Oct. 17, 1933. W. F. CURTIS 1,930,924

HARMONIC SELECTOR CIRCUIT FOR FREQUENCY MULTIPLIERS

Filed March 13, 1931

FIG. 1

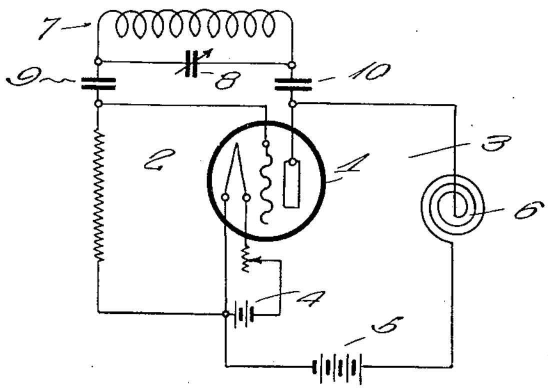
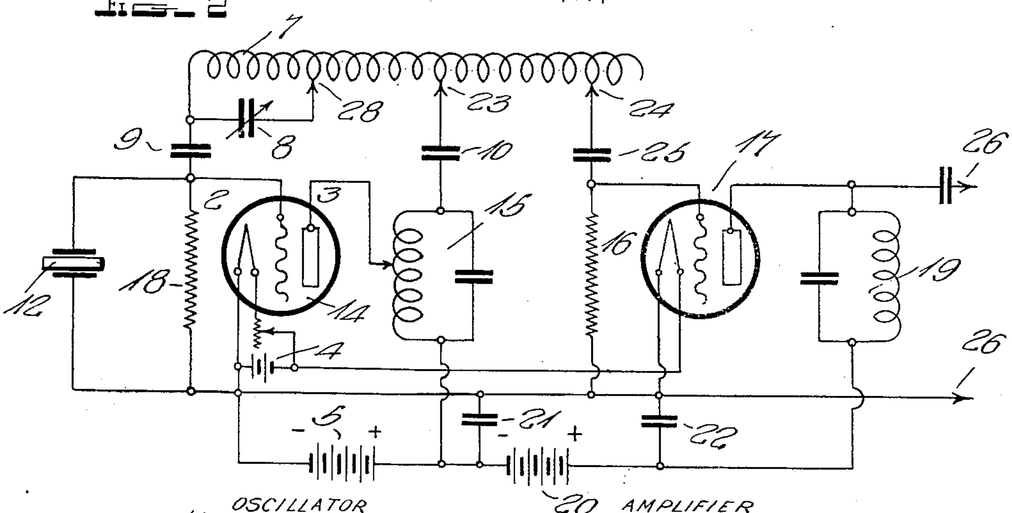


FIG. 2



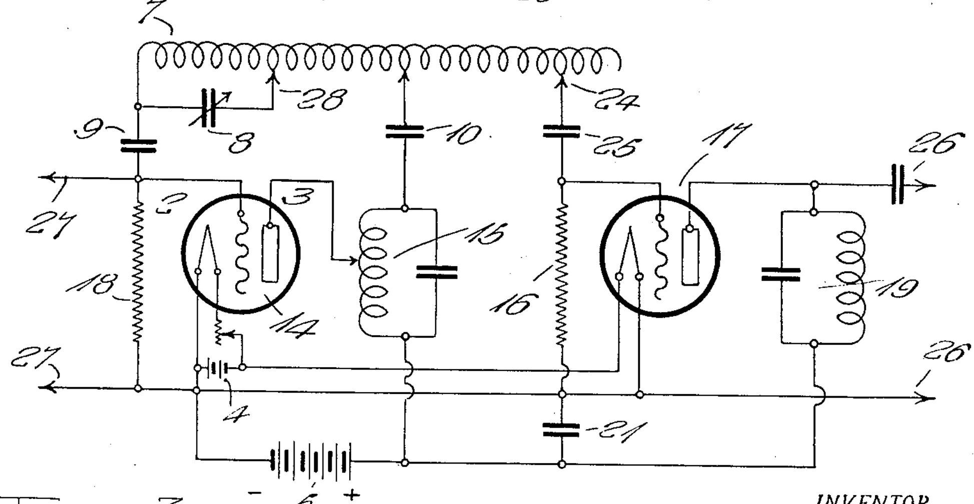


FIG. 3

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Patented Oct. 17, 1933

1,930,924

UNITED STATES PATENT OFFICE

1,930,924

HARMONIC SELECTOR CIRCUIT FOR FREQUENCY MULTIPLIERS

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Application March 13, 1931. Serial No. 522,422

4 Claims. (Cl. 250—36)

My invention relates broadly to electron tube circuits and more particularly to a harmonic selector circuit or frequency multiplier.

