March 21, 1939. W. VAN B. ROBERTS 2,151,332

OSCILLATOR AND FREQUENCY MULTIPLIER

Filed Oct. 1, 1935 2 Sheets-Sheet 1

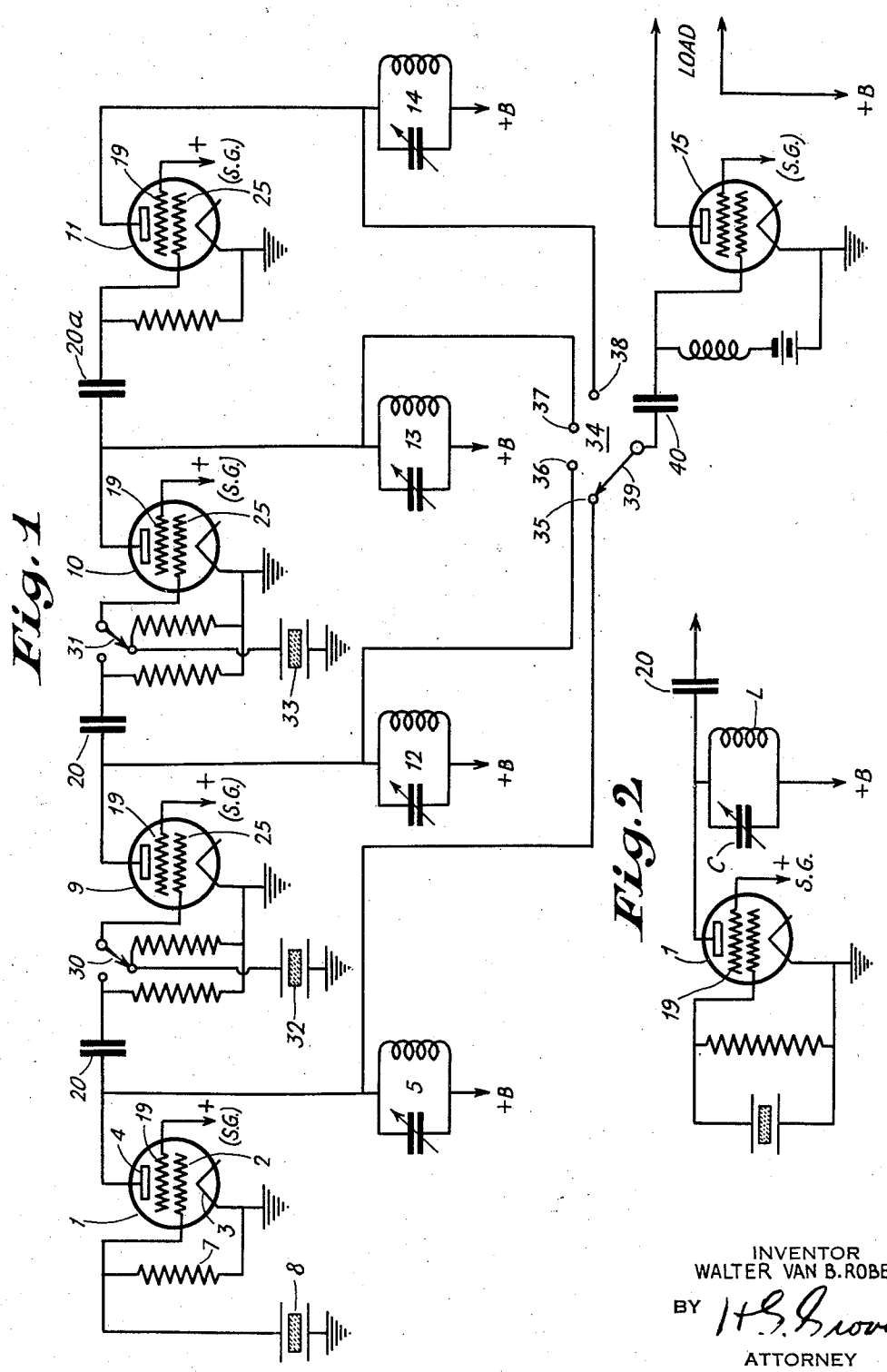


Fig. 1

Fig. 2

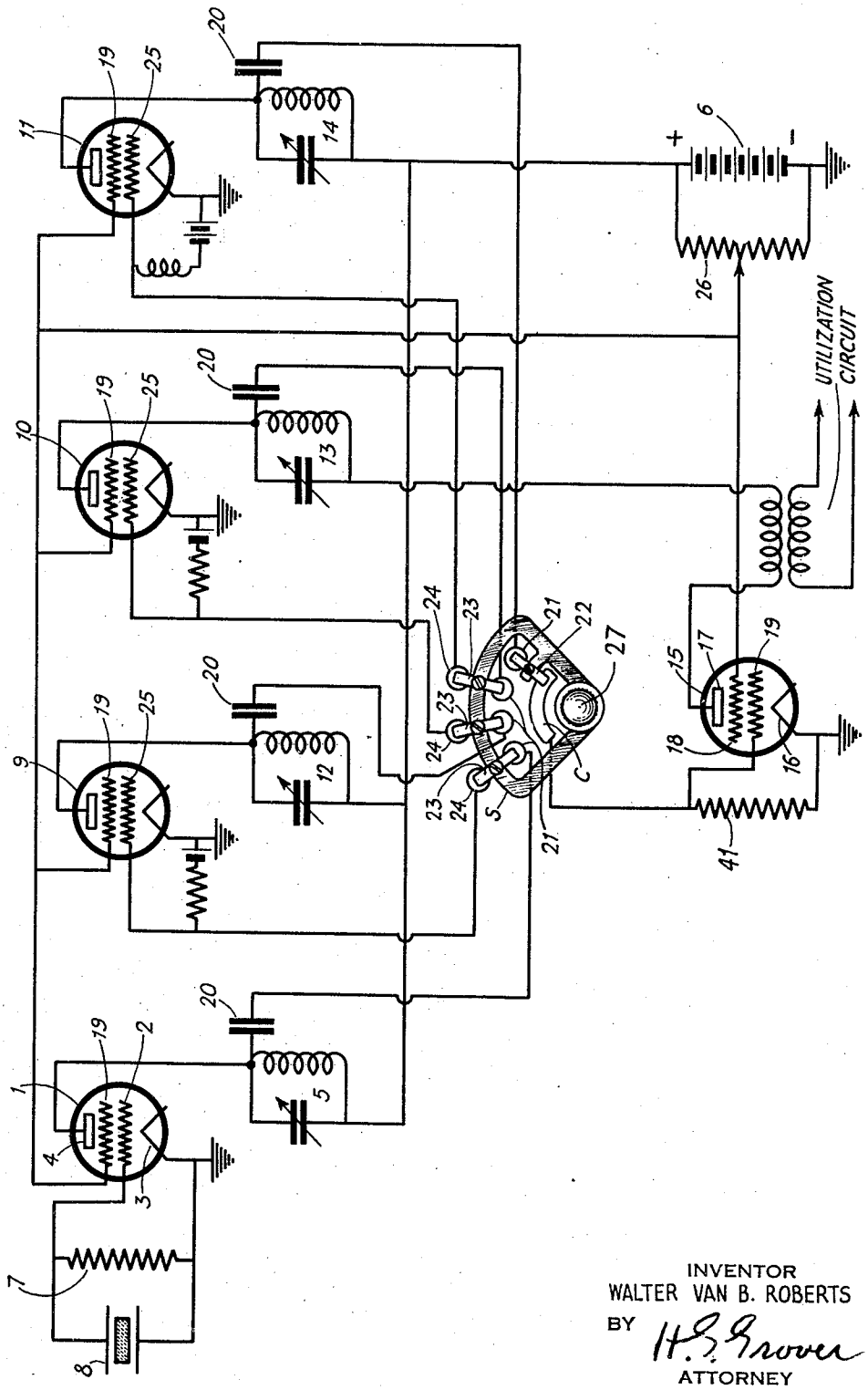
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Fig. 3



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OSCILLATOR AND FREQUENCY MULTIPLIER

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Application October 1, 1935, Serial No. 42,991

6 Claims. (Cl. 250—36)

This invention relates to radio frequency transmitting apparatus and particularly to a device of this character which is adapted to serve both as an oscillation generator and as a frequency multiplier.

