Dec. 17, 1929. C. W. RICE 1,740,371

DIRECTIVE RADIO TRANSMITTING SYSTEM

Filed Nov. 25, 1924

Fig. 1.

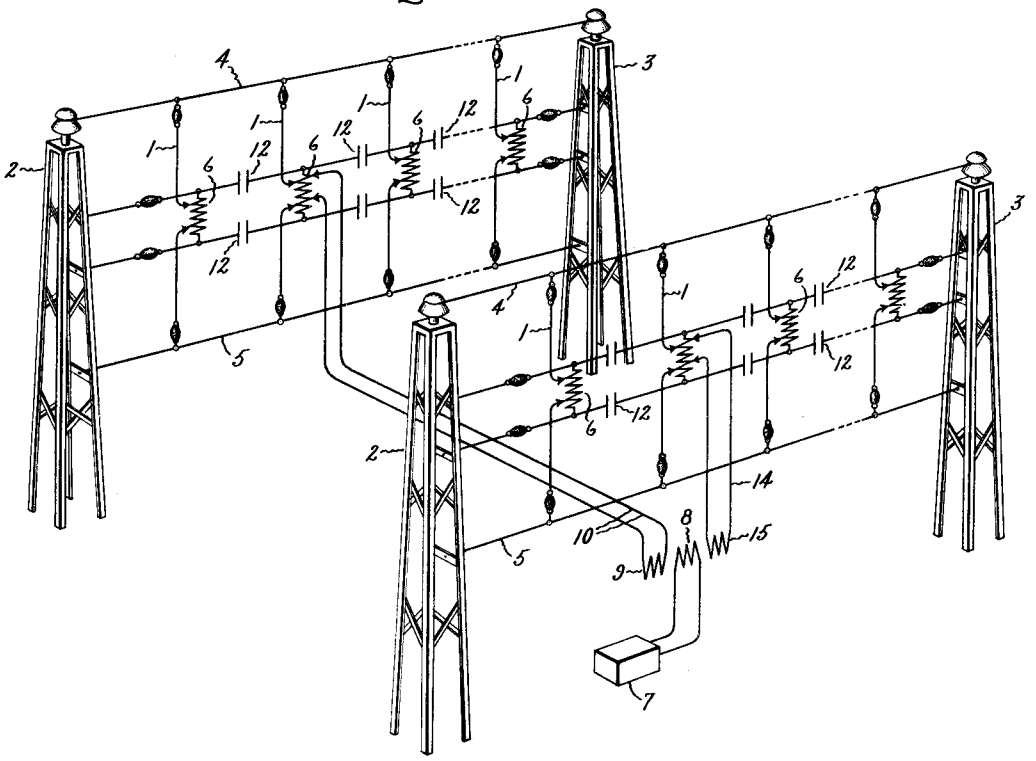
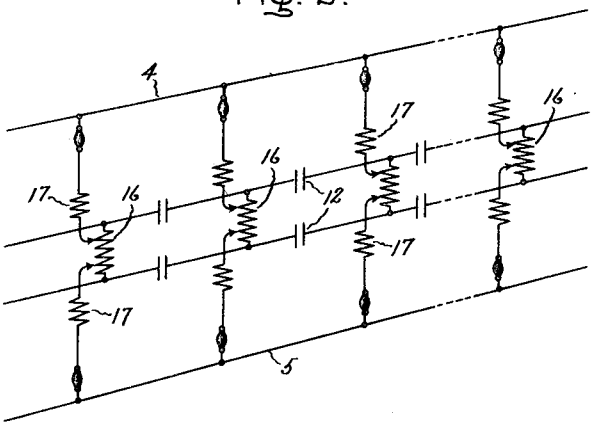


Fig. 2.



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UNITED STATES PATENT OFFICE

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DIRECTIVE RADIO TRANSMITTING SYSTEM

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My present invention relates to directive systems for radiating energy, and more particularly to systems in which the greater part of the effective radiation will be in one direction only.

