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HIGH-FREQUENCY MULTIPLIER SYSTEM

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FIG. 1

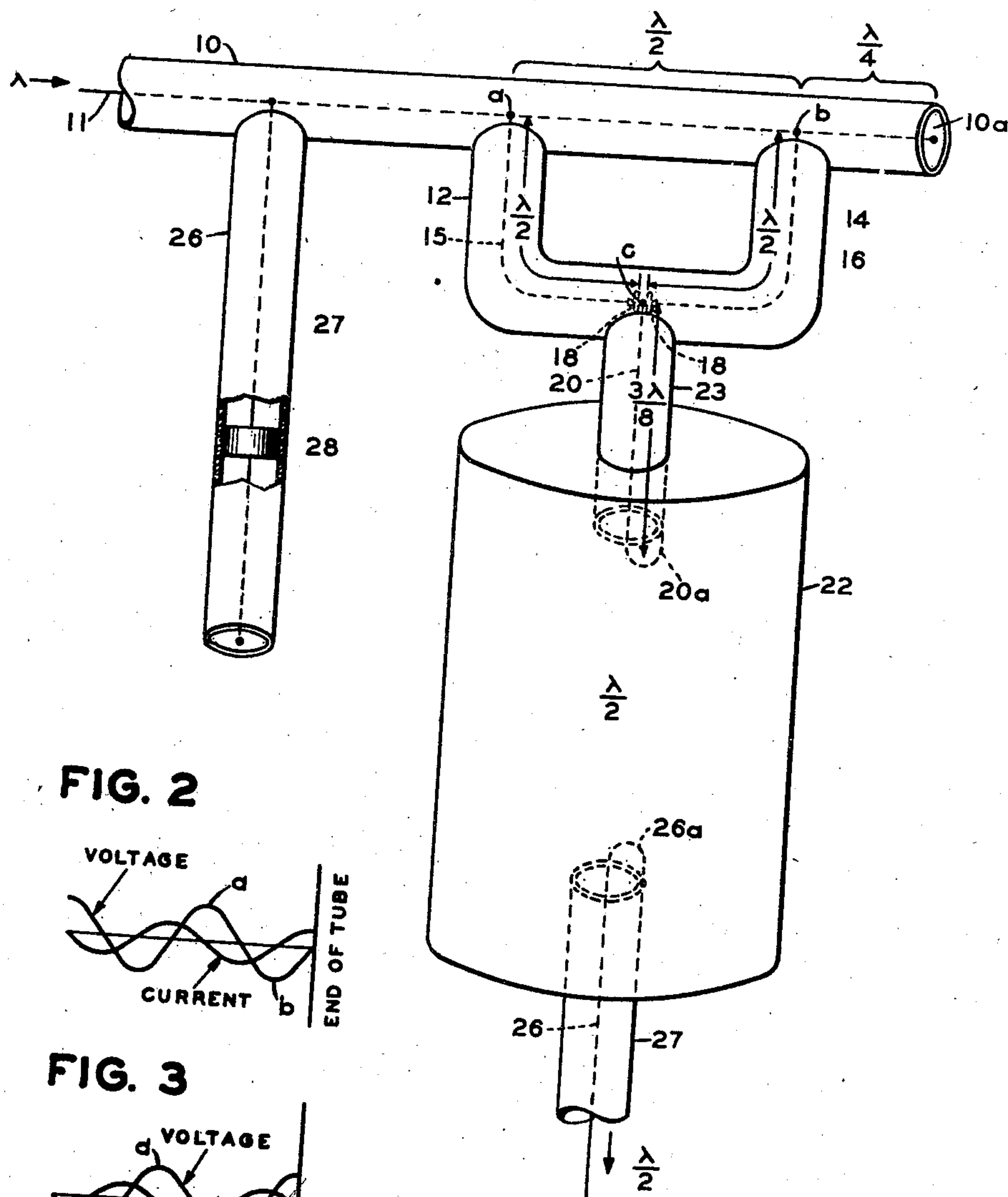


FIG. 2

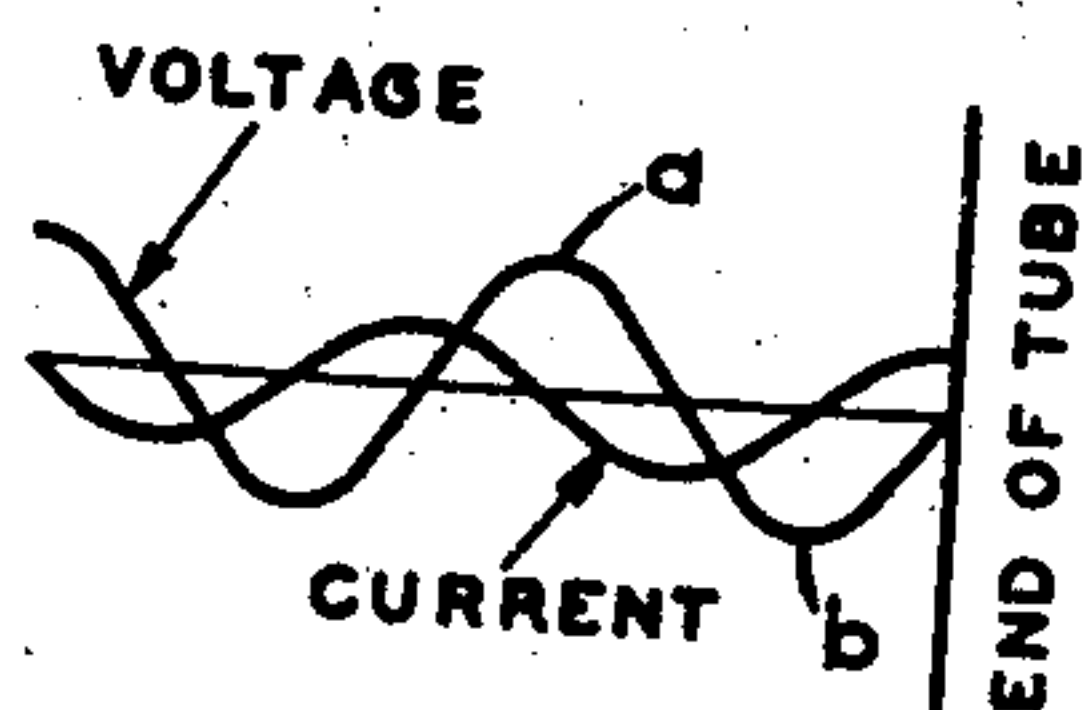
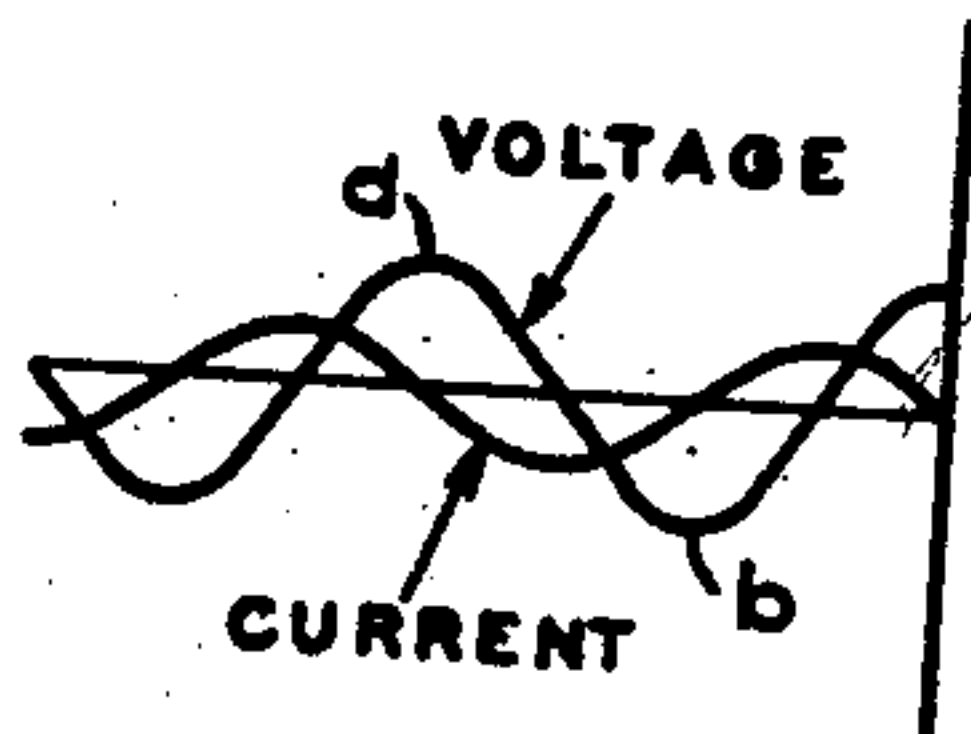


FIG. 3



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HIGH-FREQUENCY MULTIPLIER SYSTEM

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7 Claims. (Cl. 172-281)

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This invention relates generally to high frequency harmonic generators, and more particularly to multipliers for producing ultra-high frequencies and microwaves.

