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E. PETERSON

2,317,482

WAVE GENERATING SYSTEM

Filed Dec. 31, 1941

FIG. 1

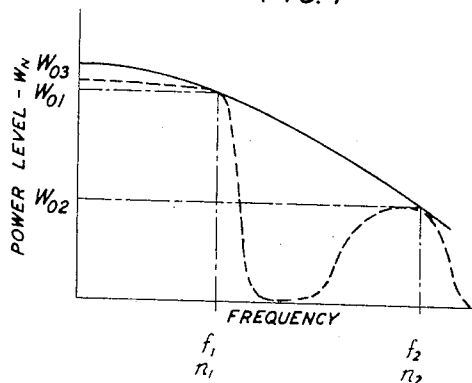


FIG. 5

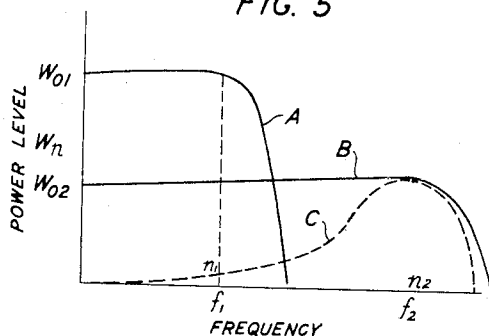


FIG. 2

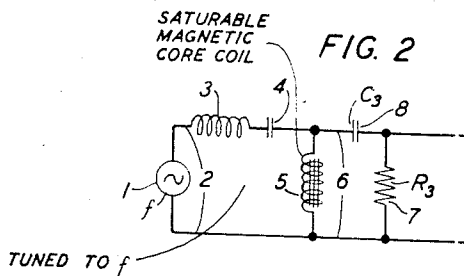


FIG. 3

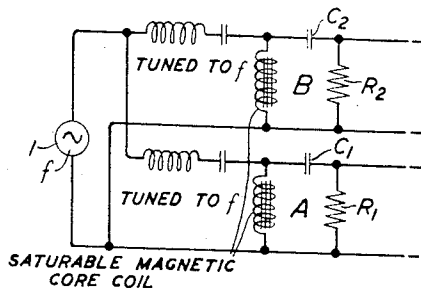


FIG. 4

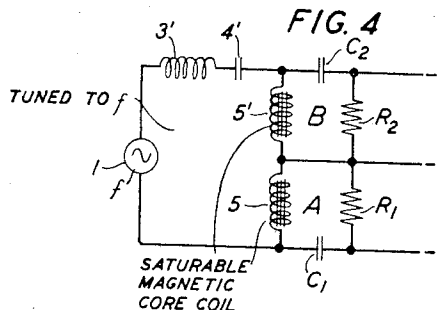
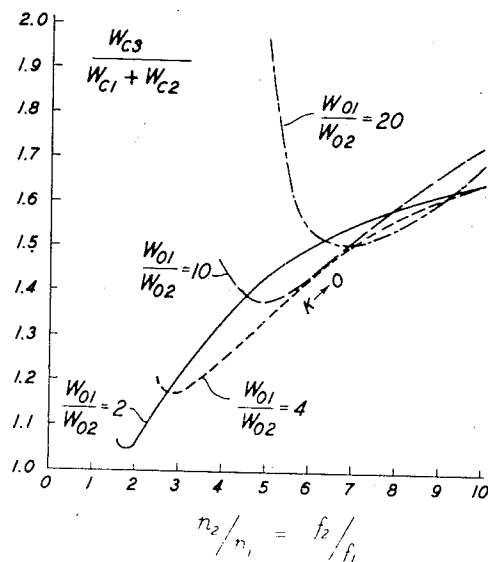


FIG. 6



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WAVE GENERATING SYSTEM

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Application December 31, 1941, Serial No. 425,087

7 Claims. (Cl. 172-281)

The invention relates to the generation of alternating current waves and particularly to the generation of a number of alternating current waves of different frequencies from a single wave of a given frequency.

In certain carrier communication systems it is required to have two different groups of carrier frequencies with a wide frequency spacing between the groups, all frequencies in both groups being different harmonics of the same fundamental frequency, and it is usually satisfactory for the group of higher frequencies to be at a lower power level than the lower group of carrier frequencies. It is known how to employ for the carrier supply in such a system a harmonic generator of the type providing a range of harmonics extending from a low harmonic to a high one with the amplitudes of the harmonics decreasing gradually as their frequency position in the harmonic scale increases.

