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R. BOWN

DIRECTIVE RADIO SYSTEM

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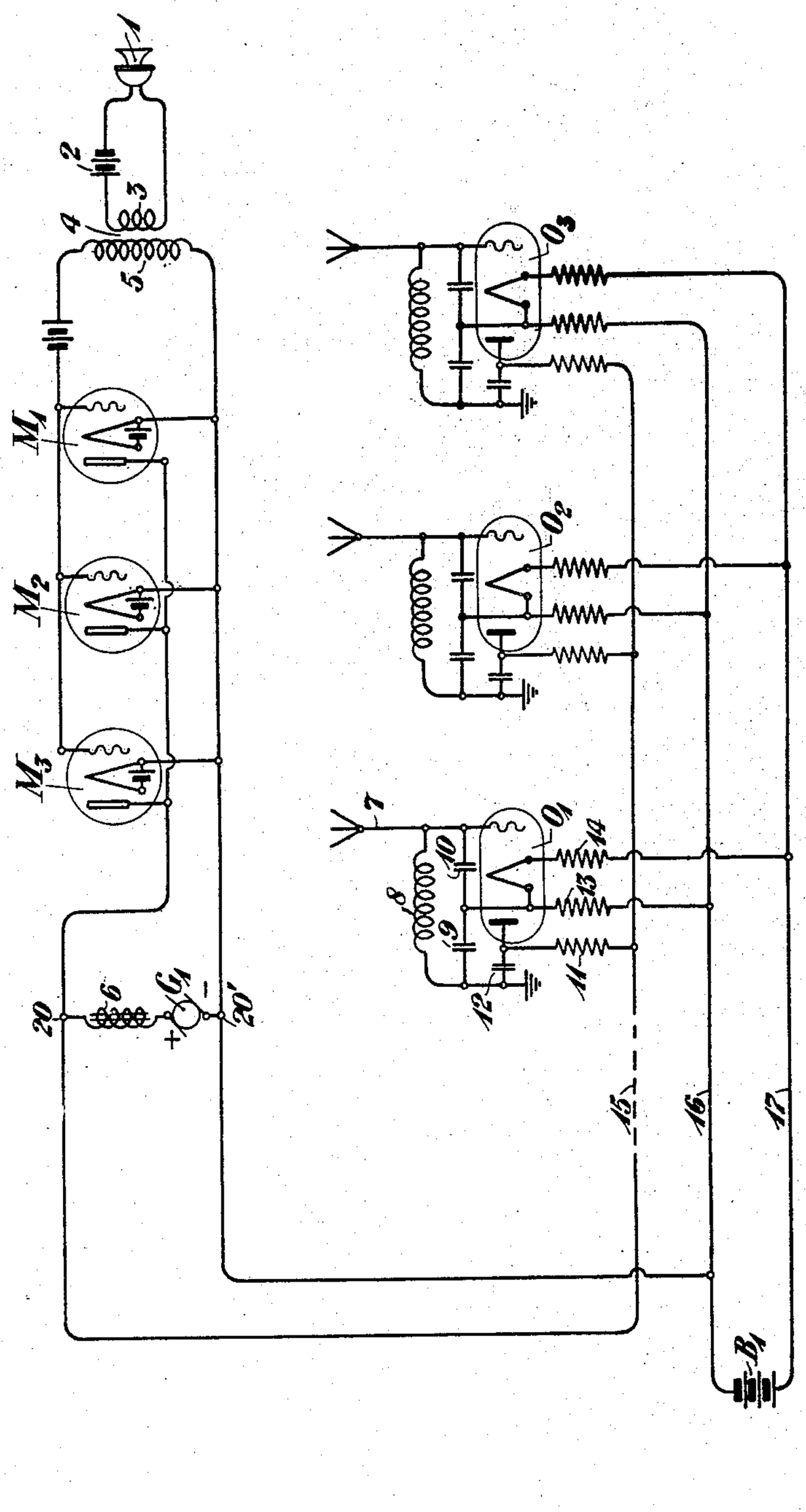

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DIRECTIVE RADIO SYSTEM.

Application filed November 12, 1920. Serial No. 423,604.

To all whom it may concern:

Be it known that I, RALPH BOWN, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain Improvements in Directive Radio Systems, of which the following is a specification.

This invention relates to directive radio systems and especially to means for synchronizing the radiation from a plurality of antennæ embraced in an antenna array.