Various types of frequency multipliers, and particularly frequency doublers, for relatively low frequency currents have long been known. Such multipliers commonly involve an input transformer having a primary winding on which is impressed an original frequency, the transformer having its secondary winding associated with a rectifier circuit to provide full wave rectification of the original wave impressed on the input winding. The rectified current includes an alternating current component of twice the frequency of the original wave, and by means of a second transformer or other circuit elements an alternating current component is obtained which is twice the frequency of the original wave. Other known arrangements involve applying two or more alternating currents, differing in phase from each other, to rectifier and transformer circuits to obtain the second harmonic of the input frequency. None of these prior arrangements, however, is suitable for harmonic generators of ultra-high frequencies and microwaves.

In high frequency systems it has been proposed heretofore to employ harmonic generators, such as frequency doublers, involving electron tubes that are biased to operate at or past the knee of their saturation curves. These require complicated electronic structures and circuit arrangements, with attendant close and critical spacing of the electron elements, and are subject to variation which prevents them from having a desired stability of performance, and they involve serious adjustment and maintenance problems.

One of the objects of the present invention is to provide a harmonic generator for very high frequencies, in which various of the structural and operating disadvantages of devices heretofore proposed are obviated.

Another object is a harmonic generator of ultra-high frequencies and microwaves, which is simple in structure and is extremely stable in operation.

An additional object is a harmonic generator of the character described in which no electronic devices or complicated arrangements are required.

A further object is an improved harmonic generator which is especially adapted for use with coaxial systems for generating extremely short electromagnetic waves, for example, having wave lengths of the order of a few centimeters.

Other objects and advantages will be apparent from the following detailed description of one

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illustrative embodiment thereof, taken in connection with the accompanying drawings in which:

Fig. 1 shows a microwave frequency doubler constructed in accordance with the principles of the invention;

Fig. 2 shows wave form curves of certain standing wave components of voltage and current produced in the operation of the device of Fig. 1; and

Fig. 3 shows similar wave form curves employed in explaining the operation of a modified form of the device.

Referring to the drawings, there is shown a coaxial line structure comprising a metallic tube 10, of brass, copper or other suitable material, which encloses a central conductor 11, these elements being connected to, or comprising a portion of, a coaxial system that provides an input source of alternating current having, for example, a frequency of 2500 mc., corresponding to a wave length of 12 cm. The central conductor 11 may be either a solid wire or a small hollow tube, and is centrally supported within the outer tube 10 in known manner, as by means of spacers or washers of polystyrene, isolantite or other suitable low-loss insulating material. Any other suitable supporting means may be employed so long as it does not interfere with the desired tuning and resonant characteristics of the tube structure. In the embodiment illustrated in the drawing the right hand end of the tube 10 is closed by a solid plate 10a of brass, copper or other material, although as hereinafter pointed out the tube may be open at this end.

Secured to and in communication with the tube 10 are two bent coaxial sections 12 and 14 within which are centrally positioned conductors 15 and 16, the input ends of which are electrically connected at points a and b to the conductor 11, their output ends being connected to crystal rectifiers 18 centrally positioned within the tubes 12 and 14, the distance between the rectifiers preferably being as short as possible. The rectifiers are poled with respect to each other, as indicated in the drawing, and are rigidly supported in position within the tubes 12 and 14 in any suitable manner, as by mounting them within washers or blocks of polystyrene or other suitable means.

The distance between the points a and b and, consequently, that portion of the tube 10 between these points, is such that for an input wave having a given wave length λ , the spacing between these points on the standing wave is such that

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and current set up in tube 10 will correspond to a length of

$$\frac{\lambda}{2}$$

The term standing wave hereinafter referred to is to be understood as including a traveling energy component which is small compared to the stored energy component. That portion of the tube between the point b and the closed end 10a thereof has a length which corresponds to

$$\frac{\lambda}{4}$$

of the fundamental wave, whereby the voltage of the standing wave will reach its maximum value at the points a and b and produce adjacent crests which have a 180° phase difference, the one being negative when the other is positive and vice versa, as shown in Fig. 2. A current pulse per cycle of the fundamental wave is thus produced in each of the conductors 15 and 16.

