May 19, 1942. R. M. WILMOTTE 2,283,619

RADIO ANTENNA SYSTEM

Filed Dec. 18, 1941 2 Sheets-Sheet 1

Fig. 1.

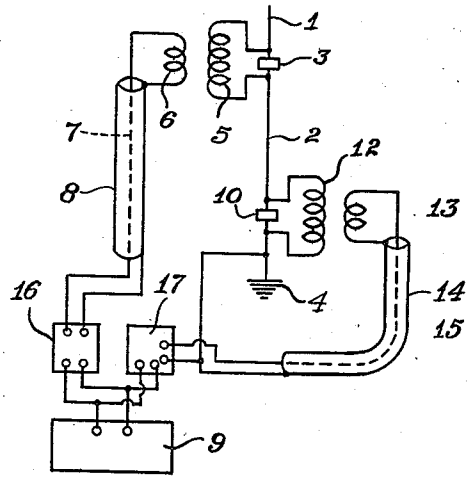


Fig. 2.

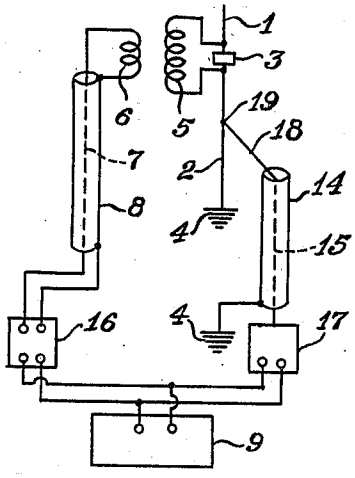


Fig. 3.

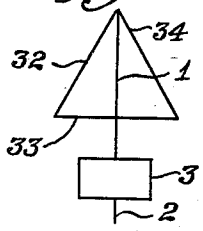


Fig. 4.

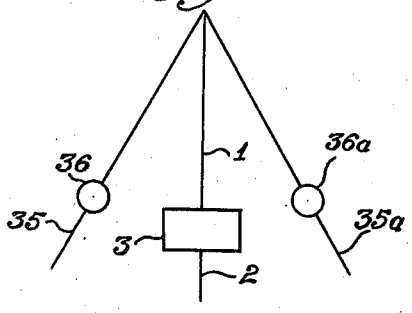
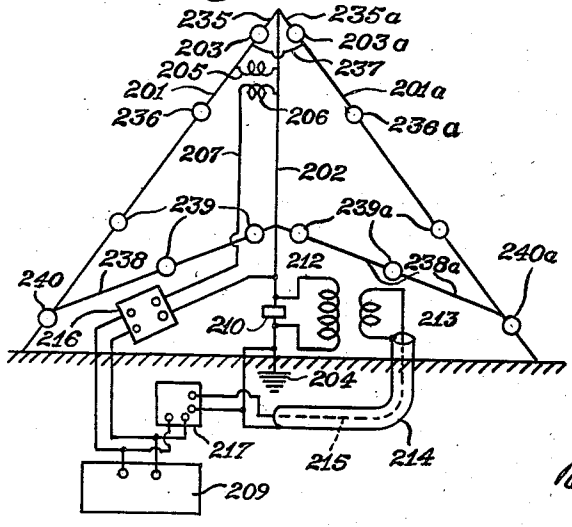


Fig. 5.



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Fig. 6.

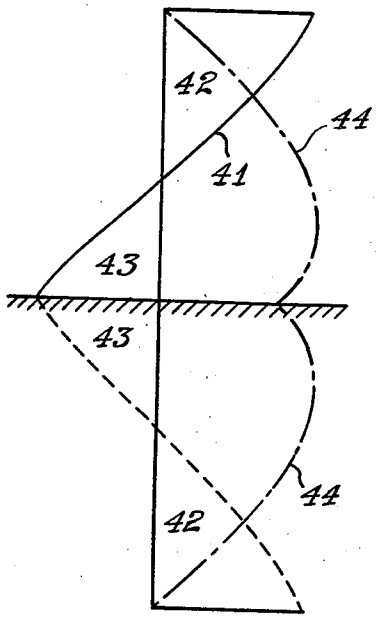


Fig. 7.

