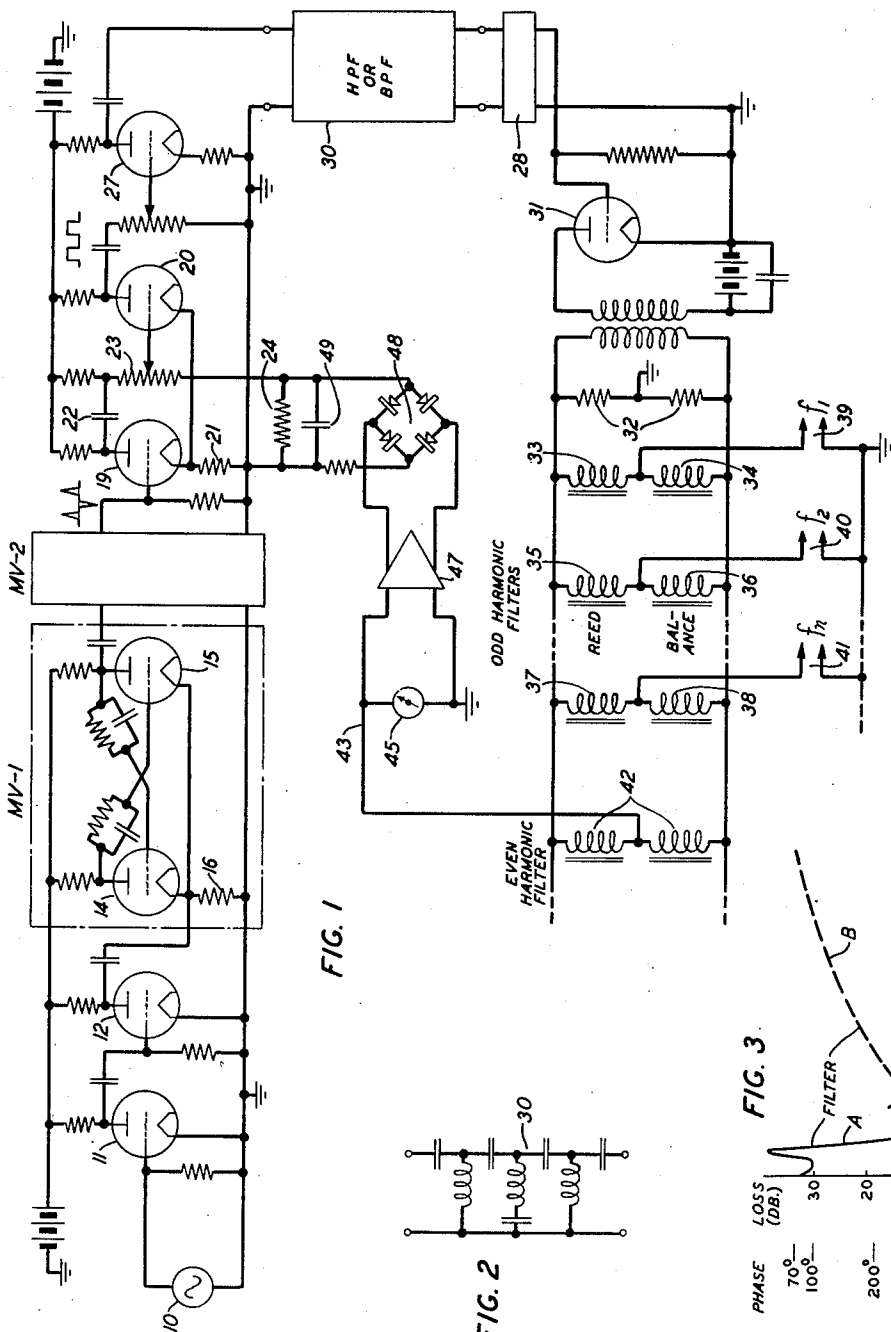


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MULTIFREQUENCY GENERATOR

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MULTIFREQUENCY GENERATOR

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The present invention relates to a multifrequency wave source for producing a large number of waves closely spaced in frequency within a given band and for separating said waves into individual circuits for independent use.

