May 29, 1934. R. M. HEINTZ ET AL 1,960,630

POWER ANTENNA

Filed Sept. 16, 1930 4 Sheets-Sheet 1

Fig. 1.

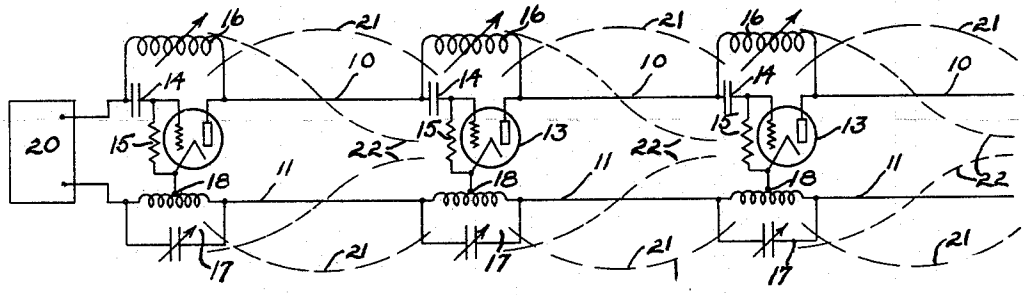


Fig. 2.

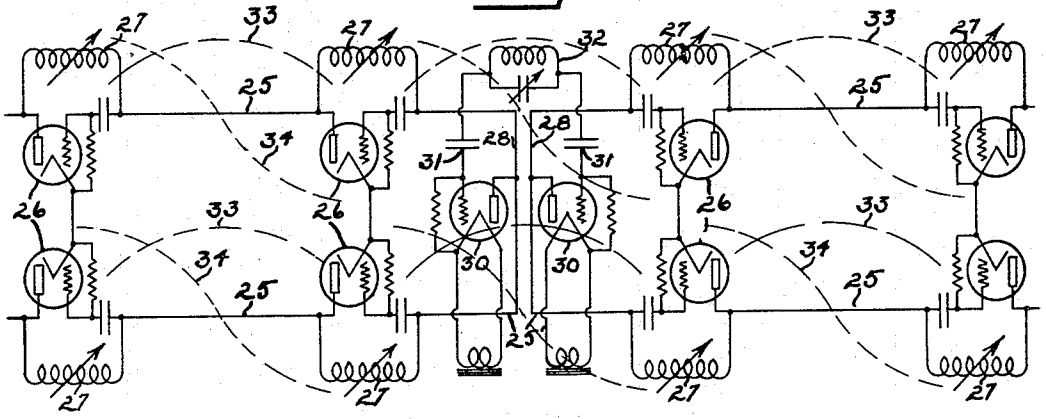
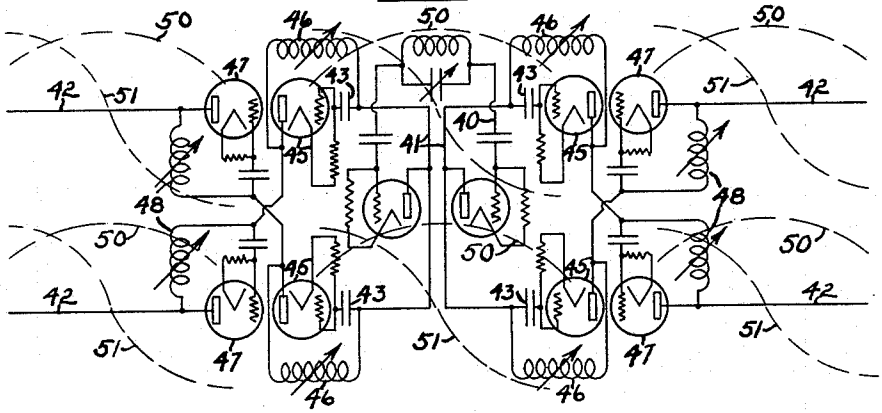


Fig. 3.



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Filed Sept. 16, 1930 4 Sheets-Sheet 2

Fig. 4.