It is well-known that directivity may be obtained in a radio system by grouping the antenna in a certain predetermined manner and by controlling the amplitude and the phase of the oscillations radiated by each antenna of the group. Such an arrangement is disclosed in the copending application of George A. Campbell, Serial No. 327,553, filed September 30, 1919.

It is the object of the present invention to provide means for controlling the frequency of oscillation of each antenna connected with such a directive system, so that all of the antennæ in an antenna array will remain in synchronism automatically, without using high frequency transmission lines or balancing circuits between the various systems of such an array.

Another object of this invention is to modulate simultaneously and from a central source the oscillations generated by the oscillation circuits individual to each antenna of the antenna array. Another object of the invention is to provide an arrangement for supplying from a central source the power necessary to heat the filaments of the vacuum tubes associated with the oscillation circuits of the antennæ.

Other and further objects of this invention will appear from the following description, when read in connection with the attached drawing, which shows one form of embodiment of the invention.

In the arrangement shown in the figure, a microphone 1, connected in series with a battery 2 and one of the windings 3 of a repeating coil 4, constitutes a source of the low frequency variations which are impressed upon the other winding 5 of the said repeating coil, which is connected with the grids and filaments of a plurality of vacuum tube modulators M_1, M_2 and M_3 in parallel. The source of low frequency variations is represented as a microphone for purpose of illustration only, and not to limit the scope of the invention, since any source of variation may be employed such as telegraph transmitting devices or other signaling apparatus. Bridged across the plate-filament circuits of these modulators in parallel is a source of direct current potential G_1, which is connected in series with a choke coil 6 which, if desired, may be of the iron-core type. This generator and its associated choke coil are likewise bridged across the plate-filament circuit of a plurality of vacuum tube oscillators, which are associated with a plurality of antennæ constituting an antenna array. Each antenna circuit comprises an antenna 7, which is connected to ground through an inductance 8 and condensers 9 and 10, the said condensers being serially connected with each other, and together in parallel with the said inductance.

It will be seen that the positive side of the generator G_1 is connected by conductor 15 and through a retardation coil 11 with the plate of each vacuum tube oscillating device. The negative side of the generator G_1 is connected by conductor 16 and through a retardation coil 13 not only to the filament of the vacuum tube oscillator, but also to the midpoint between the two condensers 9 and 10 of the oscillating circuit. The grid of the vacuum tube oscillator is connected directly with the antenna 7. For the purpose of heating the filament of each vacuum tube of each oscillation circuit, current may be supplied from a central source B_1 to the filaments in parallel over conductors 16 and 17, conductor 16 being common to the plate circuit and the filament heating circuit. Although the source of filament-heating current is represented as a battery, it is to be understood that either direct or alternating current may be used for this purpose, and any appropriate type of apparatus may be employed. Each of the antennæ connected with the common modulating source has the same type of oscillating circuit, and these antennæ are so spaced geographically as to have an appreciable reaction among themselves.

Having in mind the foregoing description of the various parts of this arrangement and

the function of each part, this invention will be better understood from the following description of its mode of operation.

When no low frequency variations are impressed upon the modulating system, only the direct current potential set up by the generator G_1 will be impressed upon the plate-filament circuits of the modulators M_1, M_2, M_3, etc., and of the oscillators O_1, O_2 and O_3, etc. The impression of a direct current potential across the plate-filament circuit of each oscillator tube, the filaments of which have been heated, will allow or cause the oscillation circuit of each antenna to function which results in the generation and radiation of unmodulated oscillations of a definite, predetermined frequency depending upon the constants of the oscillation circuit. This action, as is well known, arises from the electrical instability of circuits of this type. Briefly stated, the impression of a potential across the plate-filament circuit of an oscillator either charges, or varies the charge upon condensers 12 and 9. The effect upon condenser 9, in turn varies the grid potential which consequently results in a variation of the plate-filament current. The cycle of operations, thus begun, will continue so long as a potential is applied to the plate-filament circuit, and the oscillation circuit, of which the antenna forms a part, will continue to generate and radiate oscillations, of predetermined frequency. It is to be noticed that such generation is not dependent upon the impression of low frequency variations upon the oscillator.