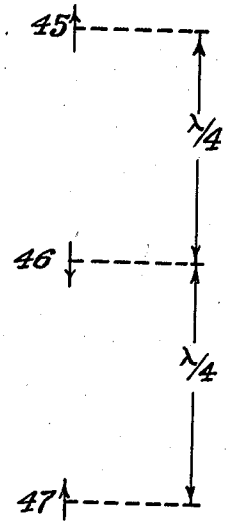


Fig. 8.

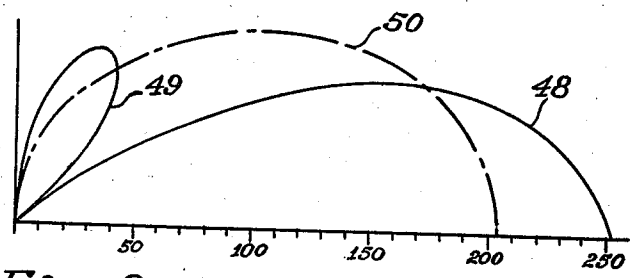
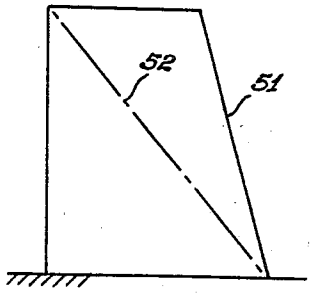


Fig. 9.



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UNITED STATES PATENT OFFICE

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RADIO ANTENNA SYSTEM

Raymond M. Wilmotte, Washington, D. C.

Application December 18, 1941, Serial No. 423,540

12 Claims. (Cl. 250—33)

This is a continuation-in-part of my co-pending application entitled Antenna, Serial No. 392,439, filed May 8, 1941.

This invention relates to radio antenna systems and, more particularly, to radiators having a controlled pattern of radiation.

It is known that the radiation pattern of an antenna depends on the current distribution in the radiating element. In the usual vertical radiating element, generally energized at the bottom end, the current distribution is approximately a section of a sine curve, having a zero value at the top end of the radiator. It is possible to use a somewhat different section of the sine wave by using a top loading in the vertical element. One object of this invention is to provide a system wherein the current distribution along the radiator may be predetermined and may be adjusted. If a simple vertical element is used the invention will permit selecting a current distribution corresponding approximately to any desired part of the sine curve without the use of an expensive structure. There have been some other approaches to the problem of obtaining a current distribution other than that obtainable in a simple vertical antenna; such an antenna is that known as the Franklin antenna, and variations thereof, wherein two or more half wavelength sections were aligned end-to-end and fed at the bottom and/or junction point, the radiation pattern corresponded to a current distribution of two or more sine curves, one for each section, each comprising equal half a wave loops of line curve. By the present invention it is intended, first, to produce a current distribution along a radiator which may be varied at will and, second, to provide a system wherein the radiator need not be any simple relation to a wavelength. In this system, for instance, a radiator of shorter length than would normally be used may be utilized, with obvious constructional and economic advantages as well as operating flexibility.

The present invention contemplates a transmission line extending from phase and amplitude control apparatus, preferably near the base of the tower, upwardly and closely adjacent the tower structure substantially to the top thereof. Additionally, where the tower is insulated at its base from the ground, it is also intended to prevent the transmission line adjacent the tower from short circuiting the base insulator.

Specifically, it is now proposed to provide a vertical radiator fed both at the ground and also at an upper point, and to control the current distribution along the length of the radiator by controlling the phase and amplitude of the energy fed at one point relative to that fed at the other.

These and other objectives will appear from the following specification and drawings, in which:

Figure 1 shows a two section antenna fed with predetermined voltages between the sections and between the lower section and ground.

Figure 2 shows a two section antenna fed between the sections and fed in shunt near the grounded end of the lower section.

Figure 3 shows a form of top loading on an antenna.

Figure 4 shows another form of top loading on an antenna.

