

Feb. 12, 1935.

R. M. HEINTZ

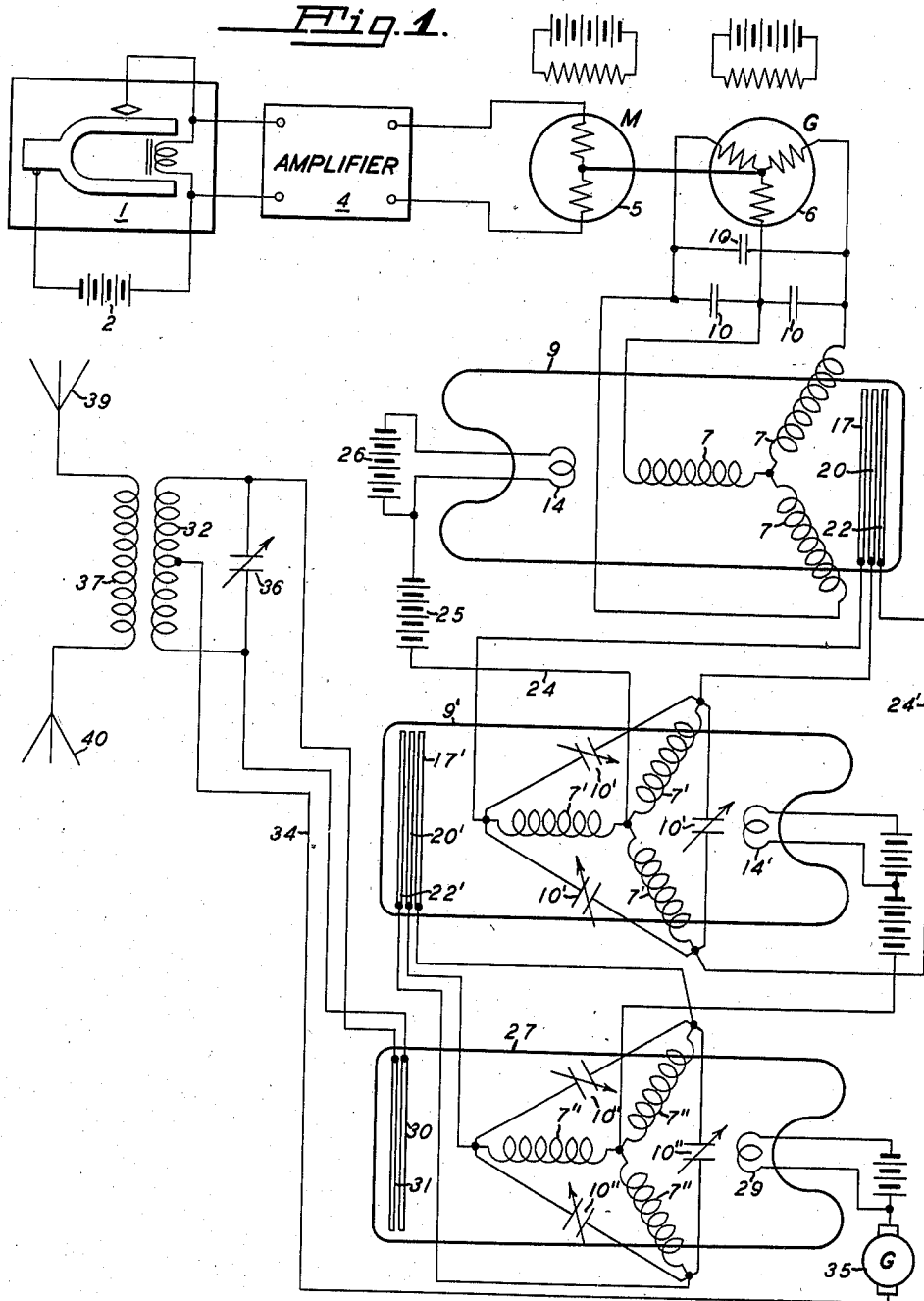
**1,990,733**

## FREQUENCY MULTIPLYING SYSTEM

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2 Sheets-Sheet 1

Fig. 1.