An object of the invention is to produce in systems of the above-described type the required range of harmonics at the desired power levels efficiently and economically.

This object is attained in accordance with the invention by employing two harmonic generators controlled from the same source of fundamental frequency, one for each group, each generator supplying a substantially flat band of harmonics at the required power levels, extending from a very low harmonic or the lowest harmonic in its group to the highest one in its group.

The invention will be better understood from the following detailed description when read in conjunction with the accompanying drawing, in which:

Fig. 1 shows harmonic distribution curves which would provide the required two groups of frequencies for a carrier communication system of the above-described type.

Fig. 2 shows schematically a magnetic harmonic generator circuit of known type which may be utilized in the system of the invention;

Figs. 3 and 4 show schematically different arrangements of a plurality of harmonic generators of that type for accomplishing the object of the invention;

Fig. 5 shows curves of harmonic distribution obtainable with the systems of Figs. 3 and 4; and

Fig. 6 shows curves comparing the power efficiency of the systems of the invention as shown in Figs. 3 and 4 with that of the prior art system of Fig. 2.

One way of supplying the desired harmonics for a carrier communication system of the above-described type is to make the harmonic distribution of a single harmonic generator fall off

slowly enough to include both groups at the desired power levels. As shown in the solid line curve of Fig. 1, the harmonic distribution of such a generator would start out at a power level W_0 for the lowest frequency in the lower frequency group, decrease to a power level W_1 at the highest frequency f_1 in that group, and decrease further to the power level W_2 at the highest frequency f_2 in the auxiliary high frequency carrier group. Such a harmonic distribution may be obtained with a magnetic harmonic generator such as disclosed in L. R. Wrathall Patent 2,117,752, issued May 17, 1938, the circuit of which is shown in Fig. 2. As shown, that harmonic generator includes a source 1 of sinusoidal waves of the fundamental frequency f , a primary circuit 2 tuned to that frequency, comprising the linear inductance element 3, the capacitor 4 and the non-linear inductance 5, which may be a saturable magnetic core coil, connected in series across the source 1, and a secondary circuit 6 comprising the highly resistive impedance 7 and the capacitor 8 connected in series across the non-linear inductance 5. In the manner explained in the aforementioned patent, such a generator with proper relative proportioning of the circuit elements may be made to produce in the resistance element 7 an impulse wave containing a large number of odd harmonics of the fundamental frequency f , which over a wide frequency range will have appreciable power level gradually decreasing from the lowest frequency to the highest frequency in that range.

Another way to obtain the desired two groups of frequencies, which is more efficient under certain conditions given below than the use of the single harmonic generator for the purpose, is to employ two harmonic generators with harmonic distributions as shown in the curves of Fig. 5. In one such arrangement in accordance with the invention, shown in Fig. 3, two separate harmonic generators A and B of the known type illustrated in Fig. 2 are supplied in parallel from the same base frequency source 1. The circuit elements of the harmonic generator A in the system of Fig. 3 would be properly proportioned so that it supplies a band of harmonics of the frequencies and power levels required for the lower frequency group of carriers in the referred-to carrier supply system, and the circuit elements of the harmonic generator B of the system of

Fig. 3 would be properly proportioned to provide a band of harmonics of the frequencies and power levels required for the higher frequency carrier group in that system. As shown by curve A of Fig. 5, the generator A would be designed to supply a flat band of harmonics at the power level W_{01} up to the highest frequency f_1 in the lower carrier frequency group with the amplitude of the harmonics above that frequency falling off rapidly, and as shown by curve B of Fig. 5 the generator B would be designed to supply a flat band of harmonics at a lower power level W_{02} from a very low harmonic up to the highest frequency f_2 in the higher frequency carrier group with the amplitude of higher frequency harmonics falling off rapidly.

Unless it were possible to obtain a harmonic distribution as shown by the dashed line of Fig. 1 from a single harmonic generator, the most efficient way of supplying the higher frequency carrier group would be with a generator having a harmonic distribution such as shown by the dashed line C in Fig. 5 in which power would not be wasted at the low frequencies. This alternative harmonic distribution for the higher group of carrier frequencies may also be readily obtained by proper relative proportioning of the circuit elements of harmonic generator B in the system of Fig. 3, and by adding an inductance in series with C_2 .