Figure 5 shows another embodiment of the invention.

Figure 6 shows a typical current distribution in a radiator of the type illustrated in Figures 1 to 5.

Figure 7 shows the direction of the currents in a radiator according to the present invention.

Figure 8 shows a radiation pattern of an antenna according to the present invention.

Figure 9 shows the current distribution in the radiator which is small compared with the wavelength according to the present invention.

In Figure 1 is shown one form of the present invention wherein the radiator comprises the top section 1 separated from a lower section 2 by an insulator 3. The top section may be a simple vertical section and which, for instance, may be provided by means of capacity or top loading. The lower section is insulated at its base by insulator 10. The antenna is fed through a coupling network such as from the secondary 5 of the transformer 6—5 by connecting secondary 5 between antenna sections 1 and 2 across insulator 3. Primary 6 is fed from a remote source of power such as transmitter 9 over a suitable transmission line such as 7—8. By means of another coupling circuit shown by transformer 12—13, in which the secondary 12 is connected across the insulator 10 and the primary 13 is coupled to the transmitter 9 through transmission line 14—15 and coupling circuit 17, the radiator is fed at a second point along its length; namely, across insulators 3 and 10. The current distribution in radiator 2 is controlled by the phase and amplitude relation of the excitation across insulators 3 and 10. The voltage fed at these points may be in any phase and may be positive or negative relative to the current flowing at these points. This control of the current distribution may be achieved through the coupling

circuit 16 and 17. Under certain conditions power may be fed back to the transmitter through one or other of the coupling circuits. Top section 1 may be so designed as to cause some radiation or not, depending on the radiation distribution required.

Figure 2 shows the variation of the present invention in which the insulator 10 of Figure 1 is removed and the excitation near the ground is replaced by the system well known in the art as shunt feed, which is achieved by connecting the transmission line 14—15 by means of wire 18 to a point 19 located along the length of the radiator 2. The radiation pattern may be controlled by varying the dimension of sections 1 and 2, the location of point 19, to which the shunt feed to section 2 is made and the relative phase, amplitude of the two exciting voltages, etc.

Figure 3 shows a well known form of top loading in which capacity is added to radiator of section 1 by an added conductor formation, as, for instance, that of conductors 32, 33 and 34.

Another form of top loading is shown in Figure 6, which comprises portions of guy wires 35, 35*a*, insulated at a selected distance from the top section 1 by means of insulators 36, 36*a*.

Many other forms of loading will be apparent to those skilled in the art within the spirit and scope of the invention. They may be used not only on the top section 1, but also if desired on the lower section 2. They may also be used at some other point than the top, if desired.

Figure 5 is another embodiment of the invention wherein guy wires of which 235, 235*a*, 201, and 201*a* are parts and which may assist in the support of radiator 202, further constitute means of feeding radiator 202 at the top end thereof. It will be seen that the top conductor now consists of sections 201, 201*a* of guy wires lying between insulators 203, 203*a* and 236, 236*a* and connected together by wire 237. Radiator 202 is excited near its top end by means of means of transformer 205—206, one end of the secondary 205 being connected to guy wire sections 201, 201*a* and the other end being connected to radiator 202 near its top. The primary 206 is coupled by means of a transmission line which consists effectively of a wire 207, and the radiator 202, to coupling circuit 216, which couples it to a transmitter 209. The radiator 202 is insulated at the base by insulator 210 across which is connected the secondary 212 of transformer 212—213. The primary 213 of this transformer is coupled through the transmission line 215—214 to coupling circuit 217 to transmitter 209. The radiator 202 is shown supported by other guy wires such as 238, 238*a* which are insulated in sections as is common in the art, by insulators such as 239, 239*a* and 240, 240*a*.

The performance of a radiator excited according to this invention will depend on the design of the radiator and on the type of circuits and on the type of excitation. It is possible to change the type of excitation without changing the overall height, as for instance, by exciting the radiator at an additional point, loading it at some other point along its length, exciting the radiator at the same number of points but changing the location of these points along the radiator, changing the physical structure of the radiator, etc. In the case of a guyed radiator, the structure can be readily loaded at an intermediate point along its length by using suitable sections of guy wires.