Many arrangements have been proposed in the past whereby directive radiation of energy can be obtained, but none of these systems have been employed to any great extent in actual practice. Most of the systems proposed have not furnished means for producing a radiation which is sharp enough in its directivity to offer any material advantage over a radiating system in which the radiation is produced in all directions equally.

The object of my invention is to provide a system whereby the sharpness of the directivity obtained may be made as great as may be desired. Another object of my invention is to provide a directive system which radiates in only one direction in which the effective radiation is practically all confined to an angle of less than 90°, together with means for supplying currents to the various elements of the radiating system in such a way that the desired result is obtained.

All useful radiation in radio communication takes place from a vertical conductor carrying high frequency current. All directive transmitting systems which have been proposed heretofore comprise two or more vertical conductors separated in space and carrying currents having such phase relation that the radiated waves add in certain directions and partially or completely interfere with one another in other directions. For point to point communication the sharper the directivity (i. e. the smaller the solid angle in which the radiation is concentrated) the more efficiently the power output will be utilized.

The problem of providing an efficient directive transmitter therefore requires for its solution the selection of the best arrangement of the radiating vertical conductors and the supplying of power to the various vertical conductors in such a way that each will carry its due proportion of current in the proper phase relative to the currents in the other vertical conductors.

One of the requirements for obtaining extremely sharp directivity is that the radiating system must have a dimension of the order of one or more wave lengths. Many of the directive systems proposed in the past have failed in their accomplishment because of the fact that they have fallen short of this requirement.

Another requirement for obtaining sharp directivity is the use of a considerable number of vertical conductors. Here again many of the arrangements proposed in the past have failed in their practical accomplishment because of the fact that they have proposed to use only a few, and in many cases, only two vertical conductors.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation will best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates diagrammatically a system which may be employed for producing unidirectional radiation, and Fig. 2 shows a modification in the method employed in supplying energy to the individual vertical conductors of the system shown in Fig. 1.

I have indicated in Fig. 1 a radiating system comprising a plurality of radiating units which in the case illustrated consist of vertical conductors 1 arranged in a row extending in a direction at a right angle to the desired direction of radiation. This row should preferably have a length greater than the wave length of the waves to be radiated although useful directive results may be obtained with a length less than a wave length and the separation between individual vertical conductors may be only a small fraction of a wave length.

As one possible method of supporting the row of conductors I have indicated a pair of towers 2 and 3 having catenary suspension wires 4 and 5 stretched between them, and the vertical conductors 1 secured to the two suspension wires and insulated from one another either by the insertion of sectionalizing

insulators in the catenary wires themselves, or by the use of insulators between the vertical conductors and the wires.

The case illustrated is a special case of a row of vertical conductors in which both ends are electrically free in space. My invention however is not limited to this particular case but may be applied to any type of radiating unit. The vertical conductors 1 are tuned by means of inductances at their middle points. In order to obtain radiation in a direction at right angles to the direction of the row the currents supplied to all of the vertical conductors should be in phase with one another. This may of course be accomplished by providing individual transmission lines from the source of energy for each of the vertical conductors, care being taken to have all of the lines designed for equal time of propagation so that currents supplied by the source will have the same phase in all of the vertical conductors.

In order to avoid the necessity of providing individual transmission lines for all of the vertical conductors, I have indicated a method whereby energy may be supplied to all of them by a single transmission line. The source of power 7 supplies energy to a coupling coil 8 to which is coupled a coil 9 connected to a transmission line 10. This transmission line is connected directly to suitable points in an inductance 6 which is connected in shunt to the portion of the transmission line from which energy is directly fed to the different verticals. The points of connection should be so chosen that the impedance through which energy is fed will be substantially equal to the surge impedance of the transmission line from the source whereby wave reflections will be prevented. The transmission line is extended along the length of the row of verticals in both directions and is so constructed that the apparent velocity of wave propagation along the length of the row is infinite in order that the current supplied to the various verticals may all be in phase. To produce this effect the series inductance of the transmission line is neutralized by series condensers 12 uniformly distributed along its length, preferably at points intermediate each pair of adjacent verticals. The shunt capacity of the transmission line is neutralized by the shunt inductances 6. The distance between adjacent condensers and inductances should not be greater than $\frac{1}{\pi}$ times the wave length and may to advantage be even less than this. In the case illustrated in Fig. 1 the two portions of the verticals are connected to two points in the inductances 6 so chosen that the portions of inductances 6 thus connected in series with the verticals serve for tuning purposes.