One of the objects of my invention is to provide an electron tube circuit arrangement for the selection of harmonic frequencies or for frequency multiplication.

Another object of my invention is to provide a harmonic selector circuit or frequency multiplier wherein the harmonic frequency is directly produced in the circuit of an electron tube oscillator system.

Other and further objects of my invention reside in the harmonic selector or frequency multiplier circuit as set forth more fully in the specification hereinafter following by reference to the accompanying drawing, in which: Figure 1 shows a self oscillating circuit illustrating the principles of my invention; Fig. 2 shows a harmonic selector frequency multiplier circuit embodying my invention; and Fig. 3 shows a modified form of harmonic selector circuit having means for producing a strong harmonic frequency in a self oscillator circuit.

My invention provides a circuit for amplifying any desired harmonic of a piezo electric crystal controlled oscillator circuit, so that the harmonic frequency may be utilized for high frequency radio transmission. By producing the harmonic used in the crystal controlled tube itself instead of in an amplifier stage as has heretofore been the practice, radiation on the crystal fundamental frequency is reduced and the efficiency of transmission increased, and it is possible to obtain high frequencies with lower frequency multiplying stages than has heretofore been accomplished.

My invention will be explained by referring first to Fig. 1, which represents a self oscillating electron tube circuit including electron tube 1 having input and output circuits 2 and 3. The cathode is heated from battery 4. The plate circuit is energized from source 5 connected in series with the inductive load 6. The input and output circuits 2 and 3 are coupled through inductance 7 shunted by tuning condenser 8. The circuit constituted by the inductance 7 and condenser 8 is coupled to the input circuit 2 through condenser 9 and to the output circuit 3 through condenser 10. If condensers 9 and 10 in this circuit are sufficiently large, the circuit will maintain oscillations at a frequency determined by inductance 7 and condenser 8. If the capacities of condenser 9 and condenser 10 are made as small as the inter-electrode tube capacities, the frequency of oscillation is remarkably constant. Oscillations cease if the capacities of condensers 9 and 10 are made too small. The important fact established by this circuit is that if a parallel tuned circuit 7—8 is connected to the grid and plate of a vacuum tube through suitable reactances, regeneration on a frequency

$$f=\frac{1}{2}''\sqrt{L'C'}$$

occurs even though no neutral capacity or ground connection is made to the L′ C′ circuit where L′ represents the inductance of coil 7 and C′ indicates the capacity of condenser 8. This regeneration can be controlled over a wide range by proper adjustment of the coupling reactances.

In Fig. 2, electron tube 14 and allied circuits constitute an oscillator. Its output circuit 15 is connected to the input circuit 16 of amplifier 17. Let the frequency of the piezo electric crystal 2 be f. The plate circuit 15 is then tuned to frequency f. Resistance 18 may have its conventional value, or it can be replaced by a choke coil and a biasing battery. The circuit 7—8 is tuned to a frequency $f'=nf$ where n is an integer larger than unity. The tuning condenser 8 connects to inductance 7 through adjustable tap 28. Condensers 9—10 are always so adjusted that no self-oscillation can take place. There is, however, sufficient regeneration on the frequency f' so that the nth harmonic of the crystal frequency is greatly amplified. This action seems to be favored by a slightly abnormal grid bias, which causes the tube to distort slightly, without appreciably impairing efficiency. Due to the tuning of circuit 7—8, a circulating current of frequency f' and of considerable amplitude flows in the circuit 7—8 in the manner shown in Fig. 1. The plate circuit of the amplifier 17 indicated at 19 is tuned to frequency f'. It will be observed that the amplifier 17 is operated on normal grid bias, as it does not multiply frequency.

The plate supply for the amplifier 17 is obtained from battery 20. Suitable by-pass condensers 21 and 22 are connected around the batteries 5 and 20 as shown. The coupling between the oscillator 14 and the amplifier 17 is established through an extension of the inductance 7 forming part of the tuned circuit 7—8. A tap 23 provides an adjustable connection through condenser 10 with the output circuit 15 of the oscillator. An independent tap 24 is slidable along the extension of inductance 7 and connects through condenser 25 with the input circuit of the amplifier 17. The oscillator circuit operates upon a frequency f' which is a harmonic of the frequency of piezo electric crystal 12 and this harmonic frequency is amplified in tube 17 and the energy transferred to the circuit 19 tuned to the frequency of the harmonic at which the oscillator operates and the amplified harmonic frequency delivered at the output terminals 26. Using a 7½ watt triode for an oscillator at 14, and a 7½ watt screen grid tube at 17 as an amplifier and a crystal of a frequency of 3996.4 kilocycles with an anode potential of 220 volts applied to the oscillator and 500 volts on the amplifier utilizing parallel feed, the following operations have been successfully carried out:

(*a*) *Doubling.*—The circuits 7—8 and 19 were tuned to 7992.8 kilocycles. The radio frequency circulation current in the circuit 19 was 2¾ amperes.