In order to explain the principle of the invention a specific case will be considered. Referring to the generalized diagram of Figure 1, it will be assumed that the top section 1 will not produce any appreciable radiation, so that all the radiation will come from the lower section 2. It will also be assumed that lower section 2 is substantially uniform in cross section so that the current distribution is approximately sinusoidal. The ground 4 is assumed to be perfectly conductive. In this particular example an antenna will be assumed to be ⅓ of a wavelength long and that by properly exciting the radiator at the top and bottom by means of couplings 16 and 17, a current distribution shown by the full line 41 in Figure 6 is obtained. It will be seen that the current distribution consists of two loops, a positive loop 42 and a negative loop 43. The dashed line corresponds to the image in the ground of this current distribution. The particular current distribution selected is such that the area of loop 42 is equal to approximately twice the area of loop 43. If the radiator 2 had been excited from the base only the current distribution would correspond to that shown by the chain line 44.

As far as the radiation distribution in the vertical plane is concerned, this current distribution may be represented by the radiation from three equal dipoles 45, 46 and 47 in Figure 7, in which the flow of current in dipole 46 is in the opposite direction to the flow of current in dipoles 45 and 47. The distance between the dipoles 45 and 47 is approximately half a wavelength and dipole 46 is midway between these two. Dipoles 45 and 47 correspond respectively to the positive loops of the current distribution 41 shown in Figure 6, while dipole 46 corresponds to the negative loop 43 of the current in Figure 6.

The radiation distribution in the vertical plane from this system of dipoles is given by the equation $E=K \cos \theta$. [2 cos (90 cos θ)—1], where K is an arbitrary constant and θ is the angle of elevation.

Assuming that 1 kilowatt of energy is radiated, the effective field at one mile is shown by the full line 48, 49 in Figure 8. If radiator 2 had been excited simply at the base, thus producing a current distribution corresponding to curve 44 in Figure 6, the radiation distribution in the vertical plane would be approximately that shown by the chain line 50 in Figure 8. It will be seen by comparing curve 48, 49 with curve 50, that the radiation in the horizontal direction for the antenna excited in accordance with this invention corresponds to an unattenuated field at one mile of 252 millivolts per meter, while in the case of the simple antenna of the same height excited at the base, the effective field in the horizontal plane would be only 204 millivolts per meter. This gain in the horizontal plane is obtained because of the reduction in the radiation at high angles.

An analysis of Figure 8 will also show that at an elevation of about 45 degrees, the radiation from the antenna excited in accordance with the invention is very small. For certain purposes such as reducing or controlling the effect of the fading wall, this reduction of signal in predetemined angles of elevation is of importance.

It should be pointed out that in connection with this example, the calculations are based on the assumption that 1 kilowatt of power is radiated. In practice, however, it is usual to have a specific power available for the input of the antenna, the power radiated being the balance

between the power input and the power loss in ohmic, dielectric and ground losses in the neighborhood of the antenna. If, in the example given above, it is assumed that the losses are proportional to the integral of the square of the current flowing in the antenna (an assumption which will generally be incorrect in view of the dielectric and ground losses) it is then found that the loss in the antenna, designed in accordance with this invention, is about 28 times as great as the loss in a simple vertical antenna of the same height, but excited at the base for a given power radiated. This result means that for a given input the power radiated in an antenna according to my invention may be less than the power radiated from an antenna excited at its base. For instance, taking the radiation resistance of a simple vertical antenna ⅓ of a wavelength high to be about 58 ohms and assuming that the losses correspond to .5 of an ohm, the effective field in the horizontal plane at one mile for 1 kilowatt input to the antenna will be reduced from 204 millivolts per meter to 203 millivolts per meter. The field from the antenna operated in accordance with this invention will be reduced from 252 millivolts per meter to 226 millivolts per meter. Therefore, while the total power radiated from an antenna in accordance with my invention may be less than from an antenna excited from its base, the field in a desired direction may nevertheless be greater.