It is a principal object of my invention to provide an exciter unit for a radio transmitter which will allow operation in a plurality of wave bands at the same time that slight changes in frequency within a given band may be made, if desired.

It is a further object to provide a crystal controlled oscillator adapted to produce a maximum harmonic voltage.

It is a still further object of my invention to provide a highly flexible arrangement of frequency control apparatus for use in a radio transmitter such that changes of frequency may be made without any change of inductances in the exciter unit.

The foregoing and other objects and advantages of my invention will be better understood from the following detailed description when read in connection with the accompanying drawings, in which:

Figure 1 shows diagrammatically an exciter unit for a transmitter in which a plurality of piezo-electric crystal devices may be selectively employed;

Fig. 2 shows an oscillator adapted to produce a maximum second harmonic vlotage, this oscillator being an important feature of the invention; and

Fig. 3 shows an exciter unit having a simple switching arrangement for selectively operating the same in any one of several frequency bands without coil change.

By way of illustration my invention will be described with particular reference to its use in connection with transmitters operating in the various frequency bands assigned to amateurs. These bands are commonly referred to as the 160-meter band, the 80-meter band, the 40-meter band, the 20-meter band, the 10-meter band, etc. These bands are roughly, but not exactly, in harmonic relation to each other. In amateur operation it is desirable to be able to operate in different ones of these bands according to the distance to be covered, the time of day, and other considerations. It is furthermore highly desirable to be able to change the operating frequency by a small amount within a given band in case heavy interference is encountered. In transmitters as heretofore designed, it has been necessary to utilize a large number of crystals and to make rather tedious changes of plug-in coils in order to effect the aforesaid changes. In the present arrangement it is possible to operate in any of a number of bands with a choice of two or more frequencies within each band without recourse to coil changing and with a relatively small number of crystals.

Fig. 2 will first be referred to because an understanding of the oscillator circuit therein shown is essential to a fuller comprehension of the complete circuit schemes in either Fig. 1 or Fig. 3. The oscillator of Fig. 2, so far as can be shown diagrammatically, is of well known type. The electron discharge tube 1 is provided with a screen 19, the screening action of which is made just sufficient so as not to prevent a certain amount of internal capacity feed-back, such as would be necessary for setting up oscillations. In oscillators of this type it has heretofore been customary to tune the tank circuit LC sufficiently close to the resonant frequency of the crystal to provide the optimum value of inductive reactance in the plate circuit for oscillation generation. If, however, it is desired to utilize the second harmonic of the generated oscillation, such a tank circuit is inefficient in building up a large amount of second harmonic voltage. According to the present invention this tank circuit is constructed to be tuned to the second harmonic and at the same time to present the required inductive reactance at fundamental frequency for efficient oscillation generation. Let the desired value of inductive reactance be represented as X. Let it be further assumed that C and L are so chosen that

$$\frac{1}{CL}=\omega^2$$

where $\omega=2\pi$ times the second harmonic frequency. It is easily shown that at the fundamental frequency the reactance of the tank circuit is inductive and equal to

$$\frac{2}{3}\sqrt{\frac{L}{C}}$$

Thus, if the condition

$$\frac{2}{3}\sqrt{\frac{L}{C}}=X$$

be imposed, along with the previous condition

$$\frac{1}{CL}=\omega^2$$

then by a solution of these equations both L and C will be determined. Thus the oscillator of Fig. 2 provides a maximum second harmonic voltage while at the same time producing the desired feed-back for maintaining oscillation if L and C

are chosen to satisfy simultaneously the foregoing equations. The voltage developed across the plate circuit is impressed upon the grid of a succeeding tube through a small condenser 20 as usual.