An object of the invention is to produce waves of the type indicated each having substantially only a single frequency whereby individual frequency waves of pure sine form result.

A related object is to control a square wave generator automatically to produce square waves each cycle of which consists of two halves which, to a high degree of accuracy, are of equal duration.

The invention while capable of general application will be disclosed as embodied in a system for generating a group of waves at closely spaced frequencies for use at a central office in selective calling in a radio-wire network. Since the filters for separating the waves of the different frequencies for individual use must be sharply selective, it is necessary to hold the generated frequencies to close frequency limits. It is desirable also to generate only pure sine waves of the separate frequencies so as to simplify the problem of separating the waves of individual frequencies. This is done in the present disclosure by generating in the first instance only the odd harmonics of a base wave. The odd harmonics within the range to be used are separated from the unused harmonics by a filter which has such a phase shift characteristic as to spread the peaks of the harmonic components in time, to prevent maximum peak voltage addition. The selected harmonics are amplified and equalized in amplitude and impressed upon an array of sharply selective filters for separating the waves of individual frequencies.

The base wave referred to is a square wave which has only odd harmonic components so long as the two half cycles in each complete cycle are of exactly equal duration. One feature of the invention comprises an automatic control circuit for detecting inequality in the two halves of the square wave and for varying a bias voltage on the square wave generator in such manner as to correct for the inequality.

The nature of the invention together with its objects and features will be fully understood from the following detailed description in connection with the accompanying drawing in which:

Fig. 1 is a schematic circuit diagram of a multifrequency source according to this invention;

Fig. 2 shows the schematic of one type of high-

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pass filter suitable for use in the circuit of Fig. 1; and

Fig. 3 shows suitable or typical filter characteristics for the filter 30.

Fig. 1 shows a type of system in which it was required to furnish a large number of closely spaced frequencies in separate output circuits 39, 40, 41, etc. In order to give a better understanding of a typical embodiment of the invention, the magnitudes of various quantities will be given for illustration but without any intention of limiting the invention to the particular values. It was required in this system to produce thirty frequencies in the output circuits 39—41, these frequencies to extend over the range from 367.5 cycles per second to 802.5 cycles per second with 15-cycle intervals between frequencies. It was required that the amplitudes of these various waves be held constant to a high degree of accuracy and that their frequencies be held to an accuracy of one part in 4,000. These output frequencies were derived in the first instance from an input wave source 10 which in this system took the form of a tuning fork oscillator generating a 240-cycle sine wave. This generator had a convenient frequency and was of such design and dimensions as to maintain the frequency constant to a high degree for long periods of time.

The sine waves from the source 10 were divided in frequency in two multivibrator stages indicated as MV-1 and MV-2 in the figure, these being of standard or known type and operating in tandem to reduce the frequency at the output of MV-2 to 7.5 cycles per second. An amplifier stage 11 followed by a peaking stage 12 was inserted between the oscillator 10 and the first multivibrator. Both multivibrators were of the same type and the first one has been diagrammed to show that it consists of the two tubes 14 and 15 with a common cathode resistor 16. The output of the peaking amplifier 12 is connected to the common cathode resistor. The frequency dividing ratio of the first multivibrator may be 4 and that of the second multivibrator may be 8, or, if desired, these two multivibrators may each have a frequency dividing ratio of 4 and may be followed by a third multivibrator (not shown) with a frequency dividing ratio of 2.

