

Describing now the operation of the system, when no voltage is applied to the input terminals 45, 46, no alternating voltage is produced at the actuating terminals 11, 12 and 31, 32 of the frequency dividers D, D', and the latter remain in a quiescent operating condition. The only voltage operating in the circuits of the rectifiers 55, 60 is then the alternating voltage of constant maximum amplitude derived, through the tubes 57 and 62 respectively, from the oscillator tube 15. The currents operating in these rectifier circuits hence comprise high frequency components, which are by-passed through the condensers 65, 66, and continuous components of constant intensity, which, in flowing through the primary windings of the transformers 63, 64, induce no voltage in the output circuit 67, 68.

If now an alternating voltage of sinusoidal wave shape is applied to the terminals 45, 46, the operation of the balanced modulator F develops, across the terminals 47, 48, an alternating voltage composed, as known, of two side-frequency components, the frequencies of which are respectively equal to the sum and difference of the carrier frequency and of the frequency of the alternating voltage applied to the terminals 45, 46. These two side frequency voltages being separated by the filter circuits G, H, the lower frequency output voltage component of the modulator F actuates, through the transformer 51, the terminals 11, 12 of the frequency divider D, while the higher frequency output voltage component of the modulator F actuates, through the transformer 50, the terminals 31, 32 of the frequency divider D'.

These frequency dividers D, D' then produce alternating voltages across their respective terminals 13, 14 and 33, 34 which have a much distorted wave shape, but the fundamental fre-

quencies of which are respectively equal to one-half the frequencies of the voltages applied to the terminals 11, 12 and 31, 32.

The voltage thus developed across the terminals 13, 14 is impressed, through the coupling tube 52, and the transformer 54, upon the circuit of the alternating current rectifier 55. Upon this same rectifier circuit is applied the substantially sinusoidal alternating voltage of one-half carrier frequency, supplied by the generator tube 15 through the coupling tube 57 and transformer 56. Alternating currents are then produced in the circuit of the rectifier 55, having frequencies respectively equal to those of the alternating voltages applied to said circuit, and to multiples of these frequencies, and the sums and differences of these frequencies. While the currents of higher frequencies are by-passed through the condenser 65, those of lower frequencies flow through the primary winding of the transformer 63, and induce in the secondary winding of the latter an alternating voltage having a wave shape which depends to some extent, in particular, on the characteristic of the rectifier 55, and a frequency equal to one-half the frequency of the voltage applied to the input terminals 45, 46 of the system.

Similarly, the voltage developed across the terminals 33, 34 of the frequency divider D' is impressed, through the coupling tube 58 and transformer 59, upon the circuit of the alternating current rectifier 60. This same rectifier circuit receives a substantially sinusoidal alternating voltage of one-half carrier frequency from the generator tube 15, through the coupling tube 62 and transformer 61. Here again, a voltage is produced in the secondary winding of the transformer 64, having a frequency equal to one-half the frequency of the voltage applied to the input terminals 45, 46 of the system.

The secondary windings of the transformers 63, 64 being connected in a common circuit, an alternating voltage is then obtained between the terminals 67, 68 of the latter, having a frequency equal to one-half the frequency of the alternating voltage applied to the input terminals 45, 46 and having a wave shape which approaches the sinusoidal wave shape of said applied input voltage, more closely, generally, than the voltages developed in either one of the transformers 63, 64.

This result is obtained, however, when the voltages developed by the two transformers 63, 64 are applied to the common output circuit 67—68 in proper mutual phase relation. Such a phase relation may be obtained by means of the phase adjusting device 69—70, which, in permitting to shift the phase of the voltage derived from the generator C in one of the two rectifier circuits correspondingly shifts the phase of the low frequency voltage developed in this same rectifier circuit, with respect to that developed in the other rectifier circuit. Such a phase shifting arrangement may be placed either between the circuit of the rectifier 60 and the generator C, as shown in the figure, or in similar manner between the circuit of the rectifier 55 and the generator C. Or else, it may be connected as a part of the coupling circuit between the modulator output terminals 47, 48 and the actuating terminals 11, 12 or 13, 32 of either one of the frequency dividers D, D', or as part of the coupling circuit between the output terminals 13, 14 or 33, 34 of one of said dividers D, D' and the circuit of the corresponding rectifier 55 or 60.

Or again, it may be inserted between the output circuit 67—68 and the circuit of either one of the rectifiers 55 or 60.