Fig. 1 shows tube 1 arranged as an oscillator in accordance with the description of Fig. 2. Its output second harmonic voltage is impressed upon the grid of tube 9 which is arranged to act as a frequency doubler, its plate circuit 12 being tuned to four times the frequency of the crystal 8 and the voltage developed therein being impressed on the grid of tube 10 which also acts as a doubler and impresses its voltage at eight times the crystal frequency upon tube 11 whose plate circuit 14 is tuned to sixteen times the frequency of crystal 8.

When it is desired to obtain frequencies slightly different from the fundamental or one of the harmonics of the frequencies of the crystal 8, then other crystals such as 32 or 33 may be employed selectively. Thus, for example, let it be assumed that the crystal 8 has a frequency of 1.79 megacycles and that the natural frequencies of the crystals 32 and 33 are respectively 3.59 megacycles and 7.19 megacycles. The switches 30 and 31 are so arranged that any one of the three tubes 1, 9 and 10 may be operated as an oscillation generator, while, if not so operated, it will serve as a frequency multiplier or else (in case it precedes the active oscillator in the cascade arrangement) it will be inactive.

In the illustration given above the frequencies of the crystals are made slightly out of harmonic relationship in order that a greater choice of frequencies in the shorter wave length bands may be obtained.

Continuing the illustrative description, the tank circuit 5 connected to the anode 4 of the tube 1 is adapted to be tuned in the 80-meter band; the tank circuit 12 correspondingly connected to the anode of tube 9 is adapted to be tuned in the 40-meter band; the tank circuit 13 is correspondingly tuned in the 20-meter band; and the tank circuit 14 in the 10-meter band.

In order that any one of the various harmonic frequencies aforementioned, as well as the fundamental frequency of the crystal 8, may be selectively utilized, I preferably employ a commutator switch 34 having contact points 35, 36, 37 and 38, each of which is connected respectively to one of the tank circuits 5, 12, 13 and 14. The movable switch arm 39 is preferably connected by way of a capacitor 40 with the input circuit of an electron discharge tube amplifier 15. The output circuit of this amplifier may include any suitable load.

In the operation of the circuit as shown in Fig. 1 either the fundamental frequency of the crystal 8 (say in the 160-meter band) or its second harmonic (say in the 80-meter band) may be utilized by variably tuning the tank circuit 5. In either case the switch 30 will be set in its lower position while the switch 34 has its contact arm 39 in contact with segment 35 so as to carry the oscillations generated directly to the amplifier tube 15. If the fourth harmonic of the crystal 8 (say in the 40-meter band) is desired, then the switch 30 will be moved into its upper position in order to utilize the tube 9 as a frequency multiplier. In this case the tank circuit 12 will be tuned to the fourth harmonic of the frequency of the crystal 8. At the same time the switch arm 39 will be placed in contact with segment 36 so as to derive this frequency. A slightly different frequency, however, may be obtained while the switch 34 has the same setting on segment 36. To do this the oscillator including tube 1 is cut out by moving the switch 30 into its lower position where the crystal 32, having a natural frequency of say 3.59 megacycles, is placed in control. The tube 9 now operates as an oscillator and the tank circuit 12 can be tuned to the second harmonic of the natural frequency of the crystal 32.

Continuing the illustration still further it will be seen that three possible frequencies are obtainable by setting the switches 30 and 31 in different positions and by selectively utilizing the crystals 8, 32 and 33 for obtaining oscillations in the 20-meter band. In each case, however, the tank circuit 13 will be tuned to the desired frequency and the energy derived therefrom will be impressed upon the amplifier 15 by setting the switch arm 39 in contact with segment 37.

In order to double any one of the three frequencies mentioned in the proceding paragraph, the oscillations so generated may be impressed across the capacitor 20_a and upon the input circuit of the frequency multiplier tube 11, the anode of which is connected to a tank circuit 14 tunable in the 10-meter band. When the tube 11 and tank circuit 14 are utilized then the switch arm 39 will, of course, be placed in contact with the segment 38.