The arrangement thus far described will produce radiation in two directions at right angles to the row of verticals. To produce radiation in one direction only additional rows of verticals may be provided extending parallel to one another, and each being constructed in the manner already described. In Fig. 1 I have indicated one aditional row of verticals. These rows should be separated from one another by a distance equal to $\frac{\lambda}{4}$, or some other odd multiple of $\frac{\lambda}{4}$, λ being the wave length of the waves to be radiated.

The two rows of verticals together may operate to produce radiation in one direction only, merely through the effect of reradiation by the second row of energy received from the first row. When the two rows are separated only by a distance of $\frac{\lambda}{4}$ quite effective results may be obtained in this way, the currents flowing in the vertical conductors of the second row being of nearly the same order of magnitude as the currents flowing in the vertical conductors to which energy is directly supplied. In some cases, however, it will be desirable to supply energy to the additional row or rows of vertical conductors. In the present case I have indicated a second transmission line 14 which is supplied with current from a coupling coil 15 which is also coupled to the coil 8. The transmission line 14 should be so constructed and arranged that the currents supplied to the second row of vertical conductors will be 90° in phase ahead of the currents supplied to the first row. This condition will result in radiation in the direction indicated by the arrow, as in that direction the waves radiated from the two rows will combine, whereas in the opposite direction the waves radiated by the two rows will largely oppose each other and be neutralized.

In the case illustrated in Fig. 1 a condition is assumed where the inductance required for tuning the vertical conductors is less than the desired shunt inductance for neutralizing the shunt capacity of the transmission line, and of about the right magnitude to furnish a suitable feed ratio.

Fig. 2 illustrates the connections which may be employed where the inductance desired for tuning the vertical conductors is not of a value which gives a suitable feed ratio. In this case the vertical conductors are connected to such points in the shunt inductances 16 that they will include only the inductance required for the desired feed ratio and additional inductances 17 are inserted in the verticals to provide the necessary tuning.

A transmission line having its series inductance neutralized by series capacity, and its shunt capacities neutralized by shunt inductance in the manner described has the characteristic of a line having low series resist-

ance and high shunt resistance. The attenuation of such a line is comparatively low and unless the sections of the line extending in either direction from the feed point are comparatively long with respect to the wave length a substantially uniform distribution of supplied energy to the radiating units can be obtained. In case the line is of such length that its attenuation is considerable the desired equal distribution of supplied energy may be obtained by suitable gradations in the value of the feed ratio through which energy is supplied to various radiating units.

When the separation between the adjacent rows of radiating units is only equal to $\frac{\lambda}{4}$ the operation may be complicated by the reason of the coupling between the adjacent rows. This element of complication may be obviated by making the length of each vertical equal to a half wave length in which case the electrostatic and electromagnetic couplings balance each other. As an alternative the units may be separated by a distance greater than $\frac{\lambda}{4}$ as by an odd multiple thereof, and thereby the coupling between adjacent rows of the radiating units will be reduced to such a value as to produce no appreciable effect in the operation of the system.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, a transmission line for supplying energy to all of said vertical conductors, said transmission line having its series inductance neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by shunt inductances uniformly distributed along its length, the arrangement and distribution of impedances in the system being such that a standing wave of current is built up therein.

2. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, a transmission line for supplying energy to all of said vertical conductors, said transmission line having its series inductance neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by shunt inductances uniformly distributed along its length, said shunt inductanes also serving to feed energy to the individual vertical conductors.

3. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, said rows being separated from one another by a distance equal to an odd multiple of $\frac{\lambda}{4}$ greater than 1, means for supplying substantially in phase currents to all of the conductors of each row and means for varying the relative phase of the currents supplied to the different rows in such a way that the greater part of the effective radiation will be in one direction only.

4. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, a separate transmission line for supplying energy to each of said rows of vertical conductors, each of said transmission lines having such constants that the apparent velocity of wave transmission thereon along its row of vertical conductors will be substantially infinite and that a standing wave of current is built up therein whereby the currents supplied to all of the vertical conductors of each row will be substantially in phase.

5. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, a separate transmission line for supplying energy to each of said rows of vertical conductors, each of said transmission lines having its series inductance along the length of the row supplied by it neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by shunt inductances uniformly distributed along its length, said shunt inductances also serving to feed energy to the individual vertical conductors.

6. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and means for supplying substantially in phase currents to all of said vertical conductors through said tuning inductances.

7. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle, and a transmission line for supplying substantially in phase currents to all of said vertical conductors through said tuning inductances, said transmisison line having such constants that the apparent velocity of wave transmission thereon along the row of vertical conductors will be substantially infinite.

8. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles

to the desired direction of radiation, each of vertical conductors having a tuning inductance at its middle, and a transmission line for supplying substantially in phase currents to all of said tuning inductances, said transmission line having its series inductance along the length of the row of vertical conductors neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by a plurality of shunt inductances, said tuning inductances having different values than said shunt inductances.

9. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, and means for supplying substantially in phase currents to all of said vertical conductors, each of said vertical conductors having both of its ends electrically free in space.

10. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having both of its ends electrically free in space and means for supplying substantially in phase currents to the middle of each of said vertical conductors.

11. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, and means for supplying substantially in phase currents to all of said tuning inductances.

12. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, and a transmission line for supplying substantially in phase currents to all of said tuning inductances, said transmission line having such constants that the apparent velocity of wave transmission thereon will be substantially infinite.

13. A directive radiating antenna system comprising a plurality of vertical conductors arranged in a row extending at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, and a transmission line for supplying substantially in phase currents to all of said tuning inductances, said transmission line having its series inductance neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by a plurality of shunt inductances, a portion at least of each of said tuning inductances forming a portion at least of one of said shunt inductances.

14. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, means for supplying substantially in phase currents to all of the conductors of each row and means for varying the relative phase of the currents supplied to the different rows in such a way that the greater part of the effective radiation will be in one direction only.

15. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, a separate transmission line for supplying energy to each of said rows of vertical conductors, each of said transmission lines having such constants that the apparent velocity of wave transmission thereon along its row of vertical conductors will be substantially infinite whereby the currents suplied to all of the vertical conductors of each row will be substantially in phase.

16. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, a separate transmission line for supplying energy to each of said rows of vertical conductors, each of said transmission lines having its series inductance along the length of the row supplied by it neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by shunt inductances uniformly distributed along its length.

17. A directive radiating antenna system comprising a plurality of parallel rows of vertical conductors each of which extends in a direction substantially at right angles to the desired direction of radiation, each of said vertical conductors having a tuning inductance at its middle and having both of its ends electrically free in space, a separate transmission line for supplying energy to each of said rows of vertical conductors, each of said transmission lines having its series inductance along the length of the row supplied by it neutralized by series capacities distributed uniformly along its length and

having its shunt capacity neutralized by shunt inductances uniformly distributed along its length, a portion at least of each of said tuning inductances forming a portion at least of one of said shunt inductances.

18. A directive radiating antenna system comprising a plurality of radiating units arranged in a row extending at right angles to the desired direction of radiation, a transmission line for supplying energy to all of said radiating units, said transmission line having its series inductance neutralized by series capacities distributed uniformly along its length and having its shunt capacity neutralized by shunt inductances uniformly distributed along its length, the arrangement and distribution of impedances in the system being such that a standing wave of current is built up therein.

In witness whereof, I have hereunto set my hand this 24th day of November, 1924.

CHESTER W. RICE.