The oscillation circuits of all the antennæ comprised in the array are tuned as closely as possible to the same frequency, and consequently there will be generated and radiated oscillations having substantially the same frequency. It has been discovered that if two vacuum tube oscillators are respectively connected to two antenna systems which are in close proximity, it is oftentimes difficult to obtain low frequency beats between the two oscillators. It has been noticed that when their frequencies are brought close to the same value, the oscillations tend to pull into exact synchronism with each other in a manner closely resembling the action of two alternators connected to the same bus-bars. Furthermore, it has been seen that the frequency of either or both oscillators, after having been brought to a state of synchronism, will jump discontinuously from the same value to slightly different values as the natural period of oscillation of the respective circuits is altered, instead of passing smothly from one value to another. This tendency of adjacent oscillatory circuits to work into synchronism and to tend to maintain such synchronous condition, is, of course, due to the coupling effect which exists between two antenna structures relatively adjacent. With a properly designed system the effect is very noticeably present, even though antenna coupling is so small that one would anticipate substantially no result therefrom.

In view, therefore, of this inherent characteristic of oscillation circuits, loosely coupled, the slight variations of frequency of the generated oscillations are compensated for, and the resulting radiated oscillations are in synchronism.

The high frequency oscillations are kept out of the circuits connected with the generator G_1 and the filament heating source B_1 by means of reactances 11, 13 and 14, inserted in the leads connecting the oscillators with the conductors of the said circuits.

When, however, variations are set up in a circuit containing the microphone 1 by the impression thereon of sound waves, similar variations will be produced in the grid-filament circuits of the modulators M_1, M_2 and M_3. These variations result in variations of the current flow in the plate-filament circuits of the same modulators, which causes a difference in potential across the circuit comprising the generator G_1 and the choke coil 6, that is to say, across the points 20 and 20′. These variations of potential will result in corresponding variations in the current flow through the plate-filament circuits of the oscillators O_1, O_2 and O_3. These variations in current flow will produce differences in potential across the condensers 12, 9 and 10 which, in turn, result in varying the charge upon the grid of the oscillator. The high frequency oscillations which are being generated by each oscillation circuit are modulated in accordance with the variation of potential across the points 20—20′ which modulation results from the current variation of the plate-filament circuit of the modulators M_1, M_2 and M_3 when low frequency variations are impressed on the said modulators. No claim for invention is made for this mode of modulating high frequency oscillations, which is substantially that disclosed in the copending application of Heising, Serial No. 131,868, filed November 17, 1916. Furthermore, my invention is not limited to the use of this particular system of modulation but may be embodied in arrangements in which other and different systems of modulation may be employed.

My invention consists broadly in the application of the observed principle of self-synchronization of oscillation circuits to an arrangement which is designed to obtain directivity in a radio system. The antennæ which are associated with the oscillators O_1, O_2 and O_3 should be so spaced that the effect of any one antenna would always be in synchronism with the effect of any other antenna at the point of location of any an-

tenna whatever in the system. The mode of arrangement of these antennæ is clearly set forth in the Campbell application, heretofore referred to, the simplest case of which is, of course, a linear arrangement where the antennæ are spaced apart by an even multiple of the wave length. No claim is made by me for the proper spacing of the antennæ in such an array. My invention lies in the application of the principle, heretofore described, to any antenna array, or arrays.

It will be seen that, by utilizing the principle of self-synchronization of a plurality of oscillation circuits, loosely coupled by means of their associated antennæ, I am further enabled to control the operation and to modulate the oscillations of the said oscillation circuits from some central point adjacent to or remote from the place where the said oscillation circuits are located, and thereby to minimize the cost of installation and of maintenance of such systems. The cost of installation is minimized by the application of the principle of self-synchronization, whereby all the antenna units of an antenna array will remain in synchronism automatically without the use of high frequency transmission lines or balancing circuits between the various units of the array. By means of the arrangement embracing my invention, it is necessary to have at each antenna unit of such an antenna array only an oscillation circuit connected with a transmission line with which may also be connected at some central location a source of modulated direct current, for controlling the oscillations radiated from the entire array. Furthermore, the energy for filament heating is also supplied from a central source over a transmission line to each vacuum tube. Broadly speaking, all apparatus requiring attention except the vacuum tubes associated with the oscillation circuits, is located at the central control point, so that the maintenance costs of such system is reduced to a minimum.

Although this invention has been described in connection with a specific circuit arrangement, it is to be understood that it is capable of embodiment in other forms and arrangements, without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a high frequency signaling system, the combination with a plurality of antennæ, each having an oscillation circuit and a multi-electrode thermionic oscillation device associated therewith, the antennæ being spaced an even multiple of a wave length apart, of a common modulating arrangement, whereby the oscillations of each oscillation circuit may be simultaneously varied, and a common source of energy for heating one of said electrodes of the said thermionic devices.