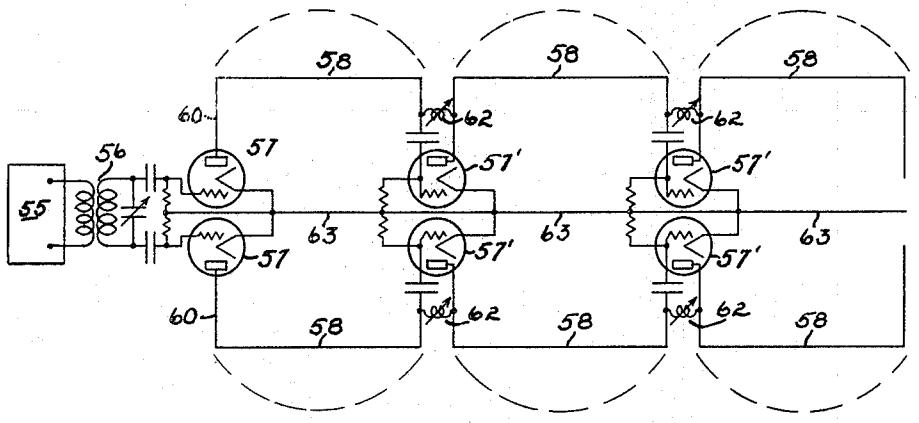


Fig. 5.

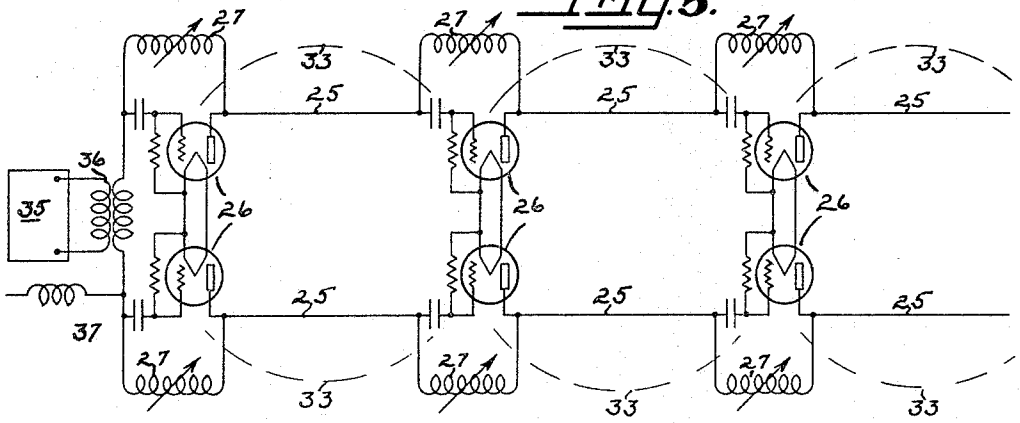
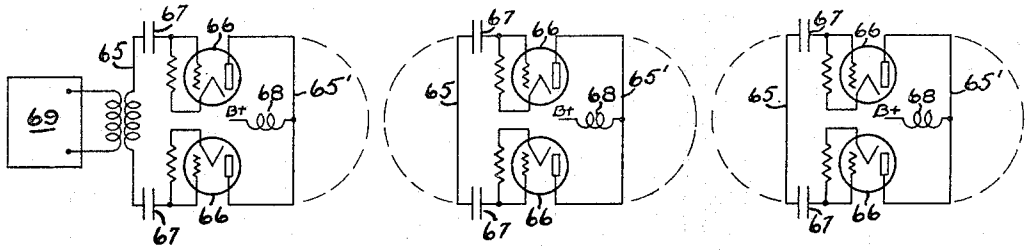


Fig. 6.



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POWER ANTENNA

Filed Sept. 16, 1930 4 Sheets-Sheet 3

Fig. 7.