The total power required for producing the required harmonic distribution for the two groups of carrier frequencies in the case of a single generator and the two generator system may be readily calculated as follows:

For the first case, that is the case of the use of the single harmonic generator as shown in Fig. 2, a distribution with k small ($k=L_0/R^2C$ where L_0 is the saturated inductance of the non-linear coil) is used, since this gives the smallest slope over the widest band of frequencies. This distribution is represented by

$$W_n = \frac{W_0}{1 + (npCR)^2}$$

where W_n is the power at the n th harmonic, W_0 is the power level at low harmonics, C and R are respectively the capacity and resistance in the secondary circuit & p is 2π times the fundamental frequency f . In this generator let the product of capacity and resistance in the secondary circuit & equal C_3R_3 . Then in order to have this distribution (Fig. 1) pass through the two required points, $W_n=W_{01}$ at $n=n_1$ and $W_n=W_{02}$ at $n=n_2$, we have

$$W_{01} = \frac{W_{03}}{1 + n_1^2(pC_3R_3)^2} \text{ and } W_{02} = \frac{W_{03}}{1 + n_2^2(pC_3R_3)^2} \quad (1)$$

to determine W_{03} and pC_3R_3 , where n_1 and n_2 are the harmonic numbers corresponding to f_1 and f_2 . The quantity pC_3R_3 may be deduced from Equation 1. We also have that the total power in this spectrum is

$$W_{\Sigma} = \frac{\pi}{4} \frac{W_{03}}{pC_3R_3} \quad (2)$$

which we find by use of the above relations is

$$W_{\Sigma} = \frac{\pi}{4} n_1 W_{01} \frac{\left(\frac{n_2^2}{n_1^2} - 1\right)}{\sqrt{\left(\frac{n_2^2}{n_1^2} - \frac{W_{01}}{W_{02}}\right)\left(\frac{W_{01}}{W_{02}} - 1\right)}} \quad (3)$$

This shows that the above conditions cannot be satisfied when

$$\frac{W_{01}}{W_{02}} \geq \frac{n_2^2}{n_1^2}$$

because the distribution for $k=0$ is not steep enough. When this inequality is not satisfied, a value of $k>0$ must be used and under this condition no simple expressions can be given.

For the other case where two generators are used (Fig. 3 or 4) we choose $npCR=1.0$ at the highest frequency in the particular band. Thus

$$\frac{1}{pC_1R_1} = n_1 \text{ and } \frac{1}{pC_2R_2} = n_2$$

Then the total powers in these distributions are

$$W_{\Sigma 1} = \frac{\pi}{4} \frac{W_{01}}{pC_1R_1} = \frac{\pi}{4} n_1 W_{01}, \quad W_{\Sigma 2} = \frac{\pi}{4} \frac{W_{02}}{pC_2R_2} = \frac{\pi}{4} n_2 W_{02} \quad (4)$$

The total power developed in this case is then

$$W_{\Sigma 1} + W_{\Sigma 2} = \frac{\pi}{4} (n_1 W_{01} + n_2 W_{02}) \quad (5)$$

The ratio of total powers in the two cases is

$$\frac{W_{\Sigma 2}}{W_{\Sigma 1} + W_{\Sigma 2}} = \frac{\left(\frac{n_2^2}{n_1^2} - 1\right)}{\sqrt{\left(\frac{n_2^2}{n_1^2} - \frac{W_{01}}{W_{02}}\right)\left(\frac{W_{01}}{W_{02}} - 1\right)}} \frac{1}{\left(1 + \frac{n_2}{n_1} \frac{W_{02}}{W_{01}}\right)} \quad (6)$$

This ratio is plotted in Fig. 6 as a function of $n_2/n_1=f_2/f_1$ for several values of the ratio W_{01}/W_{02} .

It is necessary to use $k=0$ for the distribution of Fig. 1 for the values shown by the curves of Fig. 6. For other values, determined by

$$\frac{n_2^2}{n_1^2} > \frac{W_{01}}{W_{02}}$$

the distribution curve can be passed through the two required points in more than one way depending on the value of k , and thus there is not a unique value for the total power.

Thus there is an increase in efficiency by using the two generators, which increases with the frequency separation of the two bands. For example, if the ratio of highest frequencies f_2/f_1 is 8, the power required with two generators is about $\frac{2}{3}$ the power required with a single generator. These results were worked out under the assumption that only odd harmonics are used. While the separate total powers would be twice as large if both odd and even harmonics were developed, the ratio of total powers in the two cases shown in Fig. 6 should be unchanged.