2. In a high frequency signaling system, the combination with a plurality of antennæ, each having an oscillation circuit and a multi-electrode thermionic oscillation device associated therewith, the antennæ being spaced an even multiple of a wave length apart, of a common source of energy remote from the said antennæ for heating one of the electrodes of the said thermionic device.

3. In a directive radio system in which the antennæ are spaced an even multiple of a wave length apart, the method of controlling the waves radiated from the plurality of antennæ having a plurality of multi-electrode vacuum tube oscillators associated therewith, which consists in tuning the oscillation circuits of each antenna to substantially the same frequency, impressing upon two of the electrodes of each vacuum tube oscillator waves modulated in accordance with the impressed signals and allowing the generated oscillations of the various antennæ to interact so as to produce substantial synchronism between the various antennæ of the system.

4. In a directive radio system, the combination of a plurality of antennæ having certain predetermined relative positions, each of the said antennæ having an oscillation circuit and a thermionic oscillator connected therewith, a thermionic modulator having a source of low frequency variations connected with the grid thereof, and a source of direct current bridged across the plate-filament circuits of the said modulators and the said oscillators, whereby oscillations may be set up on the said oscillatory circuits in accordance with the low frequency variations, and means for varying the frequency of each of the said antennæ until the degree of difference between the respective frequencies is such as to be compensated for by the natural reaction between the respective antennæ, whereby absolute synchronism is obtained.

5. In a high frequency signaling system containing an antenna array consisting of a plurality of antennæ spaced at even multiples of a wave length apart, each of said antennæ having individual thereto a vacuum tube oscillation circuit, a power circuit common to all of said vacuum tubes and a modulating circuit common to all of said antennæ and adapted to control the energy output thereof, the method which consists in tuning the said oscillation circuits to substantially the same frequency, supplying from a central point to each of said oscillation circuits the energy to be radiated therefrom and simultaneously modulating the energy in each of said oscillation circuits.

6. In a system such as is set forth in claim 1, the method for remotely controlling a directive radio signaling system, which consists in setting up from a central point oscillations at each of a plurality of antennæ

arranged in an antenna array, tuning the said antennæ to obtain substantial identity of frequency and modulating from a central point the oscillations set up at each of said antennæ.

7. In a system such as is set forth in claim 1, the method of remotely controlling a directive radio signaling system comprising a plurality of thermionic oscillators associated with a plurality of antennæ spaced an even multiple of a wave length apart and forming an antenna array, which consists in supplying from a remote central source energy for each of said oscillators, tuning said antennæ for substantial identity of frequency and simultaneously modulating the oscillations produced by each oscillator.

8. In a high frequency signaling system, the combination of a plurality of antennæ spaced an even multiple of a wave length apart, an oscillation circuit individual to and associated with each of said antennæ, a power circuit common to all of said oscillation circuits having a source of power connected therewith and a common modulating arrangement connected with said power circuit whereby the oscillations of each oscillation circuit may be simultaneously varied.

9. In a high frequency signaling system, the combination with a plurality of antennæ spaced an even multiple of a wave length apart constituting an antenna array, of a plurality of vacuum tube oscillation circuits individual to and connected with each of said antennæ and a power supply circuit common to all of said vacuum tube oscillation circuits to furnish the energy necessary to create oscillations in said circuits.

10. In a high frequency signaling system, the combination with a plurality of antennæ spaced an aven multiple of a wave length apart constituting an antenna array, of a plurality of vacuum tube oscillation circuits individual to and connected with each of said antennæ, a power supply circuit common to all of said vacuum tube oscillation circuits to furnish the energy necessary to create oscillations in said circuits and modulating means connected with said power supply circuit for varying the oscillations set up in said oscillation circuits.

11. In a directive radio system in which the antennæ are spaced an even multiple of a wave length apart, the method of controlling the waves radiated from the plurality of antennæ of such system, which consists in energizing from a central point the oscillation circuits individual to each antenna, tuning the oscillation circuits of each antenna to substantially the same frequency and modulating from a central point the oscillations of the said oscillation circuits in accordance with impressed signals.

12. In a high frequency signaling system, the combination with a plurality of antennæ tuned to substantially the same frequency and so spaced as to have considerable interaction between them, of a plurality of vacuum tube oscilaltion generators individual to and connected with each of said antennæ, all of said oscillation generators being adjusted to produce substantially the same frequency, a vacuum tube modulator, a source of direct current connected with the plate electrodes of said oscillation generators and said modulator, and a signaling device for modulating the high frequency oscillations radiated by each of said antennæ.

In testimony whereof, I have signed my name to this specification this 11th day of November 1920.

RALPH BOWN.