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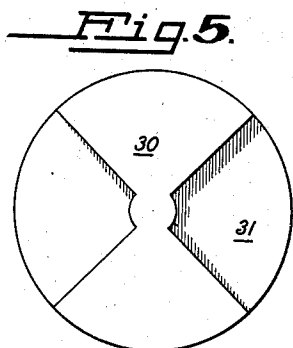
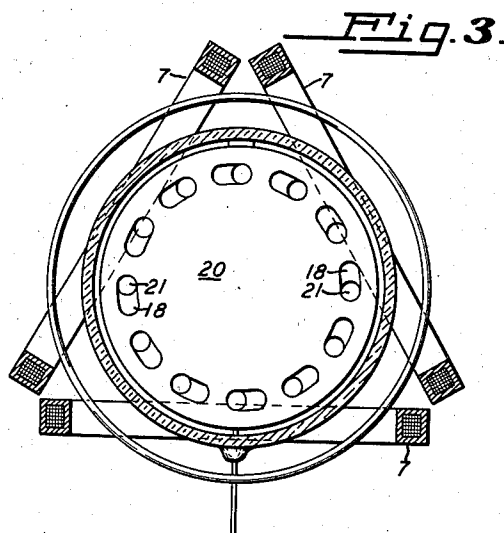
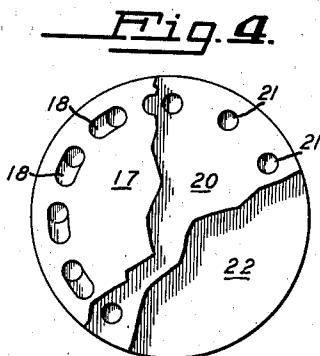
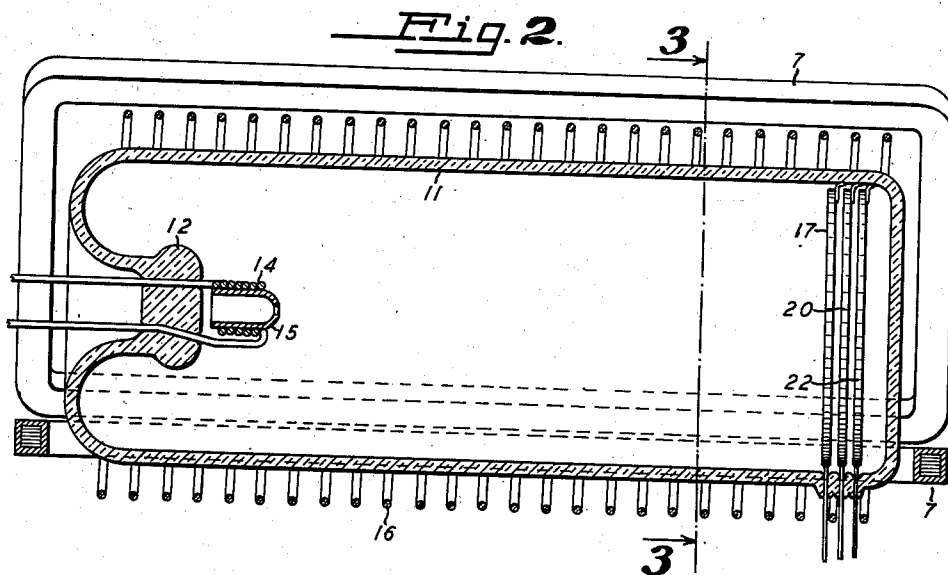
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FREQUENCY MULTIPLYING SYSTEM

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

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## FREQUENCY MULTIPLYING SYSTEM

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Application November 11, 1931, Serial No. 574,262

8 Claims. (Cl. 250—36)

This invention relates to frequency multipliers, this application covering a modification and improvement on the system described in my application, Serial No. 574,260 filed coincidentally with this application, and entitled high frequency generator.

Among the objects of my invention are: To provide a method of frequency multiplication wherein large multiplying factors may be obtained in each stage; to provide a multiplier wherein any desired number of stages may be connected in cascade to produce very great multiplication; to provide a multiplier wherein successive multiplying stages may be connected directly, without the necessity for buffer stages between; to provide a frequency multiplying system wherein power amplification may be obtained with each frequency multiplication; and to provide a means whereby a frequency standard, acting at low and readily controllable frequency, may be used to control radio frequency oscillation of the highest frequencies.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of my invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawings:

Figure 1 is a schematic diagram of a frequency multiplying system embodying my invention, wherewith a 120 cycle source is utilized to control a 13 meter radio wave.