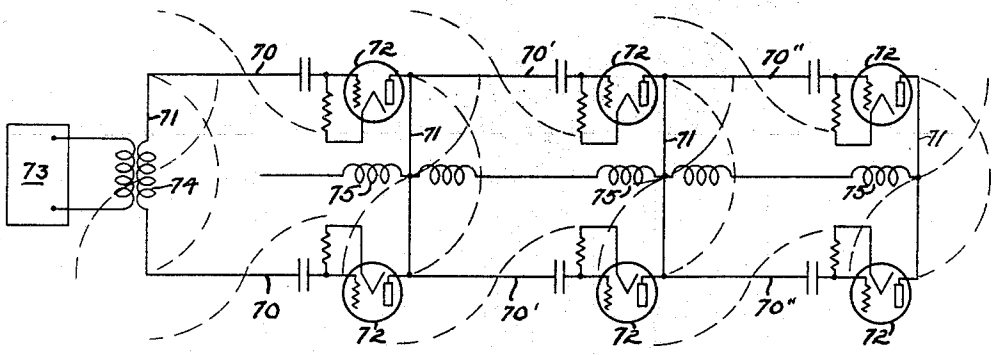
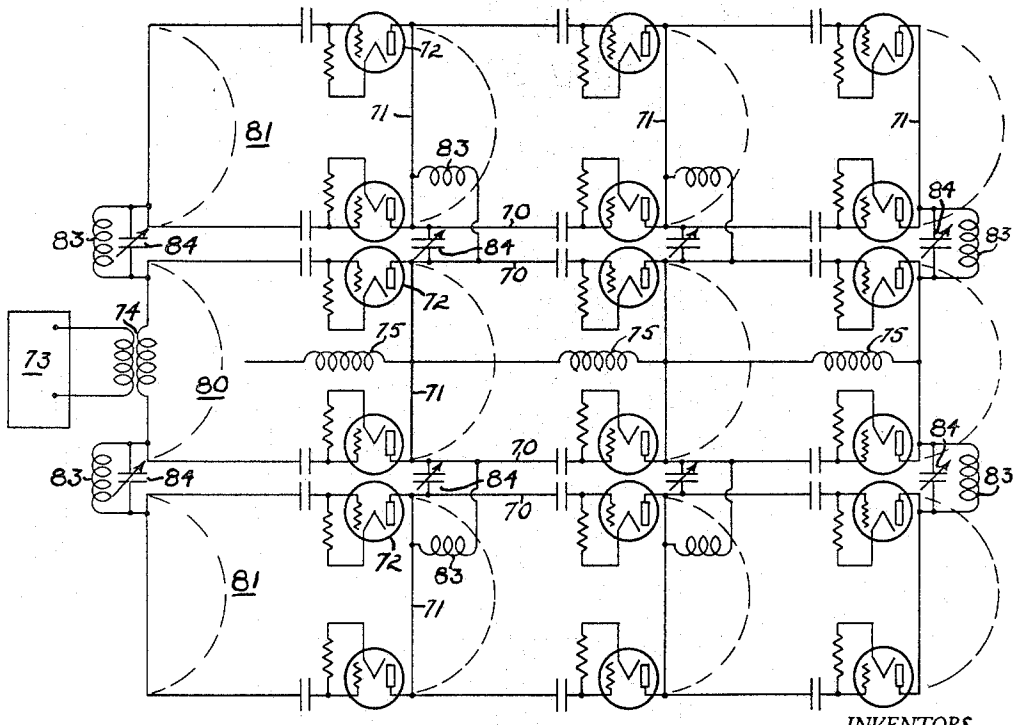


Fig. 8.



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POWER ANTENNA

Filed Sept. 16, 1930 4 Sheets-Sheet 4

Fig. 9.