The example given above is not intended to represent a condition for obtaining maximum signal in the horizontal plane for a given power input to the antenna. It will be evident that the directivity may be controlled by changing the ratio of the positive current loop **42**, to the negative current, loop **43**, of Figure 6, without changing the height of the radiator. The change in directivity thus produced will have the effect of controlling the signal in the horizontal plane relative to the signal in other directions. It will also have the effect of changing the radiation resistance and the losses. It is possible, therefore, to excite an antenna so as to produce an optimum directivity condition; if a given amount of power is to be radiated, this condition will correspond to the maximum signal in the required direction for the particular method of excitation which is equivalent to the condition of maximum directivity. If, instead, the power input of the antenna is given, the optimum condition will then depend not only on the directivity, but also on the ohmic and other losses. In certain cases it will be found that this optimum condition is controlled principally by the optimum condition for directivity, while in others, the effect of the ohmic losses may have a dominant influence.

In order to obtain approximately maximum signal in the desired direction with a given antenna height, I have found that the type of excitation must be designed so that a condition is reached in which the ohmic and other losses play an important part. One object of my invention is, therefore, to use a design whereby the directivity may be increased so that the radiation resistance becomes comparable to the "loss" resistance and is so adjusted as to produce a maximum field in the required direction.

It will generally be found that if the optimum directivity is a dominant controlling factor in obtaining a maximum signal in the desired direction for a given power input to the antenna, then it becomes possible to improve the performance of the antenna by altering the excitation in accordance with my invention until the optimum condition is reached. Since these losses are difficult to evaluate and measure, it is important in many cases to be able to adjust the excitation until the measured field is a maximum. The invention is particularly suitable to permit such adjustments for all that is necessary to adjust the coupling circuit **16** and **17** shown in Figure **1**.

The invention may also be used in the case of an antenna the length of which is short compared with the wavelength. In such cases, which occur frequently with long wave transmissions, the losses in the ground, dielectric and coupling circuits are frequently large compared with the power radiated, so that the efficiency of the antenna is low. According to this invention it is possible to produce a current distribution along the radiator as shown by full line **51** in Figure 9. The chain line **52** corresponds to the current distribution which would be obtained if the radiator were excited at the base. It will be seen that the field from such a radiator excited in accordance with this invention will be nearly twice as great as the field from a simple vertical antenna excited at the base, assuming that the current at the base is the same in both cases. This means that the radiation resistance of such an antenna excited in accordance with this invention may be approximately 4 times the radiation resistance of a simple vertical antenna excited at the base. While the radiation distribution will be approximately the same in both cases, the efficiency of the antenna excited according to my invention will therefore be considerably greater than the efficiency of a simple vertical antenna excited at the base.

In accordance with the practice in the art, the antenna system, while intended primarily for transmission, may be used for reception, the term translating means being intended to cover both receivers and transmitters.

The invention described above is not limited to the specific disclosure, but should be given the full range of substitutions and equivalents within the scope of the following claims.

What I claim is:

1. In a radio antenna system, an antenna element having first and second ends, an aperiodic electrical loading element juxtaposed at one end of said antenna element, a translating means, first and second means for transferring electrical energy between said first and second ends, respectively, of said antenna element and said translating means, means coupling said first means between said antenna element and said aperiodic element, and means for controlling the relative phase and amplitude of the voltages on said antenna element, whereby to control the current distribution along said antenna element.

2. In a radio antenna system, a radiator having first and second ends, an aperiodic electrical loading element adjacent one end of said radiator, first and second means for transferring signal energy at said first and second ends, respectively, means coupling said first means to the end of said radiator adjacent said aperiodic element, and means for controlling the relative phase and amplitude of the voltages on said radiator whereby to control the current distribution along said radiator.

3. In a radio antenna system, a radiator, an aperiodic electrical loading element juxtaposed to one end of said radiator, a source of signal

energy, first and second feed means for transferring signal energy between said radiator and said source of signal energy at both ends respectively, means electrically coupling one of said feed means between said radiator and said aperiodic element, and means for controlling the phase and amplitude of the signal energy on said radiator, whereby to control the current distribution along the length of said radiator so as to maintain the radiation resistance of the radiator in the same order of magnitude as the loss resistance.