Figure 2 is a diagrammatic longitudinal sectional view of a frequency multiplier embodying my invention.

Figure 3 is a transverse section of the frequency multiplier structure shown in Figure 2, the plane of projection being indicated by the line 3—3 in the second figure.

Figure 4 is a front elevation of the anode structure utilized in the tube shown in Figure 2, portions of the front anodes being cut away more clearly to show the arrangement.

Figure 5 is a front elevation of the anode structure utilized in the output tube of the frequency multiplier arrangement shown in Figure 1.

Broadly considered, the frequency multiplier of my invention comprises a tube for generating a beam of cathode rays. Means are provided for deflecting this beam of rays by means of a polyphase rotating field, in a substantially circular closed two-dimensional path. Positioned to intercept the path of the ray, is an anode

structure comprising a plurality of anodes, these anodes being positioned so that they intercept the beam of rays successively. The anodes are connected to a tuned polyphase circuit, and the successive excitation of the anodes by the impinging beam of rays, generates polyphase current in this circuit, the tuning of the circuit filtering out the high frequency components to provide substantially pure sine wave form in each phase. The anodes are preferably placed one behind the other, the forward anodes being perforated to permit the passage of the rays therethrough to the rear anode, and since there may be a plurality of such perforations in the path traced by the rays in one cycle of the deflecting current, the polyphase output circuit carries current of a multiplied frequency. The output circuit in turn is used to establish a rotating polyphase field for deflecting a second beam of cathode rays, which is utilized, as was the first, to provide a second frequency multiplication. As many such multiplications as desired may be provided, but since it is possible to produce 46 megacycles or even more, starting with a 120 cycle source and utilizing but three stages of cathode ray frequency multiplication, more than three stages is ordinarily superfluous. As little actual power is used to deflect the rays in any stage, large power amplification may be obtained with each frequency multiplication, and it is therefore possible to build high frequency radio transmitters, using no amplifiers of the ordinary three-electrode type, and with complete elimination of harmonic generators, buffer stages, and similar critical apparatus.

Describing in detail a frequency multiplier system utilizing my invention, Figure 1 shows an electrically driven tuning fork 1, of conventional design, which is actuated from a battery 2. This tuning fork would normally be under temperature control, but since apparatus of this type is in common use it is not shown or described here. The tuning fork output is fed into an amplifier 4, of conventional type, whose output supplies a synchronous motor 5. In practice, I preferably utilize a 120 cycle fork, which drives the two-pole synchronous motor at 7200 R. P. M.

The motor drives a generator 6, preferably of three-phase synchronous construction, and since the output required of this generator is small, I have found it readily possible, built with the large number of poles required, to obtain 14,400 cycles output. This is entirely a matter of design and of choice, since lower

frequency output may be used and an additional stage of cathode ray frequency multiplication incorporated in the multiplier.

The generator 6 feeds into the three-phase deflecting coils 7 of the cathode ray multiplier 9. The coils are shown as star connected, but they may equally well be delta connected. In order to improve the power factor of the generator, and obtain maximum effectiveness with a minimum of input, condensers 10 are preferably connected across each phase, these condensers and the coils being preferably tuned to the output frequency of the generator.

The actual structure of the frequency multiplier 9 and its surrounding coils is as shown in Figure 2. The multiplier comprises a glass envelope 11 having a stem 12, on which is mounted a cathode comprising a heating coil 14 and an internally emitting cylinder or thimble 15 for generating the beam of cathode rays. Although the heater type of cathode is to be preferred, the heating coil 14 may itself be used as a filamentary emitter, and this arrangement is shown in the diagrammatic views of Figure 1.

The deflecting coils 7 are uniformly disposed about the cylinder parallel to its axis, and generate a magnetic field which rotates at the frequency of output of the generator 6.

Any known means may be used for concentrating the beam of rays, such as "gas focusing", electrostatic focusing, or other suitable methods, but I prefer to focus magnetically by means of a solenoid 16 surrounding the tube and coaxial therewith. This arrangement has been described in detail elsewhere, including my above mentioned copending application, and is no part of this invention. The focusing coil is therefore omitted in the schematic diagram.