In place of the switch 34 it is, of course, within the scope of the invention to utilize a flexible lead between the capacitor 40 and a clip (not shown) by which connection may be made to any one of the tank circuits 5, 12, 13 and 14.

It will be seen from the foregoing description that if interference is encountered at any particular frequency then switching of circuits is so facilitated that a different crystal may be placed in control and a slightly different operating frequency is thereby obtained. Summarizing the possiblity of frequency changing it may be said that while there is only one frequency available in the 80-meter band yet there are two frequencies in the 40-meter band, three in the 20-meter band, and three in the 10-meter band. The possible variations in the frequency may be still further increased, however, if additional crystals ars used.

Referring now to Fig. 3, I show a modification of the invention in which the switching arrangements are still further simplified. Parts corresponding to Fig. 1 have been given like reference numerals.

The modification shown in Fig. 3 is best adapted to conditions in which the desired operating frequencies may be obtained either as the fundamental or a harmonic of the natural frequency of one crystal 8. In the circuit diagram of Fig. 3 several electron tube stages are shown the same as in Fig. 1 and as many stages of frequency multiplication as may be desired can be included in circuit between the oscillator 1 and the amplifier 15. Each of the tank circuits 5, 12, 13, and 14 is connected respectively across its own coupling capacitor 20 to an appropriate segment 21 of the selective switch S. Each of the tank circuits 5, 12, 13, and 14 is preferably tuned to twice the frequency of the grid excitation applied to the tube in whose output circuit it lies.

In the operation of the system as shown in Fig. 3 a suitable choice of the fundamental frequency or a harmonic of the frequency of the crystal 8 may be obtained by setting the switch S in different positions. This switch carries a brush 22 which is adapted to contact with any one of the segments 21 depending upon the point from

which energy is to be derived for controlling the amplifier 15. The brush 22 establishes connection between a selected segment 21 and the contact member C, the latter being in circuit with the grid 19 of the amplifier tube 15.

The commutator switch includes further means for interconnecting different ones of the tank circuits each with the input circuit of a succeeding frequency multiplier stage. In order to achieve this result the rotary member S carries a plurality of bridging members 23, each radially disposed so as to establish connection between one of the segments 21 and a companion segment 24 leading to its appropriate grid 25 in one of the frequency multiplier tubes. The bridging members 23 and the brush 22 are so spaced one from another when mounted on the insulator S that the desired connections may be made upon setting the switch in any selected position.

It will be understood by those skilled in the art that other switching means may be adopted for carrying out the objects of this invention without departing from the spirit thereof. Furthermore, it will be understood that various types of electron discharge tubes may be utilized other than as shown in the circuit diagram. For the sake of simplicity, however, I have merely shown such tubes as having four electrodes including screen grids 19 upon which potentials of suitable value may be applied, as when connected to a potentiometer 26, bridging the B-battery 6.

As the switch S is moved into successive positions, from left to right, additional frequency multipliers are placed in circuit between the oscillator 1 and the amplifier 15. Hence energy may be taken off from any one of the tank circuits 5, 12, 13 or 14 according to the switch setting.

The commutator switch S is preferably provided with a control knob 27 mounted on the switch shaft in front of the transmitter panel. This arrangement enables one to select a desired operating frequency without disturbing any of the apparatus behind the panel and particularly without changing any inductance coils.

While I have illustrated my invention in its application to exciter controls as used in different portions of the amateur bands reserved particularly for telegraphic communication, it is obvious that by a suitable choice of crystal frequencies the practice of the invention may be extended to cover frequency control in other carrier wave bands including those utilized for telephony. In constructing the amplifier stage in which the tube 15 lies it is preferable to adjust the values of the coupling condensers 20 and of the grid leak 41 so that the amount of exciting voltage impressed upon the amplifier tube 15 is maintained the same at all operating frequencies.