The output pulses in this case having a frequency of 7.5 cycles per second from the multivibrator MV-2 are impressed on a single trip multivibrator consisting of the two tubes 19 and 20. These two tubes are coupled by a common cathode resistor 21. This multivibrator has a

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stable condition in which the tube 20 is passing saturation current and the tube 19 is cut off. The reverse condition is unstable and the circuit returns to its stable condition after a time determined by the time constant of the condenser 22 and associated resistances. Negative pulses impressed on the grid of tube 19 from the multivibrator MV-2 have no effect. Each positive pulse, however, impressed on the grid of tube 19 causes space current to flow through that tube. The current in tube 20 is cut off by the rise in current in resistor 21 and also by the transfer of a negative pulse to the grid of the tube 20 by way of the coupling condenser 22 and potentiometer resistance 23.

The purpose of the circuit of the multivibrator 19, 20 is to generate square waves consisting of opposite half cycles of equal duration. When the tube 20 has its current cut off in the manner described, the initial rise in the positive direction is generated for the first half cycle of the square wave. Tube 20 remains cut off for a time determined by the bias on its grid and by the time constant of the interstage circuit. Condenser 22 which was discharged by the energizing of tube 19 recharges from the plate battery, carrying the voltage on the grid of tube 20 with it in the positive direction. When a sufficiently positive voltage is attained by the grid, the tube 20 again conducts saturation current and tube 19 is deprived of current due to the coupling by way of the cathode resistor 21. The grid of tube 20 receives a bias from the resistor 24 associated with the full wave rectifier 48 and smoothing capacity 49 in a manner that will be described presently.

When the tube 20 reconducts current in the manner described, the falling portion of the first half cycle of the square wave is generated and, as already described, the length of the first half cycle of the square wave was determined by the duration of interruption in current flow through the tube 20, this being in turn determined partly by the time constant of the circuit and partly by the bias voltage on the grid received from resistor 24. Tube 20 continues to pass saturation current throughout the second or negative half cycle, that is, until the next positive pulse is received from the multivibrator MV-2, when the process repeats itself.

The square wave generated in the circuit 19, 20 is amplified at 27 and sent through a high-pass or band-pass filter 30. It can be shown that a square wave consisting of half cycles of exactly equal length contains no even harmonic components but only odd harmonic components. It can also be shown that these harmonic components fall off in amplitude with increasing frequency at a definite rate, the reduction occurring over the band from 367.5 cycles to 802.5 cycles amounting to approximately 6 decibels. The lower of these two frequencies is the 49th harmonic of 7.5 cycles and the higher is the 107th harmonic. If a band-pass filter is used at 30 it is designed to have lower and upper cut-off frequencies such as to permit this band of frequencies to pass but to suppress both higher and lower frequency components. The reason that it is satisfactory in many cases to use a high-pass filter is that the frequencies above the desired range are relatively weak in amplitude and it is not so necessary to suppress them.

The output of the filter 30 is impressed on the grid of a buffer amplifier 31 which serves to prevent reaction on the filter 30 of the selective circuits on the output side of the amplifier and also

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to raise the level of the harmonics to the desired value. An equalizer 28 is indicated as lying between the output of the filter 30 and the input of amplifier 31, this equalizer having a 6-decibel slope in such direction as to equalize the harmonics over the range passed by the filter 30. While this equalizer is indicated as a separate element in the figure, it may, if desired, be incorporated into the filter 30 or into the design of the amplifier 31.

