Jan. 3, 1939. O. E. KEALL 2,142,195

FREQUENCY MULTIPLYING APPARATUS

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Fig. 1

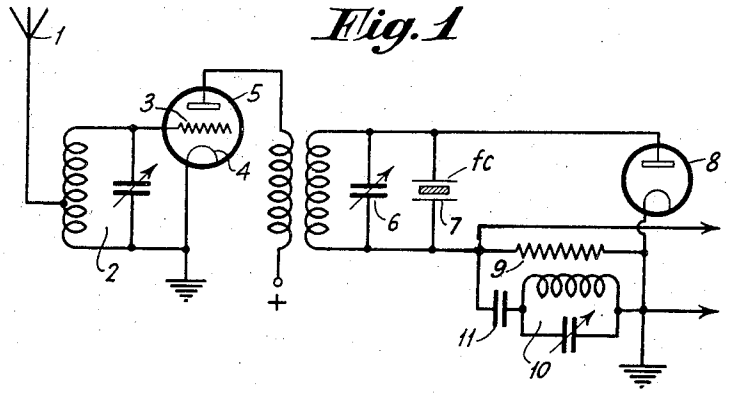
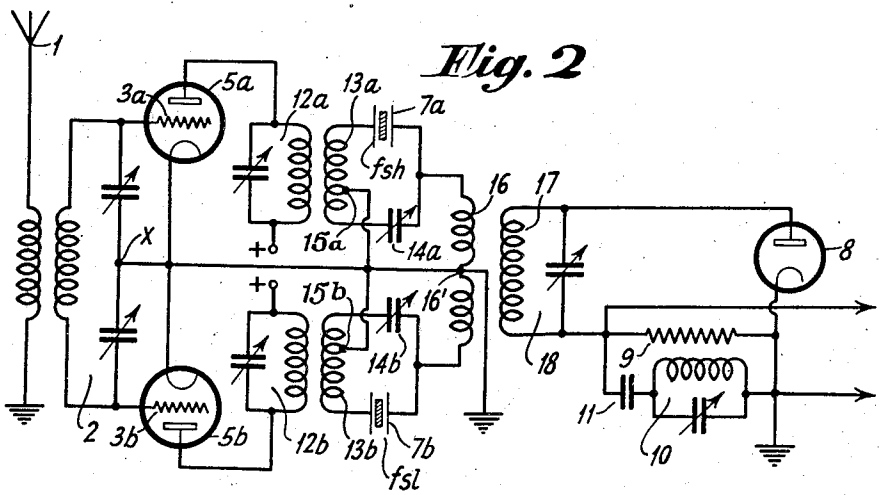


Fig. 2



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FREQUENCY MULTIPLYING APPARATUS

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6 Claims. (Cl. 250—36)

This invention relates to frequency multiplying apparatus and has for its object to provide an improved and simple apparatus whereby a given frequency may be multiplied to provide a harmonically related frequency output of good amplitude.

There are many known methods of frequency multiplication, but in most of these methods, use is made of non-rectilinear circuit elements—e. g., a tube operated over the curved part of its characteristic—to provide an output which is relatively rich in harmonics and the desired harmonic frequency is selected from this output, for example, by means of a tuned circuit. In such systems it is difficult to obtain by means of a single frequency multiplying stage a harmonic output—especially an upper harmonic output—of appreciable amplitude. Furthermore, the dependence upon non-rectilinear circuit elements generally requires the use of comparatively expensive and complex filtering apparatus in order to select the desired harmonic. In a known frequency multiplying system of the kind referred to, it is usually the case that the component of output of the desired harmonic frequency is of very small amplitude as compared with other components of output.

In the description which follows it will be assumed that in carrying out the invention the frequency which is to be multiplied to yield a harmonic frequency is present in the form of a modulation of a carrier frequency, but it is to be understood that where this is not the case, the said frequency, hereinafter termed the "initial" frequency, will first be employed to modulate a carrier so that it will be present in the form of a modulation.

According to this invention frequency multiplication is obtained by filtering out the carrier component in a carrier frequency modulated by an initial frequency, rectifying the envelope of the resultant remaining side bands, and selecting a desired harmonic output frequency from the rectified resultant. Preferably the filtering out of the carrier component is obtained by means of a piezo-electric crystal or a combination of piezo-electric crystals, but ordinary tuned circuits or other resonant means may be utilized for the same purpose, if desired.

Two embodiments of the invention are illustrated in Figures 1 and 2 of the accompanying diagrammatic drawing.

Referring to Figure 1, which shows one way of carrying out the invention, a carrier frequency modulated by an initial frequency, for example, a modulated carrier frequency received upon a radio receiving aerial 1, is applied via a circuit 2 tuned to the said carrier frequency, between grid 3 and cathode 4 of a carrier frequency amplifying tube 5 whose output circuit is coupled to a tuned circuit 6 which is also tuned to the carrier frequency. This tuned circuit is shunted by a piezo-electric crystal 7 which is series resonant sharply to the carrier frequency. The said tuned circuit is also shunted by a diode 8 or other rectifier in series with a load resistance 9. The load resistance is shunted by a parallel tuned circuit 10 resonant to the desired harmonic in series with a by-pass condenser 11. The desired harmonic frequency output is taken by coupling from the tuned circuit 10, or alternatively, as shown, it may be taken directly across the load resistance 9, for it will be possible in many cases to select the value of the by-pass condenser 11 in such manner that this condenser, in conjunction with the tuned circuit 10, acts as a series resonant circuit (and hence as an effective short circuit) for some present frequency component which is not desired and is below the desired harmonic frequency.