The length of each of the conductors 15 and 16 preferably is such as to correspond to

$$\frac{\lambda}{2}$$

or any odd one-half wave length of the fundamental wave. This will in general minimize the crystal current at the fundamental frequency thereby to obviate possibility of injury to the crystals. Connected to the conductors 15 and 16, at a point c which is midway between the crystal rectifiers 18, is a centrally positioned conductor 20, the lower end of which forms a loop 20a within the upper end of a cylindrical resonant wave chamber 22, of brass or other suitable material, for exciting the chamber. The conductor 20 is centrally positioned within a length of tubing 23 thereby forming a coupler that extends from the adjoining ends of the tubular sections 12 and 14 through an end wall of the chamber 22. The length of the conducting path between each of the crystal rectifiers 18 and the exciting loop at the output end of conductor 20 preferably corresponds to

$$\frac{3\lambda}{8}$$

or any odd one-eighth wave length of the fundamental wave above referred to, thereby to provide maximum transfer of energy to the transmitting loop for exciting the chamber 22, and also to minimize crystal current at the frequency of the second harmonic.

Positioned within the lower, or output, end of the resonant chamber 22 is a conductor 26 having an end 26a that forms a receiving or pickup loop for the waves set up within the resonant chamber. The conductor 26 is centrally positioned within a tube 27, and in the coaxial circuit formed by the elements 26 and 27 there is induced an alternating current having a frequency that corresponds to the resonant frequency of the chamber 22.

In the illustrative embodiment the positions of the exciting and pickup loops, and the configuration and proportions of chamber 22, cause the chamber to be resonant at the wave length of

$$\frac{\lambda}{2}$$

for example, 6 cm., thereby causing a strong magnetic field of corresponding frequency, as 5000 mc., to be set up in the pickup loop 26a. The arrangement thus operates to select and re-

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transmit wave lengths which are one-half that of the fundamental wave length of the energy input to the resonant section 10, 11. Other forms of exciting and pickup loops, or antennae, may be used, and the configuration of the resonant chamber will vary accordingly, depending upon the radiation characteristic and pattern of the particular transmitting and receiving antennae employed. While the resonant chamber illustrated serves to select and retransmit the second harmonic of the fundamental wave length, it may be designed to select and retransmit various other even-numbered harmonics thereof, although the second harmonic is predominant and thus the greatest transfer of energy to the line 26, 27 will occur at such frequency. The linear dimension of the resonant section between the points a and b, and that of the section between the point b and the right hand end of the tube 10, will be different for operation at different input frequencies, and to facilitate this adjustable trombone sections may be inserted to cause the system to be resonant at the applied input frequency.

25 An adjustable tuning stub comprising a length of tubing 26 with a centrally positioned conductor 27, is connected to the resonant section 10, 11, and provides a means for closely matching the input impedance of the frequency multiplier to the impedance of the generator or other input source of the fundamental frequency. Tuning may be effected either by a slidable trombone section embodied in the stub or by a washer 28 of brass or other metal which is slidable along the central conductor 27 of the stub.

30 The right hand end of the tube 10 may be open, instead of closed, and reflection also will occur and standing waves are formed, but in this case a maximum voltage value of the standing wave will appear at the open end, and thus the point b would be located at a distance from the end of the tube corresponding to one-half of the fundamental wave, as shown in Fig. 3, so that points a and b will represent adjacent crests or maximum voltage values of the standing wave component. Such an arrangement, however, is not as efficient as that in which the end of the tube 10 is closed, because some of the energy escapes or is radiated from the open end.

40 The frequency multiplier may be employed with a resonant section in a transmission line, in which case a traveling wave, instead of a standing wave, will cause a difference in potential at the points a and b such as to induce in the resonant chamber 22 waves which are received by the pickup loop 26a. The standing wave arrangement is preferred, however, because of the higher voltage crests resulting therefrom and hence a greater amount of power obtainable.

50 While the frequency multiplier is primarily adapted for relatively low power because of the current limitations of the crystal rectifiers, a sufficient output is obtained to provide a very high frequency source for use in connection with wave guides, chambers, and the like, and the high frequency source thus obtained may, if desired, be amplified by suitable amplifiers designed to operate at such frequencies.

60 It will be apparent from the foregoing that the frequency multiplier unit may be constructed in various physical forms other than that specifically illustrated, and various modifications thereof may be employed, so long as the system enables suitable balanced voltages to ground to be obtained and applied to the resonant chamber

22. The specific embodiment illustrated is, therefore, for the purpose of disclosing the principles of the invention which is not to be regarded as limited except as indicated by the scope of the appended claims.

What is claimed is:

1. A high frequency multiplier system comprising a transmission line structure having an input portion for receiving a source of high frequency alternating current whereby an electromagnetic wave is set up in the transmission line structure in response to said input current, at least two rectifiers having input circuits respectively coupled to said transmission line structure at longitudinally spaced places corresponding to points on said electromagnetic wave that differ in phase whereby a plurality of current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said transmission line structure, a wave chamber which is resonant at a frequency that is a harmonic of the fundamental frequency of said alternating current input, coupling means connecting the output circuits of the rectifiers with said resonant wave chamber including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to the harmonic selected by the resonant chamber.