Supposing now that, instead of being of sinusoidal wave shape, the alternating voltage applied to the input terminals 45, 46 of the frequency halving system of Figure 1 is composed of two sinusoidal components of different frequencies and of substantially equal amplitudes, it is only for certain particular relative frequency values of said components that voltages components having frequencies respectively equal to one-half the frequencies of the two input voltage components are developed at the terminals of one of the two transformers 63, 64. But I have found that, irrespective of the relative frequency values of the two input voltage components of the system, a voltage of frequency equal to one-half the frequency of one of these input voltage components is developed across the secondary winding of the transformer 63, while a voltage of frequency equal to one-half the frequency of the other frequency component of said input voltage is developed across the secondary winding of the transformer 64. These two voltages thus complement each other, and in applying them to the common circuit 67—68, a voltage may then be obtained, comprising components having frequencies respectively equal to one-half the frequencies of the two components of the alternating voltage applied to the input terminals 45, 46, and having a wave shape approaching that of said input voltage, if the phase shifting device 69—70 is properly adjusted.

Similarly, when the input voltage energizing the terminals 45, 46 comprises more than two different frequency components, and depending, to some extent, on the relative frequencies, phases and amplitudes of said components, the voltages developed, respectively, in the transformers 63, 64 are in a measure complementary, and the application of these two voltages to a common circuit 67—68 permits to obtain, more completely than through either one of these, a sub-multiple frequency reproduction of the alternating voltage applied to the input terminals 45, 46.

While the system illustrated in Figure 1 is shown as utilizing two frequency halving devices, the same disposition of its various circuit elements may be used with two frequency dividers D, D' and a frequency multiplier E of other frequency transformation ratios, providing that the input-output frequency ratio of each of the frequency dividers D, D' is equal to the output-input frequency ratio of the frequency multiplier E, said ratios being measured when the devices are operated with applied alternating voltages of sinusoidal wave shape.

The system illustrated by the schematic diagram of Figure 2 is laid out according to the same general arrangement as the system of Figure 1, but with another disposition of the demodulating and output circuits. As in the system of Figure 1, a generator C, producing an alternating voltage of substantially sinusoidal wave shape, actuates a frequency multiplier E which supplies an alternating voltage of carrier frequency, multiple of the frequency of the generator C, to a modulator F. The modulating circuit terminals 45, 46 of this modulator F constitute the input terminals of the system and to these terminals is applied the alternating voltage, the sub-multiple frequency reproduction of which is to be developed across the output termi-

nals 67, 68 of the system. The output terminals 47, 48 of the modulator F are connected, as in Figure 1, to the input terminals 11, 12 and 31, 32 of two frequency dividers D, D' respectively through a filter circuit H passing the low frequency side band output voltages of the modulator F and a filter circuit G passing the high frequency side band output voltages of said modulator. The output terminals 13, 14 and 33, 34 of the frequency dividers are connected respectively between the grid and filament of coupling tubes 71, 72, the plate circuits of which are energized by a battery 73. The plate circuits of these tubes are coupled, through transformers 74, 75, to the circuit of an alternating current rectifier 76. This same rectifier circuit is also coupled, through a transformer 77, to the plate circuit of a triode 78, energized by the battery 73, and the grid circuit of which is actuated by the voltage produced by the generator C. The circuit of the rectifier 76 also comprises a transformer 79 shunted by a high frequency by-pass condenser 80, and the secondary winding terminals 67, 68 of said transformer constitute the output terminals of the system. The system of Figure 2 thus differs from that of Figure 1 in that the output voltages of the two frequency dividers D, D' operate, together with a voltage derived from the generator C, in the circuit of a common rectifier 76, instead of operating in the circuits of separate rectifiers 55, 60 respectively.

Since the voltages developed across the terminals 13, 14 and 33, 34 by the frequency dividers D, D' respectively are of non-sinusoidal wave shape, filter circuits I, J may be inserted between said terminals and the circuit of the rectifier 76, so arranged as to pass the low frequency components of said voltages, and to attenuate such harmonics thereof, particularly the third and higher, as may produce disturbing low frequency components across the output terminals 67, 68 of the system.

Furthermore, in order to permit an adjustment of the phase relations between the output voltage components produced through the operation of one of the two frequency dividers and those produced by that of the other, a phase adjusting device 81—82, which may be similar to the phase adjusting device 69—70 of Figure 1, may be connected between the output terminals 47, 48 of the modulator F and the input terminals 11, 12 or 31, 32 of either one of said dividers, or between the output terminals 13, 14, or 33, 34 of either of said dividers and the circuit of the rectifier 76.