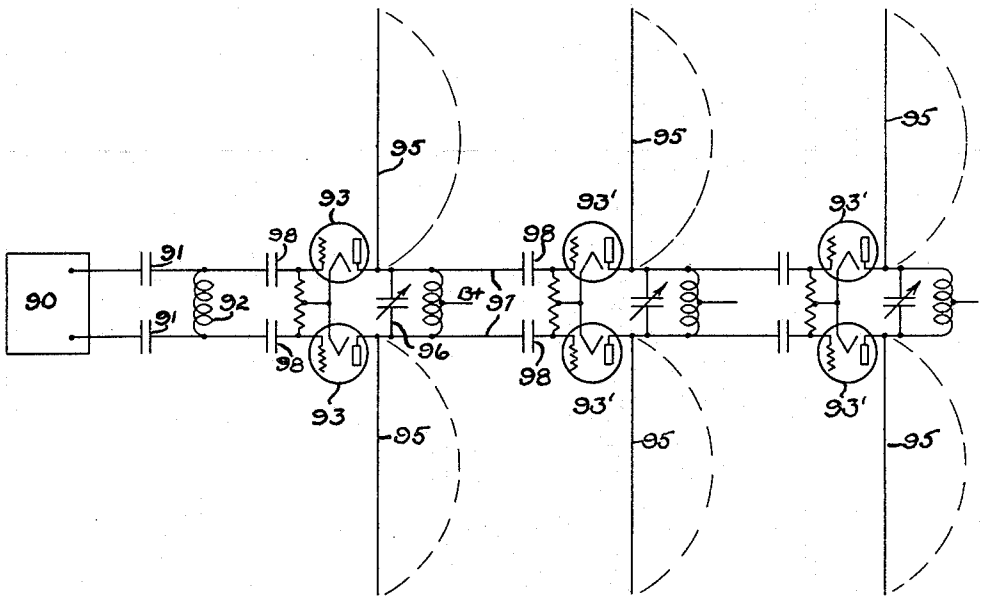
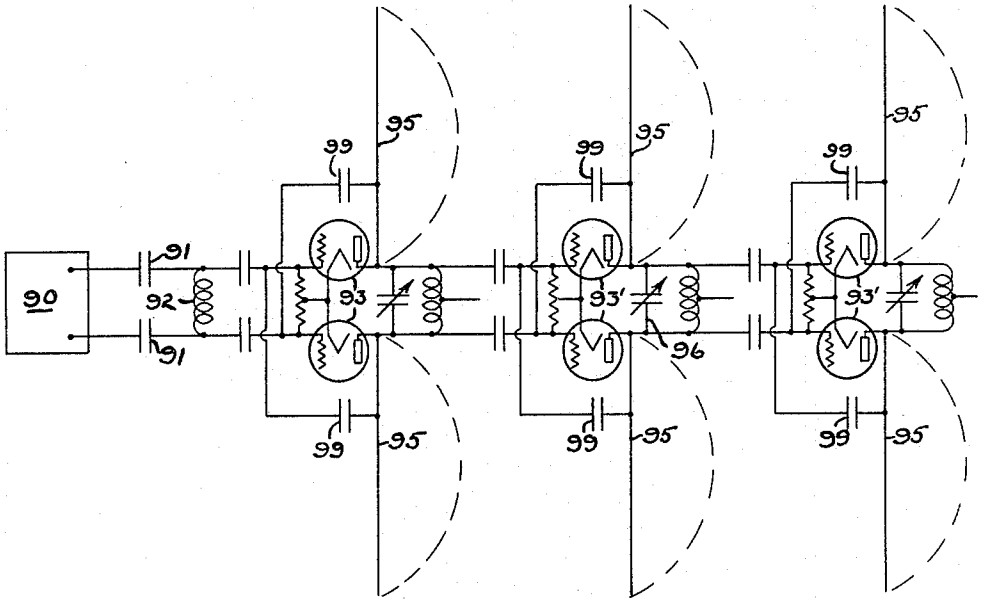


Fig. 10.



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UNITED STATES PATENT OFFICE

1,960,630

POWER ANTENNA

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Application September 16, 1930, Serial No. 482,246

10 Claims. (Cl. 250—11)

Our invention relates to antenna systems for radio transmission, and particularly to such systems for radiating power at high frequency.

Among the objects of our invention are: To provide a power antenna system having a minimum of transmission losses; to provide a directive antenna system wherein each element of the antenna array is equally excited; to provide a radiating system having a maximum of power in the radiating circuit and a minimum loss in non-radiative connecting circuits; to provide a system wherein the radiated wavelength is accurately determined by the spacing of the elements; and to provide a system having a high degree of frequency stability.

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

The figures of the drawings, numbered from 1 to 10, inclusive, are schematic diagrams showing antenna arrays embodying our invention. In these diagrams only the essential oscillating or high frequency circuits are shown, the supply circuits being omitted for the sake of clarity. These supply circuits, carrying direct or low frequency alternating current, may be of any suitable form, a number of which are well known to all skilled in the radio art.

In order that the circuits may be clearly shown within the limited space of the drawings, it is necessary to depict the oscillators as occupying a space of the same order as the antenna sections, but it should be borne in mind that this apparatus is actually localized at the nodal points.

In short-wave or high frequency practice, antennas are usually made an integral number of quarter wavelengths long, usually one half wavelength. Complete antennas may be made of a plurality of half wavelength sections, each section being essentially an individual antenna, and the sections being joined by suitable phase reversing means in order to bring the currents and potentials in the individual sections into the phase relation required in order that the waves radiated from the sections may reinforce each other a predetermined direction. Half wavelength antennas may be spaced in extended array, each antenna or section being spaced from its neighbors by an integral number of quarter wavelengths. Thus arranged, the complete antenna array may be made highly directional, the direction of transmission being dependent upon the spacing and arrangement of the sections.