A plurality of anode plates, positioned one behind the other, are provided to intercept the cathode beam. In the arrangement shown the foremost plate 17 is provided with a circle of elongated holes 18, these holes being positioned in the path swept out by the deflected beam of rays from the cathode, so that the beam will pass through the holes for a portion of its travel along its path. The holes are preferably spaced by a distance which is one-half their maximum length, so that the beam is intercepted by the anode 17 for one-third of the time.

The second anode 20 is provided with a series of circular holes 21, which are alined with one end of the elongated holes in the anode 17. The third or rearmost anode 22 need not be perforated.

When the rays are deflected by the field from the coil 7 into a substantially circular path, they are first intercepted by the anode 17, then strike the holes 18 and pass through to the anode 20, and then pass through the holes 21 to reach the anode 22, after which they again fall on the anode 17, this cycle of operation being repeated a number of times for each deflecting cycle.

Figures 3 and 4 show a series of twelve holes in each of the anodes 17 and 20, giving a frequency multiplication of 12, but it is easily possible to obtain frequency multiplication of 40 or more, particularly in the first stage where small powers are used and the beam of cathode rays may be highly concentrated.

Each of the three anodes connects to one terminal of a second set of deflecting coils 7', these coils preferably being connected in star, and the lead 24 connects from the neutral, through a battery of other source 25, back to the cathode

14 of the tube 9. The cathode is shown as heated by a separate battery 26.

The output coils 7' are preferably tuned by variable condensers 10' in the same manner as the deflecting coils of the tube 9. These coils also produce a three-phase rotating field, whose speed of rotation or frequency is higher than that of the coils 7 by a factor equal to a number of holes in the anodes of the tube 9.

Arranged within the coils 7' is a tube 9', similar to the tube 9 but preferably of larger and heavier construction, since amplification may be obtained between the tubes. The parts of the tube 9' bear the same reference characters as are applied to like parts of the tube 9, but are distinguished by accents. In practice, however, the tube 9' is usually designed for a smaller multiplying factor, a practical application utilizing half the number of holes in the anode 17' that are used in the anode 17.

The output leads from the anodes 17', 20' and 22' connect in turn to a three-phase deflecting system comprising the coils 7'' and condensers 10''. Within this coil system is a tube 27, having an electrode-emitting cathode 29 and a pair of anodes 30 and 31. Except in the arrangement of its anodes the tube 27 is similar to tubes 9 and 9', although preferably built larger to handle greater power. The anode 30 is a plain disk, as shown in Figure 5, while the anode 31, placed in front of the anode 30, has opposite quadrants cut away to give it a "butterfly" shape. These two anodes connect to the opposite ends of an inductance 32, whose central tap connects through a lead 34 and a D. C. generator 35 back to the filament 29. The inductance 32 is tuned by a condenser 36, and is coupled to an inductance 37 which feeds an antenna 39, 40. In the figure this is shown as a doublet of the usual type.

The frequency multiplications obtainable with this system are extremely large. Using the 14,400 cycle input before mentioned, a multiplying factor of 40 has been obtained in the first tube, 20 in the second, and the anode structure shown gives a frequency multiplication of 2 in the last stage. This leads to an output frequency of 23,040 kilocycles, corresponding to a wave-length of approximately 13 meters. The substitution of a four sector anode for the two sector "butterfly" anode 31, would double this or give a wave-length of 6½ meters. It is therefore obvious that by varying the number of multiplying stages, the speed of the original driving fork, or the number of poles of the generator 6, that any frequency within the ordinarily useful radio range may be obtained with but three stages of tube multiplication. By the use of an additional stage a generator with a much smaller number of poles may be utilized as the initial drive, and the entire range may still be covered with anywhere from two to four tube multiplier stages.

The amount of work required from the output of each of these multiplying tubes, except the last, is relatively small. Their duty is merely to supply the deflecting field for the succeeding tube, which is a purely reactive load. The tuning condensers connected to the coils carry most of this load, at the same time filtering out the harmonics in the output current, so that only the losses need be supplied by the multiplying tube. The later tubes in the series utilize higher voltages and greater currents, and more deflecting field is therefore necessary in each succes-

sive tube, but amplifications of at least ten are readily available in each stage.