The system illustrated in Figure 3 follows the same general pattern as shown in Figure 2, but with another arrangement of the sources of the carrier voltage energizing the modulator F and the sub-multiple sinusoidal voltage actuating the demodulating rectifier circuit. Corresponding elements of Figures 2 and 3 are therefore designated by the same letters and numerals in both figures.

In the arrangement of Figure 3, the carrier frequency alternating voltage is supplied to the modulator F by a generator K of said frequency, to the output terminals 87, 88 of which it is connected. The sub-multiple frequency voltage actuating the circuit of the rectifier 76 is applied to this circuit by a frequency demultiplier L of same input-output frequency ratio as the frequency dividers D, D', and actuated by the generator K. The demultiplier L may be a frequency divider similar to the frequency divider

ers D, D'. Its input terminals 83, 84 are then connected to the output terminals 87, 88 of the generator K, while its output terminals 85, 86 are connected to the grid circuit of the coupling tube 78. This latter connection is preferably made through a resonator circuit formed, for instance, by a condenser 89 shunted by an inductance coil 90, tuned to the sub-multiple output frequency of the divider L, for the purpose of supplying to the circuit of the rectifiers 76 an alternating voltage of substantially sinusoidal wave shape.

Or else, the frequency demultiplier L may be constituted by a multivibrator, synchronized by the generator K at a suitable multiple frequency, or by a synchronized submultiple frequency tuned oscillator, in which latter case the resonator circuit 89—90 may, in some instances, be dispensed with.

In all of the systems illustrated, the half-wave rectifiers 55, 60, 76 may be replaced by full-wave rectifier arrangements. Moreover, the function of said rectifiers being to develop so-called combination frequency voltages in their respective circuits, proportional to the product of the voltages applied to said circuits, modulating circuit arrangements and devices may be used instead of these rectifiers, through which the sub-multiple frequency sinusoidal voltage supplied by the generator C or demultiplier L is made to modulate the output voltages of the frequency dividers D, D' or vice-versa.

Finally, when the alternating voltage applied to the input terminals 45, 46 of the system comprises several components of different frequencies, the alternating voltages actuating the input terminals 11, 12 and 31, 32 of the frequency dividers undergo wide variations of their maximum amplitudes. The reversible apparatus formed by the tubes 1, 2 and 21, 22 and their associated circuit elements should then preferably be adjusted to operate with small reversing voltages, and the modulator F with sufficiently large carrier and modulating voltages. Amplification of the output voltage of said modulator may also be provided before applying said voltage to the input terminals of the dividers D, D'.

Moreover, the differential voltages developed by the tubes 9, 10 and 29, 30 of the frequency dividers may be amplified before being applied to the circuits of their corresponding triode pairs 1, 2 and 31, 32 respectively. One possible manner of achieving this is illustrated in Figure 4, which shows the circuits of the system B of the divider D of Figure 1, to which an intermediate amplification stage as just set forth has been added. Thus, the resistances 6, 7 through which the filaments of the tubes 1, 2 are connected to each other, instead of being connected in the plate circuits of the rectifier tubes 9, 10, are included respectively in the plate circuits of two triodes 91, 92 energized by a battery 93 and operating as a "push-pull" amplifier. The grid circuits of these two triodes 91, 92 comprise, respectively, resistances 94, 95, which are connected in series with each other across resistances 96, 97 of the plate circuits of the tubes 9, 10 respectively. As in the arrangement of Figure 1, the filaments of these tubes 9, 10 are connected to the terminal 11 of the frequency divider, while the common connection point of the resistances 96, 97 is connected to the terminal 12. As in Figure 1, output terminals 13, 14 of the frequency divider are taken off the plates of the tubes 9, 10. The system A of the divider D of Figure 1 being

altered in a manner similar to that shown in Figure 4 for the system B, the grids of the tubes 9, 10 of the system B are connected, as before, to suitable points of the plate circuits of the tubes 2, 1 of the system A through wires 98, 99 respectively, while the grids of the tubes 9, 10 of the system A are connected to suitable points of the plate circuits of the tubes 1, 2 of the system B, through wires 100, 101 respectively.

What I claim is:

1. In a frequency dividing system for electric alternating currents comprising a modulated wave alternating carrier current generator including a source of alternating carrier current and a modulating circuit and two modulating voltage input terminals and two modulated voltage output terminals, the combination of two frequency dividers having equal frequency transformation ratios and each provided with a pair of actuating terminals and a pair of output terminals, frequency selective means for coupling said actuating terminals to said modulated voltage output terminals in such a manner that one of said dividers shall be actuated by the upper side frequency components of said modulated voltage and the other of said dividers shall be actuated by the lower side frequency components of said modulated voltage, a source of alternating current having a substantially sinusoidal wave shape and a frequency which is a sub-multiple of the carrier frequency of said generator in the same ratio as the frequency transformation ratio of each of said dividers an output circuit, and alternating current demodulating means coupled to said source of sinusoidal current, to said output terminals of said dividers and to said output circuit.