Suppose the initial frequency be one of 1 k. c. and be received as a modulation of a carrier of 100 k. c. Then there will be received 3 frequencies, namely 99, 100 and 101 k. c. The carrier frequency of 100 k. c. is removed by the crystal filter 7, leaving two frequencies of 99 and 101 k. c. respectively, of equal amplitude. These two frequencies of course possess an envelope of the familiar heterodyne type having a fundamental frequency of 2 k. c. and harmonics thereof. It is characteristic of the heterodyne type of envelope that it comprises a large number of harmonics of amplitudes which decrease relatively slowly with increase in frequency. For example, the amplitude of the fifth harmonic, 10 k. c., is approximately 3% of that of the fundamental, 2 k. c., frequency. With a known frequency multiplying system dependent upon a non-rectilinear circuit element for its operation, it would normally be necessary to employ at least two non-rectilinear stages in cascade in order to obtain a tenth harmonic, 10 k. c., output approaching 3% of the amplitude of an initial frequency of 1 k. c.

In a slightly modified arrangement in accordance with this arrangement and shown in Figure 2 a balanced or push-pull circuit is used. In this circuit the modulated carrier is applied by means of a tuned circuit between the two grids 3*a*, 3*b* of a pair of carrier frequency amplifying tubes 5*a*, 5*b* connected in push-pull. The center point X

of the tuned circuit, which is between two series condensers, is connected to the common cathode point, and is usually grounded. The output circuit of each amplifying tube 5a, 5b contains a tuned circuit 12a or 12b and each of these tuned circuits is coupled to a secondary coil 13a or 13b. Each secondary coil is in series in a loop circuit with a variable condenser 14a or 14b and a piezo-electric crystal 7a or 7b. Each of the symmetrically positioned taps 15a, 15b on the two secondary coils is connected to the common cathode point. The junction point between one piezo-electric crystal 7a and the associated series variable condenser 14a is connected to the corresponding junction point between the other crystal 7b and variable condenser 14b through a center-tapped coil 16 the center tap 16' of which is earthed and connected to the common cathode point. The coil 16 is magnetically coupled to the coil 17 of a further circuit 18 tuned to the working frequency, and this circuit 18 is shunted by a diode 8 in series with a load resistance 9 shunted by a circuit 10 tuned to the desired harmonic in series with a by-pass condenser 11. The desired harmonic output is obtained either by coupling to this tuned circuit 10, or, as shown, directly from across the load resistance 9. The principal difference between the embodiment of Figure 2 and that of Figure 1 is that in Figure 2 two crystal bridges are used, each of which acts as a pass filter for one of the two side band frequencies. These side band frequencies are then combined and fed to the diode or other rectifier circuit. The two crystal circuits may be so adjusted that each acts to pass only one side band. The variable condensers 14a, 14b associated with the crystal circuits may be set either so that each crystal bridge possesses a symmetrical frequency response curve relative to the respective side band frequencies, or so that each crystal bridge offers a high impedance to the carrier frequency while at the same time offering a low impedance to the respective side band frequencies.

Although in the preceding description crystal filters have been referred to, the invention is, of course, not limited to this type of filter but other suitable forms of filters, e. g., tuned circuits or more complex circuits may be used.

I claim:

1. In a frequency multiplying circuit, a thermionic tube amplifier means for impressing carrier wave energy modulated by wave energy of a second frequency on said wave amplifier, a circuit tuned to the carrier wave frequency coupled with the output of said amplifier to be energized thereby, a piezo-electric crystal sharply series resonant to the carrier frequency shunted across the said tuned circuit, a circuit including a rectifier in series with a direct current permeable impedance connected with said crystal and circuit, a further circuit including a parallel tuned circuit resonant to a desired harmonic of said wave energy of said second frequency connected with said impedance, and an output circuit including said last mentioned tuned circuit connected with said rectifier.

2. In a harmonic generator a pair of tubes having input and output electrodes connected in push-pull circuits, means for impressing carrier frequency energy modulated by potentials of a second frequency on said input and output electrodes, a pair of networks each connected with and fed from the output of one of said tubes, each network including a piezo-electric crystal and a condenser, a circuit differentially energized by the outputs from said networks, said circuit including a rectifier in series with a direct current permeable impedance shunted by a further circuit including a parallel tuned circuit resonant to a desired harmonic of said second frequency, and means for taking output energy from a circuit including said last mentioned tuned circuit.

3. An arrangement as recited in claim 2 wherein the networks are adjusted to have symmetrical frequency response curves relative to the respective side band frequencies.

4. An arrangement as recited in claim 2 wherein the networks are adjusted to offer high impedance to the carrier frequency to substantially suppress the same and low impedance to the respective side band frequencies so that the same are passed with little reduction in amplitude.

5. An arrangement as claimed in claim 2 wherein said further circuit consists of the harmonically resonant tuned circuit and a condenser in series, the combination being series resonant at an undesired harmonic below the desired harmonic and the output energy being taken from across a circuit including the said combination.

6. An arrangement as recited in claim 1 wherein said further circuit includes a condenser in series with the parallel tuned circuit resonant to the desired harmonic, the tuned circuit and condenser in series being resonant at an undesired harmonic below the frequency of a desired harmonic, said further circuit also including means for derivng output energy from the terminals of said series condenser and resonant circuit.

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