Fig. 4 shows a modified arrangement in accordance with the invention in which the two harmonic generators A and B are combined in such manner as to enable the use of fewer circuit elements. In that arrangement the common primary circuit for the two generators A and B connected across the source 1 and tuned to the fundamental frequency f supplied by that source, comprises the non-linear inductances 5, 5' and a single linear inductance element 3' and a single capacitor 4' in series, the other elements of the two generators A and B being arranged in the same way as in Fig. 3. By proper relative proportioning of the circuit elements of Fig. 4 harmonic distribution characteristics as shown in Fig. 5 may also be attained.

Any harmonic generators which will provide the harmonic distribution characteristics shown in Fig. 5 may be employed in place of the particular magnetic harmonic generators A and B illustrated in the systems of Figs. 3 and 4. For example, a gas-tube harmonic generator of the type disclosed in my Patent 2,174,165 issued September 26, 1939, may be employed in place of each of the generators if their circuit elements

are suitably proportioned to give the required harmonic distribution curves as shown in Fig. 5. Other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. A system for supplying efficiently one group of frequencies at a desired power level and a second group of frequencies considerably higher than those of said one group at an appreciable but lower power level, all frequencies in both groups being harmonics of the same fundamental frequency, comprising two harmonic generators both controlled from the same wave source of said fundamental frequency, means for causing one of said harmonic generators to produce a band of harmonics of said fundamental frequency having substantially said desired power level over the frequency range of said one group and means for causing the other harmonic generator to produce a band of harmonics of said fundamental frequency having said appreciable but lower power level over the frequency range of said second group.

2. The system of claim 1, in which said harmonic generators are caused to respectively produce a band of harmonics of uniform power level extending from the lowest frequency in said one group to the highest frequency in a different one of said groups.

3. The system of claim 1, in which one of said generators is caused to produce a band of harmonics of said fundamental frequency having uniform power over a range extending from the lowest frequency in said one group to the highest frequency in said one group and the second generator is caused to produce a band of harmonics of uniform power over a range extending from the lowest frequency in said second group to the highest frequency in said second group.

4. A system for efficiently supplying carrier waves in a carrier communication system employing a basic group of carriers and an auxiliary group of carriers of frequencies considerably higher than those of the basic group, all frequencies being harmonics of the same base frequency, comprising two harmonic generators, a common source of waves of said base frequency for controlling both generators, and means for causing said generators to respectively supply a band of harmonics of a desired uniform power level over the frequency range of said basic group, and of a desired lower uniform power level over the frequency range of said auxiliary group.

5. The system of claim 1 in which said generators are of the saturable magnetic core coil type, the different frequency ranges of desired power level being obtained by different proportioning of the circuit constants of the two generators.

6. The system of claim 1 in which said harmonic generators include a common primary circuit connected across said source and tuned to the fundamental frequency thereof, comprising two non-linear inductances, a linear inductance and a capacitor in series, individual secondary circuits each including a resistive impedance and a capacitor connected in series across a different one of said non-linear inductances, the circuit elements of the two harmonic generators being respectively properly proportioned to produce in the secondary circuit of each generator an impulse wave having the harmonic distribution required for a different one of said groups, and means for picking off the produced harmonic wave from the secondary circuit of each generator.

7. A system for supplying efficiently one group of frequencies at a desired power level and a second group of frequencies considerably higher than those of said one group at an appreciable but lower power level, all frequencies in both groups being harmonics of the same fundamental frequency, said system comprising a single source of sinusoidal waves of said fundamental frequency and two harmonic generators each comprising a non-linear inductance, a primary circuit including said non-linear inductance, tuned to said fundamental frequency, connected across said source, a secondary circuit including a highly resistive impedance and a capacitor in series, connected across said non-linear inductance, the non-linear inductance and the elements in the secondary circuit of one harmonic generator being relatively proportioned so that the generator produces a band of harmonics of said fundamental frequency having substantially said desired power level over the frequency range of said one group, the non-linear inductance and the elements in the secondary circuit of the other harmonic generator being differently relatively proportioned so that the latter generator produces a band of harmonics of said fundamental frequency having said appreciable but lower power level over the frequency range of said second group, and means for taking off the produced harmonics from the secondary circuit of each harmonic generator.

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