2. A high frequency multiplier system comprising a coaxial line structure having an input portion for receiving a source of high frequency alternating current whereby an electromagnetic wave is set up in the coaxial line structure in response to said input current, at least two rectifiers having input circuits respectively coupled to said coaxial line structure at longitudinally spaced places corresponding to points on said electromagnetic wave that differ in phase whereby a plurality of current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said coaxial line structure, a wave chamber which is resonant at a frequency that is a harmonic of the fundamental frequency of said alternating current input, coupling means connecting the output circuits of the rectifiers with said resonant wave chamber including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to the harmonic selected by the resonant chamber.

3. A high frequency multiplier system comprising a resonant line structure having an input portion for receiving a source of high frequency alternating current and characterized in that a standing electromagnetic wave is set up in the resonant line structure in response to said input current, at least two rectifiers having input circuits respectively coupled to said resonant line structure at longitudinally spaced places corresponding to points on said standing electromagnetic wave that differ in phase whereby a plurality of current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to the resonant line structure, a wave chamber which is resonant at

a frequency that is a harmonic of the fundamental frequency of said alternating current input, coupling means connecting the output circuits of the rectifiers with said resonant wave chamber including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to the harmonic selected by the resonant chamber.

4. A high frequency multiplier system comprising a coaxial resonant line structure having an input portion for receiving a source of high frequency alternating current and characterized in that a standing electromagnetic wave is set up in the coaxial line structure in response to said input current, at least two rectifiers having input circuits respectively coupled to said wave guide at longitudinally spaced places corresponding to points on said standing electromagnetic wave that are approximately opposite in phase whereby at least two current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said coaxial line structure, a wave chamber which is resonant at a frequency that is a harmonic of the fundamental frequency of said alternating current input, coupling means connecting the output circuits of the rectifiers with said resonant wave chamber including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to the harmonic selected by the resonant chamber.

5. A high frequency multiplier system comprising a coaxial resonant line structure having an input portion for receiving a source of high frequency alternating current and characterized in that a standing electromagnetic wave is set up in the resonant line structure in response to said input current, at least two rectifiers having input circuits respectively coupled by means of coaxial tube sections to said resonant line structure at longitudinally spaced places corresponding to points on said standing electromagnetic wave that are approximately opposite in phase whereby at least two current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said resonant line structure, the effective length of each of said coaxial tube sections corresponding approximately to the wavelength of a harmonic of the fundamental frequency of said alternating current input, a wave chamber which is resonant at the frequency of said harmonic, coupling means comprising other coaxial tube sections connecting the output circuits of the rectifiers with said resonant wave chamber and including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to said harmonic selected by the resonant chamber.

6. A high frequency multiplier system comprising a coaxial resonant line structure having an input portion for receiving a source of high

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frequency alternating current and characterized in that a standing electromagnetic wave is set up in the resonant line structure in response to said input current, at least two rectifiers having input circuits respectively coupled to said resonant line structure at longitudinally spaced places corresponding to points on said electromagnetic wave that are opposite in phase and one-half the wavelength of that of said alternating current input whereby two current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said resonant line structure, a wave chamber which is resonant at the second harmonic of the fundamental frequency of said alternating current input, coupling means connecting the output circuits of the rectifiers with said resonant wave chamber including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to said second harmonic selected by the resonant chamber.

7. A high frequency multiplier system comprising a transmission line structure having an input portion for receiving a source of high frequency alternating current whereby an electromagnetic wave is set up in the transmission line structure

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in response to said input current, at least two rectifiers having input circuits respectively coupled by means of coaxial tube sections to said line structure at longitudinally spaced places corresponding to points on said electromagnetic wave that differ in phase whereby at least two current pulses of different time phase are passed by the rectifiers during each cycle of the alternating current input to said line structure, the effective length of each of said coaxial tube sections corresponding approximately to an odd one-half wavelength of the fundamental wave of said alternating current input, a wave chamber which is resonant at a frequency that is a harmonic of the fundamental frequency of the alternating current input, coupling means comprising another coaxial tube section connecting the output circuits of the rectifiers with said resonant wave chamber and including means within the chamber for exciting it by the unidirectional current pulses received from the rectifiers, the effective length of said last named coaxial tube section corresponding approximately to an odd one-eighth wave length of said fundamental wave, and an output circuit including pickup means in said resonant chamber responsive to the waves set up therein for producing a source of alternating current having a fundamental frequency corresponding to said harmonic selected by the resonant chamber.

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