(*b*) *Tripling.*—The circuits 7—8 and 19 were tuned to 11909.2 kilocycles. The radio frequency circulating current in the circuit 19 was 1½ amperes.

(*c*) *Quadrupling direct.*—The circuits 7—8 and 19 were tuned to 15985.6 kilocycles. About ½ an ampere radio frequency was obtained in the circuit 19.

(*d*) *Double-double.*—The circuit 7—8 was tuned to 7992.8 kilocycles, and the circuit 19 tuned to 15985.6 kilocycles. A high negative bias was applied to the grid of the amplifier. About ½ ampere radio frequency was obtained in the circuit 19.

The exciting voltage applied from grid to neutral on the oscillator tube may come from any source other than a piezo electric crystal. Fig. 3 shows a circuit for frequency multiplication. The frequency which is applied to the circuit of Fig. 3 is obtained from a source connected to terminals 27. The circuit of Fig. 3 is similar in arrangement to the circuit of Fig. 2 except that the plate potential for both the oscillator and amplifier tubes 14 and 17 is obtained from the common source 5. The output of the amplifier 17 is delivered to the terminals 26 in the manner explained in connection with Fig. 2. If a circuit tuned to the same frequency as the circuit 15 be connected across from grid to neutral circuit as shown in Fig. 3, that is the input points, the resulting circuit provides a self-oscillator with one strong harmonic. It is possible to control this oscillation by means of an oscillation of frequency nf coupled into the circuit 7—8. This circuit operates as a frequency divider.

While I have described my invention in certain of its preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A frequency multiplier comprising a plurality of electron tubes each having input and output circuits, a piezo electric crystal element connected in the input circuit of one of said electron tubes, a tuned circuit connected with the output circuit of said last mentioned electron tube for sustaining oscillations at the fundamental frequency of said piezo electric crystal element, an inductance, capacitive connections between the input and output circuit of said last mentioned electron tube at positions along said inductance and a capacitive connection between the input circuit of a succeeding electron tube and another position on said inductance and means for tuning a portion of said inductance to the harmonic frequency of said piezo electric crystal element for selectively transferring energy at said harmonic frequency to said succeeding electron tube.

2. A frequency multiplier comprising an electron tube oscillator circuit, an electron tube amplifier circuit, an electromechanical vibrator for sustaining oscillations in said oscillator circuit at a predetermined frequency, an inductance, capacitive connections between separated taps along said inductance and the input and output circuits of said electron tube oscillator and said electron tube amplifier, a tuned circuit connected with the output of said electron tube oscillator circuit, said tuned circuit being adjustable to the fundamental frequency of said electromechanical vibrator, a tuned circuit connected with the output of said electron tube amplifier circuit and adjustable to the harmonic frequency of said electromechanical vibrator, and means for tuning that portion of said inductance immediately adjacent the tap thereon which leads to said oscillator circuit to the said harmonic frequency.

3. A frequency multiplier comprising a pair of electron tubes each having tuned output circuits, an electromechanical oscillator connected with the input circuit of one of said electron tubes, an inductance, capacitive connections along said inductance to the input and output circuits of said last mentioned electron tube and to the input circuit of the succeeding electron tube, the output circuits of said tubes being tuned respectively to the fundamental and a harmonic frequency of said electromechanical oscillator, and means for selectively tuning a portion of said inductance to the harmonic frequency to which the output circuit of the succeeding electron tube is tuned.

4. A frequency multiplier comprising an electron tube oscillator, an electron tube amplifier, each having input and output circuits, an inductance, taps disposed at separated intervals along said inductance, an electromechanical vibrator connected in the input circuit of said oscillator, a tuned circuit adjustable to the fundamental frequency of said electromechanical vibrator connected with the output circuit of said oscillator, a connection between one of the taps on said inductance with the input circuit of said oscillator, a connection between the second tap on said inductance with said tuned circuit, a connection between a third tap on said inductance and the input circuit of said electron tube amplifier, a condenser coupling device interposed in each of said connections, a tuned circuit connected with the output of said amplifier and adjustable to the harmonic frequency of said electromechanical vibrator, and a tuned path connected across said inductance intermediate said first and second taps for adjusting a portion of said inductance to the harmonic frequency of said electromechanical vibrator.

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