Considered broadly, our invention comprises an antenna of this type provided with separate vacuum tube oscillators spaced along the antenna to provide power for each section. The various tubes are excited and held in synchronism by standing waves set up along the system. Such an antenna differs from the usual type in that there is no attenuation of these standing waves along the array, the waves being built up by the tubes located at the nodal points along the antenna. In certain types of antenna, the wave along the antenna may be reinforced by waves radiated from one antenna section, picked up or received by another section, and transmitted back to the control electrode of the tube energizing the section which radiated the wave. In this latter form, the structure may be considered as strictly self-exciting, as it will oscillate without tuned circuits other than the antenna structure itself. It is, however, advisable to use a master or driver oscillator in all cases, since such an oscillator injects into the circuit a stabilizing frequency which prevents oscillation upon harmonics of the fundamental antenna frequency and greatly increases the power which may be radiated from the antenna.

The diagram of Figure 1 represents an antenna array comprising two antennas, one consisting of the half wavelength sections 10, and the second consisting of similar half wavelength sections 11, arranged parallel to the sections 10 and spaced therefrom by one quarter wavelength. Spaced along the first antenna is a plurality of vacuum tubes 13, each having its plate or output electrode connected to one section and its control electrode connected to the adjacent section. A blocking condenser 14 is interposed between the control electrode of each tube and the antenna section to which it is connected, in order to block off the plate potential of the tube from the control electrode. The customary leak 15 is provided for biasing the control electrode.

A variable inductance 16 is bridged across the inter-electrode capacity of the tube, and is tuned to resonance with the antenna frequency. The parallel tuned circuit thus formed reverses the phase of a wave traveling along the antenna, so as to bring the adjacent sections 10 into the same phase, thereby causing the radiated waves to reinforce each other. Parallel tuned circuits 17 are interposed between the antenna sections 11, for the same reason. These circuits are provided with taps 18 at their nodal points, and the cathodes of the tubes 13 are connected to the taps.

The control electrode of the first tube 13' of the series is connected to a driving oscillator 20, which is tuned to the frequency of the antenna and makes the oscillations stable and positive.

The current and potential distribution along the two antennas is indicated by the curves 21 and 22 respectively. In this form of the device, the sections 11 are excited by radiation from the sections 10, and radiate a wave which reinforces

that from the sections 10 in the plane of the array and in the direction looking from the sections 11 to the sections 10. Since the antenna comprising the sections 10 is electrically continuous through the coils 16, no special arrangement need be provided for supplying plate potential to the tubes 13 and 13'.

In the form of our invention shown in Figure 2, a symmetrical arrangement is used. The two antennas comprising the sections 25 are identical, and are spaced one half wavelength apart. The tubes 26 are interposed between each pair of adjacent sections, and are bridged by the tuned inductors 27 in the same manner as the tubes 13 by the inductors 16. The center section 25' of each of the antennas is divided in the center, and is fed by the transmission line 28 from a symmetrical or push-pull driving oscillator.

The oscillator comprises tubes 30, whose control electrodes connect to the electrical center of the transmission line 28. The control electrodes of these tubes connect through the blocking condensers 31 to a parallel tuned circuit 32. The current distribution for this array is shown by the curves 33, and the potential distribution by the curves 34.

This arrangement has a maximum radiation perpendicular to its own plane. The transmission line 28 does not radiate, since the current in each side is equal and opposite to that in the other, and the two sides are closely contiguous in space.

Very similar to this arrangement is that of Figure 5, in which, however, the driving potential is applied at the end of the array. The reference characters have the same significance in this figure as in Figure 2 in so far as the antenna proper is concerned. The principal difference lies in the application of a driver oscillator 35, which is coupled to the system through the coupling transformer 36. The plate potential is supplied to the tubes through a radio frequency choke 37.

It will be noted that in the two cases last shown, the directional quality may be varied by changing the point of application of the driving potential. Thus, if the transformer 36 be located midway between the antennas as shown, the two antennas oscillate in opposite phase, and the array is directional in its own plane and symmetrically. If the driving potential be applied directly adjacent the end of either antenna, requiring a half wavelength transmission line to the other, the directional effect will be normal to the plane of the antennas as in the case of Figure 2.