4. A radio antenna system as claimed in claim 4, said aperiodic element comprising a second radiator.

5. In a radio antenna system, an antenna element having first and second ends, an aperiodic electrical loading element juxtaposed at one end of said antenna element, a translating means, first and second means for transferring electrical energy between said first and second ends, respectively, of said antenna element and said translating means, means coupling said first means between said antenna element and said aperiodic element, and means in said first means for controlling the phase and amplitude of the electrical energy transferred thereby relative to the phase and amplitude of the electrical energy transferred by said second means.

6. In a radio antenna system, an antenna element having first and second ends, an aperiodic electrical loading element juxtaposed at one end of said antenna element, a translating means, first and second means for transferring electrical energy between said first and second ends, respectively, of said antenna element and said translating means, means coupling said first means between said antenna element and said aperiodic element, and means in said second means for controlling the phase and amplitude of the electrical energy transferred thereby relative to the phase and amplitude of the electrical energy transferred by said first means.

7. In a radio antenna system, a radiator, an aperiodic electrical loading element adjacent to the upper end of said radiator, lower and upper feed means for transferring signal energy at the lower and upper ends of said radiator, transmission means for coupling said feed means to a source of signal energy, said transmission means including a first transmission line extending adjacent said radiator to said upper feed means, and means in said transmission lines for adjusting the phase and amplitude of the signal energy in at least one of said transmission lines relative to the phase and amplitude in the other, whereby to control the current distribution along said radiator.

8. In a radio antenna system, a radiator having first and second ends, an aperiodic electrical loading element juxtaposed at one end of said radiator, a source of signal energy, first and second feed means for coupling said source to said first and second ends, respectively, of said radiator whereby to transfer signal energy between said radiator and said source of signal energy, means coupling said first feed means between said radiator and said aperiodic element, and means between said source and said first feed means for controlling the phase and amplitude of the signal energy fed by said first feed means relative to the signal energy fed by said second feed means, whereby to control the current distribution along said radiator.

9. In a radio antenna system, a radiator having first and second ends, an aperiodic electrical loading element juxtaposed at one end of said radiator, a source of signal energy, first and second feed means for coupling said source to said first and second ends, respectively, of said radiator whereby to transfer signal energy between said radiator and said source of signal energy at both ends, means coupling said first feed means between said radiator and said aperiodic element, and means between said source and said second feed means for controlling the phase and amplitude of the signal energy fed by said second feed means relative to the signal energy fed by said first means, whereby to control the current distribution along the length of said radiator.

10. In the combination claimed in claim 1, said antenna element comprising a vertical mast, a plurality of guy wires extending from the upper end of said mast to the ground, each of said guy wires having a plurality of insulators spaced along the length thereof whereby to isolate a section thereof near the top from said mast and from the ground, said isolated sections constituting said aperiodic electric loading element.

11. In a radio antenna system, a first vertical transmission element for transmitting electrical energy, a second vertical transmission element for transmitting electrical energy, a translating means connected to said elements, adjustable means for adjusting the phase and amplitude of the electrical energy transmitted by said transmission elements, one of said elements comprising a vertical mast constituting an antenna, the other of said elements comprising a transmission line lying closely adjacent said mast, a plurality of guy wires extending from the upper end of said mast to the ground, said guy wires having a plurality of insulators spaced along the length thereof for isolating sections near the upper end of said mast from said upper end and said ground whereby to form aperiodic loading means, and means coupling said transmission line between the upper end of said mast and said isolated sections.

12. In a radio antenna system of dimension small compared with the wave length, a radiator having a first and a second end, and an aperiodic electrical loading element juxtaposed to said first end of said radiator, first and second means for transferring signal energy at said first and second ends, respectively, and means for controlling the relative phase and amplitude of the excitation of said first and second means, whereby the current in the radiating section of said antenna system is approximately constant in amplitude.

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