It will be understood by those skilled in the art that various modifications may be made in the circuits and in the structural arrangement of my invention without departing from the spirit thereof. The scope of the invention itself has such breadth as is determined by the following claims.

I claim:

1. In a device of the class described, a plurality of electron tube stages each of which except the final stage is adapted to function as an electron tube oscillator, each said oscillator having a piezo-electric crystal-controlled grid, and a unitary tank circuit connected between the cathode and a cold electrode thereof, each said tank circuit having an optimum inductive reactance value for setting up oscillations in its tube at a natural frequency of said crystal while it is at the same time tuned to substantially twice that frequency, means for shifting the function of said tubes in stages subsequent to the one selected for oscillation generation, thus to obtain one or a plurality of electron tube frequency multiplier stages each having a tank circuit tuned to twice the frequency of the energy to be applied as grid excitation to the tube of that stage, an amplifier stage, means for coupling any selected one of said multiplier stages directly to said electron tube oscillator and means for intercoupling at will a desired number of said multiplier stages between said oscillator and said amplifier stage.

2. In an oscillator and frequency multiplier, a plurality of electron discharge tubes in a cascade circuit arrangement, one of said tubes having a piezo-electrically controlled input circuit and a resonant output circuit, said output circuit comprising a single tank circuit characterized by assigning an inductive value L and a capacitive value C thereto such as to simultaneously satisfy the two equations

$$X=\frac{2}{3}\sqrt{\frac{L}{C}}$$

and

$$\frac{1}{CL}=\omega^2$$

where X is the value of inductive reactance of the tank circuit at the fundamental frequency and $\omega=2\pi$ times the second harmonic of the frequency to which said piezo-electrically controlled input circuit is naturally resonant, others of said tubes having means including input and output circuits adjusted to develop harmonics of said fundamental frequency, and a device including switching means for converting at least one of the tubes of said cascade arrangement from an oscillator to a frequency multiplier, and vice versa.

3. In an exciter for a radio transmitter, a plurality of electron discharge tube networks disposed in cascade arrangement, piezo-electric means for controlling the frequency of input energy applied to a selected one of said networks, means for selectively connecting the piezo-electric means with a desired one of said networks, each of said networks including on the output side thereof a single tank circuit whose inductive value L and capacitive value C are respectively adjusted to simultaneously satisfy the conditions necessary to establish resonance at a frequency twice that of the input energy applied to the same network, and also to present an inductive reactance at the frequency of said input energy sufficient to obtain an optimum value of feedback of that energy to said piezo-electric means upon connection of said network thereto, and means for adjusting the circuit constants of each network so that, under control of a given input frequency, frequency doubling occurs therein, and, so that upon selection of a piezo-electric means for controlling a desired one of said networks oscillations having a high second harmonic component are generated in that network.

4. In a circuit arrangement having a plurality of cascaded stages, each stage including an electron discharge tube, means for generating oscillations of a predetermined fundamental frequency in any selected one except the last stage of said tubes, means including a switching device effective upon the tubes in stages subse-

quent to the selected oscillation generation stage for shifting the function of said tubes to that of frequency multiplication whereby the output frequency of the ultimate stage is determined in dependence upon the selection of the particular stage in which to generate said fundamental frequency.

5. An arrangement in accordance with claim 4 and having a piezo-electric device in each of the alternative generating stages, said piezo-electric device constituting means for controlling the fundamental frequency of the oscillations generated.

6. A circuit arrangement comprising a plurality of electron discharge tubes connected together in cascaded stages, a tank circuit on the output side of each tube, said tank circuit being tuned to the second harmonic of a fundamental control frequency the energy of which is applied to said tube for the generation of oscillations therein, said tank circuit being further characterized in that it presents a sufficient inductive reactance at said control frequency for efficient oscillation generation, and a device including switching means for causing oscillations to be generated at said control frequency in a selected one of said tubes and for simultaneously maintaining the characteristics of the tubes in subsequent stages such that they are caused to function as frequency multipliers.

WALTER VAN B. ROBERTS.