The circuit shown in Figure 3 is also a symmetrical arrangement. A driving oscillator, similar to that shown in Figure 2, and designated by the general reference character 40, leads centrally into the transmission line 41 and thence into the two antennas comprising the half wavelength sections 42, which are spaced by a half wavelength. The outer end of each antenna section connects through a blocking condenser 43 with the control electrode of a tube 45. A tuning inductance 46 is bridged across the control and output electrodes of each tube, and the output electrode in turn connects with the control electrode of a tube 47, whose output electrode is connected with the succeeding section of the other antenna of the array. A tuning inductance 48 bridges control and output electrodes of this last mentioned tube. It will be seen that the interconnection between the pairs of tubes terminating the adjacent pairs of sections form high frequency transmission lines which do not radiate. The radiation pattern, as may be inferred from the current curves 50 and potential curves 51, is the same as that produced by the arrangement of Figure 2.

In Figure 4, the antenna is end excited by a driving oscillator 55 feeding through a tuned transformer 56 to the control electrodes of a pair of tubes 57. The output electrodes of these tubes connect to the antennas comprising the sections 58. The antennas are spaced one half wavelength, the tubes 57 being positioned midway between them and connecting thereto by quarter wavelength leads 60. Tubes 57' are similarly arranged in pairs midway between the antennas at their successive current nodal points. Control and output electrodes of each of these tubes are bridged by the tuning inductors 62. A neutral wire 63, spaced midway between the two antennas, connects the filament circuit of the successive tube.

This array radiates equally in opposite directions in its own plane. The neutral wire 63 takes no part in the radiation, since equal and opposite currents are induced in it by radiation from the two antennas.

In the arrangement of Figure 6 we have a further advance of the idea typified in the preceding figures. In this arrangement, each of the antennas 65, 65', is parallel to all of the others, and spaced one half wavelength therefrom along a common base line.

Spaced midway between each pair of antennas 65, 65' are the tubes 66, the control electrodes of each tube being connected through a blocking condenser 67 to the antenna 65, while its output electrode connects to the end of the antennas 65'. The antennas 65' are thus excited from each end, and they are fed with plate potential for the tubes through a radio frequency choke 68 connected to their central points.

The waves from any of the antennas 65' are received on the antennas 65 in proper phase to maintain oscillation in the circuit. This oscillation is self-sustaining, but because of the large amount of energy which is radiated, the circuit behaves in the same manner as oscillating circuits of high resistance, and possess considerable frequency instability. This effect may be overcome by coupling a driving oscillator 69 to the central point of any of the antennas 65. The result is a highly stable circuit which is extremely directive in both directions in its own plane.

It will be seen that whether the exciting current for any pair of control electrodes be considered as coming from its own plate circuit or from the plate circuit of an adjacent pair of tubes, it is not transmitted along the connecting wires, but is radiated by the antennas 65', transmitted across a space link, and received upon the antennas 65.

The same method of excitation of the oscillating tubes is utilized in the arrangement of Figure 7. A pair of antennas comprising the sections 70, 70', 70'', are spaced one half wavelength, and the ends of each parallel pair of sections are connected by an antenna 71 which is one half wavelength long.

The tubes 72 are connected between the sections of the antennas 70, the control electrode of each tube being connected to one section while its output electrode is connected to the next. A driving oscillator 73 is coupled through a transformer 74 to the ends of the antenna section 70 remote from the first pair of tubes. Both the antennas 70 and the antennas 71 are excited by

oscillations of the tubes 72, and the waves radiated from each of the antennas 71 arrive at the adjacent antenna 71 in proper phase to maintain the oscillation. Plate current for the tubes is supplied through radio frequency chokes 75 connected at the potential nodes of the antennas 71. The antenna is strongly directional normal to its own plane.

A plurality of structures such as that shown in Figure 7 may be combined as in Figure 8. The central portion 80 of this figure corresponds exactly to Figure 7. On either side of the central array is a similar structure 81, which is identical except for the omission of the driving oscillator 73 and coupling transformer 74. The side sections 81 are connected to the central section by parallel tuned circuits comprising the inductors 83 and variable condensers 84, which reverse the phases between the horizontal antenna portions 70, to bring the waves radiated from the vertical antenna section 71 into additive phase relation. As a result of this, the horizontal antenna sections 70 do not radiate, and hence become in reality transmission lines.