The filters for selecting the odd harmonics in the output of the amplifier 31 are of a type particularly suited to the separation of closely spaced frequencies. These filters are all alike except as to the frequency of response and are each shown as comprising an upper inductance coil 33, 35, etc. and a lower inductance coil 34, 36, etc. Each of the upper coils includes or has in its magnetic circuit a tuned reed mechanically resonant at the particular frequency to be selected. A pair of resistances 32 forms with the two coils, such as 33 and 34, a Wheatstone bridge which is balanced at all frequencies except at the particular frequency to be selected. These resistors 32 serve in common for all of the pairs of inductances used in the different filters. The balance coil simulates the damped impedance of the coil with the reed and balances the bridge at frequencies which do not cause appreciable vibration of the reed. Under these conditions, the transmission loss through the bridge is large and none of the frequencies corresponding to this balanced condition will appear in the outputs 39, 40, 41, etc. At the resonant frequency, however, the electrical motional impedance of the vibrating reed will unbalance the bridge and the transmission loss will be reduced by an amount depending upon the degree of unbalance. Although the tuned reeds in the band filters may resonate by themselves at frequencies slightly different from the driving frequency, the output frequencies will always be determined by the driving source and not by the resonant frequency of the tuned reeds. These filters in and of themselves form no part of the present invention but represent the invention of another. Their use in this particular circuit for separating the closely spaced harmonic frequencies was original with this applicant.

The harmonic filter 42 with circuit 43, rectifier 48 and biasing resistor 24, together form an automatic circuit for maintaining substantially equal the two halves of the square wave generated by the tubes 19 and 20. The filter 42 is tuned to select the 106th harmonic of the 7.5 cycle wave if such is present. The presence of the 106th harmonic, being an even harmonic, indicates inequality in the two halves of the square wave. The 106th harmonic is led over conductor 43 to amplifier 47 and thence to full wave rectifier 48 where it is converted into a direct current in bias resistor 24 and smoothed out by a shunt condenser 49. The grid bias for tube 20 is, therefore, made a function of the amount of unbalance between the two halves of the square wave.

In operation, the time constant of the interstage circuit between tubes 19 and 20 may be made such that in the absence of any bias voltage from resistor 24 the interruption period of tube 20 is slightly longer than half the period of the square wave. This results in the production of some even order harmonic which is detected, rectified, and used to bias the grid of tube 20 in such a direction as to shorten the period of interruption of current through tube 20. The control circuit reaches a stable condition in which

a minimum and substantially constant amount of even harmonic component is produced, this value however being smaller than the maximum tolerable amount, which latter is determined by the amount of corresponding reduction in the wanted odd harmonics such as the 105th, 107th, etc. The adjacent odd harmonic components decrease as the even harmonic components increase.

The filter 30 not only delimits the range of frequencies transmitted along to the odd harmonic filters but it also contributes to the purity of the output waves produced and eases the requirements on the buffer amplifier 31 by introducing a non-linear phase shift across the transmission band. All of the odd harmonic components in the square wave stand in fixed phase relation to one another and this phase relation is such that the maximum or peak voltages of the various harmonic components occur together and produce maxima which are the summations of the several peak voltages. By designing the filter 30 to have a non-linear phase shift characteristic, the energies of the various odd harmonic components may be spread out in time in such manner as to reduce these maxima, thereby minimizing the power requirement for the buffer amplifier 31. In other words, the ratio of the peak to the R. M. S. value of the harmonic voltages is reduced. The buffer amplifier 31 should have ample load carrying capacity so as not to produce intermodulation products between the various harmonics and thus impose stiffer requirements on the selective filters for the odd harmonics.

Fig. 2 shows the schematic of the configuration of one type of high-pass filter suitable for use at 30. This is a composite filter of usual or known type made up of end sections of ladder type and a middle section of carrier suppression type. The characteristics of this filter are given by the graphs in Fig. 3, the loss characteristic being shown at A and the phase shift characteristic at B. It will be noted that the phase shift characteristic is continually curved throughout the used band. This figure also includes the equalizer characteristic C for equalizer 28 which has a falling loss characteristic with increasing frequency over the transmitted band.

The invention is not to be construed as limited to the particular circuit arrangement disclosed nor to the values given since these are for illustration only and not the only values that might be used. The scope of the invention is defined in the claims.