It is obvious that the usefulness of the device is not limited to three-phase outputs and rotating fields. Quarter-phase, six-phase, or any other type of polyphase drive may be accomplished by the use of four, six, or other appropriate number of superposed anode plates. The efficiency of conversion is probably greater however, and the wave form is better, with three-phase than with other polyphase arrangements.

Where polyphase radio waves are desired, the final tube may be of the same type as the tubes 9 and 9', instead of the simpler push-pull tube shown.

I claim:

1. A polyphase frequency converter comprising an electron-emitting cathode, threephase means for deflecting a beam of cathode rays emitted from said cathode, said deflection being in a closed two-dimensional path, a succession of three anodes positioned one behind the other in line with the path of the deflected beam, the first of said anodes having openings therein to permit the passage of said beam therethrough during two-thirds of the course of its path of deflection, and the second of said anodes having openings to permit the passage of the beam therethrough during one-third of its path of deflection, three inductors connected in star to said anodes, and three condensers connected in delta for tuning said inductors.

2. The method of frequency multiplication which includes the steps of generating a beam of cathode rays, generating a threephase field to deflect said rays in a substantially circular path, intercepting said beam to divert its component electrons cyclically into a plurality of channels during each cycle of deflection to produce a threephase current of higher frequency, generating a second beam of cathode rays, and utilizing said threephase current to deflect said second beam to produce a second frequency multiplication.

3. The method of frequency multiplication which includes the steps of generating a beam of cathode rays, generating a threephase field to deflect said rays in a substantially circular path, intercepting said beam to divert its component electrons cyclically into a plurality of channels during each cycle of deflection to produce a threephase current of higher frequency, filtering said polyphase current to remove harmonics therefrom, generating a second beam of cathode rays, establishing a rotating field with said threephase current deflecting said second beam by said field, and diverting said second beam successively into a plurality of channels to produce a second frequency multiplication.

4. A frequency multiplying system comprising a cathode ray tube including means for generating a beam of cathode rays, a plurality of anodes positioned successively to intercept said beam when deflected in a closed path, a three-phase deflecting system positioned so to deflect

said beam and comprising a plurality of deflecting elements, a source of direct current, means for diverting said current successively to said deflecting elements, and threephase tuning means connected to said elements and selectively responsive therewith to the frequency wherewith said elements are excited by said direct current, whereby the alternating component imposed on said elements is converted into a substantially uniform threephase component of fundamental frequency for uniformly deflecting said beam.

5. A frequency multiplying system comprising a cathode ray tube including means for generating a beam of cathode rays, a plurality of anodes positioned successively to intercept said beam when deflected in a closed path, a plurality of deflecting coils positioned uniformly about said tube and connected in threephase relation, a source of direct current, means for diverting said current successively through said coils, and threephase tuning means connected across said coils and selectively responsive to the frequency of excitation thereof whereby the fundamental alternating frequency of said excitation effects a substantially uniform deflection of said beam.

6. In combination, a cathode ray device including a plurality of anodes positioned successively to intercept a cathode ray which is deflected in a closed path, each of said anodes being arranged to intercept said ray a plurality of times in each cycle of deflection, a second cathode ray device including anodes arranged repeatedly to intercept a cathode ray in each deflection cycle, and a threephase deflection system positioned to deflect a ray in said second device and connected for supply from the anodes of said first mentioned device.

7. In combination, a cathode ray device including a plurality of anodes positioned successively to intercept a cathode ray which is deflected in a closed path, each of said anodes being arranged to intercept said ray a plurality of times in each cycle of deflection, a second cathode ray device including anodes arranged repeatedly to intercept a cathode ray in each deflection cycle, and a plurality of deflecting coils connected in threephase relation and connected for supply to the anodes of said first mentioned device.

8. In combination, a cathode ray device including a plurality of anodes positioned successively to intercept a cathode ray which is deflected in a closed path, each of said anodes being arranged to intercept said ray a plurality of times in each cycle of deflection, a second cathode ray device including anodes arranged repeatedly to intercept a cathode ray in each deflection cycle, a plurality of deflecting coils connected in polyphase relation and connected for supply to the anodes of said first mentioned device, and tuning means connected to said deflecting coils to render the deflection caused thereby substantially uniform.

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