In Figure 9, the driver or stabilizing oscillator 90 feeds through a network of condensers 91 and inductors 92 to excite the control electrodes of a pair of tubes 93. The half-wave antennas 95 are connected to the output electrodes of these tubes, and a parallel resonant circuit 96 is connected between them to reverse the phase and make the radiated waves additive. The non-radiative transmission line 97 connects through the blocking condensers 98 with the control electrodes of the succeeding tubes 93', following which the structure repeats itself as many times as may be considered advisable. This structure has a maximum radiation normal to the direction of its own length, and is self-oscillatory as regards any section which comprises two antennas and one pair of tubes. The driving oscillator is required primarily for stability.

The circuit of Figure 10 differs from that of Figure 9, only in the inclusion of the neutralizing condensers 99, which are connected between the output electrode of each tube to the control electrode of the other tube of each pair. This destroys the self-oscillatory character of the circuit, and makes the driving oscillator 90 a necessary feature if any oscillation is to be produced.

We claim:

1. A radiating system comprising a plurality of antennas spaced substantially an integral number of quarter wavelengths apart, a vacuum tube having a control electrode connected to one of said antennas and a plate connected to another of said antennas, and a transmission line forming the connections for said plate and said control electrode of an electrical length of an integral number of quarter wave lengths such that an impulse initiated from said plate and radiated from said last mentioned antenna is received by said first mentioned antenna and returned to said control electrode in proper phase to maintain oscillation of said tube.

2. A radiating system comprising a plurality of spaced antennas, a vacuum tube having a control electrode connected to one of said antennas and a plate connected to another of said antennas, and a transmission line forming the connections for said plate and said control electrode of an electrical length which added to the spacing between said antennas equals an odd number of half wave lengths so that an impulse initiated from said plate and radiated from said last mentioned antenna is received by said first mentioned antenna and returned to said control electrode in proper phase to maintain oscillation of said tube.

3. A radiating system comprising a succession of antennas spaced substantially an integral number of quarter wavelengths apart at a predetermined frequency, and a succession of vacuum tubes arranged between said antennas and each having a control electrode connected to one antenna and a plate connected to a succeeding antenna.

4. The method of operating a vacuum tube having a control electrode and a plate electrode which comprises radiating an impulse from said plate, receiving a portion of the energy radiated, and transmitting said energy to the control electrode to initiate a new impulse from the plate.

5. An oscillating circuit comprising a plurality of antennas spaced to provide a space link in said circuit an integral number of quarter wavelengths long, and a vacuum tube having a control electrode and a plate electrode for causing oscillation in said circuit and connected respectively to said antennas to derive at least a portion of its control electrode potential from energy transmitted across said space link at the frequency of said oscillation.

6. The method of operating a vacuum tube oscillator which comprises radiating a portion of the oscillating energy, and utilizing the transmission time of the radiated energy in free space to determine the frequency of oscillation of said oscillator.

7. A radiating system comprising a pair of antennas spaced by an integral number of quarter wavelengths and each comprising a plurality of half wavelength sections, and phase reversing means between each of said sections, said phase reversing means in one of said antennas including a vacuum tube having a control electrode connected to one section and an output electrode connected to another section.

8. A radiating system comprising a pair of antennas spaced by an integral number of quarter wavelengths and each comprising a plurality of half wavelength sections, phase reversing means between each of said sections, said phase reversing means in one of said antennas including a vacuum tube having a control electrode connected to one section and an output electrode connected to another section, and means for injecting a stabilizing frequency into said system.

9. A radiating system comprising a pair of antennas spaced an integral number of quarter wavelengths apart and each comprising a plurality of half wavelength sections, parallel resonant circuits connecting adjacent sections, and a plurality of vacuum tubes each having a control electrode and an output electrode connected to different adjacent sections.

10. A radiating system comprising a pair of antennas spaced an integral number of quarter wavelengths apart and each comprising a plurality of half wavelength sections, parallel resonant circuits connecting adjacent sections, a plurality of vacuum tubes each having a control electrode and an output electrode connected to different adjacent sections, and a cathode connected to a nodal point of potential.

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