What is claimed is:

1. The method of generating a large number of waves of closely spaced frequencies which frequencies are integral multiples of the frequency spacing between them, comprising generating base waves in the form of square waves of a fundamental frequency which is the least common multiple of the desired frequencies by a square wave generator, operating said square wave generator so as to make the square wave consist of two square wave pulses of like duration and opposite polarity in each complete cycle, whereby substantially only odd harmonic components are allowed to exist in said square wave, passing said square wave through a band-pass filter having a non-linear phase shift across the band to eliminate frequency components outside the desired band and to spread out the energy in time so as to reduce the ratio of peak to root mean square voltages of the harmonic components, and amplifying and equalizing the wave

components passed by said filter to have substantially the same amplitude.

2. A system for maximizing the number of sources of waves of different frequencies within a given band, comprising a generator of base frequency waves of square wave form consisting of opposite half-cycles having equal duration to minimize production of even harmonics, a filter for selectively passing the given band of odd harmonic frequency components from said square wave generator output, an amplifier circuit for amplifying and equalizing the output wave components from said filter, said filter having such non-linear phase shift characteristic as to spread the peaks of the components in time so as to minimize direct addition of peak voltages thus reducing the peak load on said amplifier so as to minimize production therein of inter-modulation components, and a plurality of sharply resonant selective circuits for separating said amplified harmonic components into individual circuit branches.

3. A system for generating to a high degree of accuracy a plurality of oscillations of different frequencies within a desired range spaced apart by fixed frequency intervals, which frequencies are integral multiples of the frequency spacing therebetween, said system comprising a source of base alternating waves of a fundamental frequency which is the least common multiple of said different frequencies and which contains two rectangular-shaped portions of like duration and opposite polarity in each cycle thereof, a band-pass filter supplied from said source and adapted to transmit all harmonics of said fundamental frequency within said desired range while suppressing unwanted frequencies outside said range and to introduce phase shift in the frequency components of the passed band, an amplifier and associated slope equalizer for amplifying to a desired degree and equalizing the amplitudes of the frequencies in said passed band, and a plurality of other band-pass filters for respectively selecting the oscillations of said different frequencies from the resulting waves.

4. A system including a generator of rectangular wave form comprising a grid-controlled space discharge device and a driving pulse source therefor causing said device to transmit saturation current for periods separated by intervals of zero current, circuits to utilize the odd harmonics of said rectangular wave, means to detect an even harmonic component in said rectangular wave and to produce therefrom a direct current bias voltage for said grid, said driving pulse source in the absence of such detecting means tending to produce inequality in given direction between said periods and said intervals and means to apply said bias voltage to said grid in such direction as to decrease the extent of such inequality.

5. A square wave generator comprising a grid-controlled wave generator, a circuit for pulsing said grid to cause said device to produce opposite half-waves of a square wave in succession, a grid-biasing circuit for said device for, in part, determining the length of each such half-wave produced, means to detect the presence, in the output wave from said generator, of an even harmonic component and to convert such component into a direct-current bias voltage which is supplied to said grid-biasing circuit, said pulsing circuit, in the absence of said detecting circuit tending to make the opposite halves of the generated square wave slightly unequal and said supplied

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bias voltage varying in the direction and extent necessary to hold the residuum of even harmonic component substantially at a minimum.

6. A system for generating to a high degree of accuracy a plurality of oscillations of different frequencies within a desired range spaced apart by fixed frequency intervals, which frequencies are integral multiples of the frequency spacing therebetween, said system comprising a source of base alternating waves of a fundamental frequency which is the least common multiple of said different frequencies and which contains two rectangular-shaped portions of like duration and opposite polarity in each cycle thereof, a band-pass filter supplied from said source and adapted to transmit all harmonics of said fundamental frequency within said desired range while suppressing unwanted frequencies outside said range and to introduce phase shift in the frequency components of the passed band, an amplifier and associated slope equalizer for amplifying to a

desired degree and equalizing the amplitudes of the frequencies in said passed band, and a plurality of other band-pass filters for respectively selecting the oscillations of said different frequencies from the resulting waves, said other band-pass filters being of the tuned reed type.

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