2. In a frequency dividing system for electric alternating currents comprising a modulated wave alternating carrier current generator including a source of alternating carrier current and a modulating circuit and two modulating voltage input terminals and two modulated voltage output terminals, the combination of two frequency dividers having equal frequency transformation ratios each provided with a pair of actuating terminals and a pair of output terminals, frequency selective means for coupling said actuating terminals to said modulated voltage output terminals in such a manner that one of said dividers shall be actuated by the upper side frequency components of said modulated voltage and that the other of said dividers shall be actuated by the lower side frequency components of said modulated voltage, a source of alternating current having a substantially sinusoidal wave shape and a frequency which is a sub-multiple of the carrier frequency of said generator in the same ratio as the frequency transformation ratio of each of said dividers, two alternating current rectifiers, means for coupling one of said rectifiers to said source of sinusoidal current and to said output terminals of one of said dividers, means for coupling the other of said rectifier to said source of sinusoidal current and to said output terminals of the other of said dividers, and means for coupling the circuits of said rectifiers to a common output circuit.

3. In a frequency dividing system for electric alternating currents comprising a modulated wave alternating carrier current generator including a source of alternating carrier current and modulating circuit and two modulating voltage input terminals and two modulated voltage output terminals, the combination of two fre-

quency dividers having equal frequency transformation ratios and each provided with a pair of actuating terminals and a pair of output terminals, frequency selective means for coupling said actuating terminals to said modulated voltage output terminals in such a manner that one of said dividers shall be actuated by the upper side frequency components of said modulated voltage and that the other of said dividers shall be actuated by the lower side frequency components of said modulated voltage, a source of alternating current having a substantially sinusoidal wave shape and a frequency which is a sub-multiple of the carrier frequency of said generator in the same ratio as the frequency transformation ratio of each of said dividers, an alternating current rectifier, an output circuit, and means for coupling said rectifier to said source of sinusoidal current and to said output terminals of said dividers and to said output circuit.

4. A frequency dividing system for electric alternating currents according to claim 1, in which said demodulating means are coupled to said source of sub-multiple frequency current through an alternating current phase adjusting device.

5. A frequency dividing system for electric alternating currents according to claim 1, in which said output terminals of one of said dividers are coupled to said demodulating means through an alternating current phase adjusting device.

6. A frequency dividing system for electric alternating currents according to claim 1, in which said means for coupling said actuating terminals of one of said dividers to said modulated voltage output terminals of said generator include an alternating current phase adjusting device.

7. A frequency dividing system for electric alternating currents according to claim 2, in which said means for coupling said source of sub-multiple frequency current to the circuit of one of said rectifiers include an alternating current phase adjusting device.

8. A frequency dividing system for electric alternating currents according to claim 2, in which said means for coupling said common output circuit to the circuit of one of said rectifiers include an alternating current phase adjusting device.

9. A frequency dividing system for electric alternating currents according to claim 1, in which said demodulating means are coupled to said output terminals of said dividers through frequency selective means passing the lower frequency components of the output voltages of said dividers and attenuating the higher frequency components of said output voltages of said dividers.

10. A frequency dividing system for electric alternating currents according to claim 1, in which said dividers comprise circuit systems including each a reversible apparatus, rectifying relays provided with a differential output circuit, amplifying means provided with a control circuit and an output circuit, means for coupling said control circuit to said differential output circuit, and means for coupling said output circuit of said amplifying means to said reversible apparatus.

11. A frequency dividing system for electric alternating currents according to claim 1, characterized by the provision of a frequency multiplier affording a low frequency circuit and a high frequency circuit whose input-output frequency ratio is equal to the output-input frequency

ratios of the dividers, and the low frequency circuit being coupled to the source of sub-multiple frequency current and the high frequency circuit to the modulating circuit.

12. A frequency dividing system for electric alternating currents according to claim 1, characterized by the provision of a frequency demultiplier affording a high frequency circuit and a

5 low frequency circuit whose input-output frequency ratio is equal to the input-output frequency ratio of the dividers, and the high frequency circuit being coupled to the generator of alternating carrier current and the low frequency circuit to the demodulating means.

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