July 18, 1939. P. S. CARTER 2,166,750

ANTENNA

Filed Feb. 15, 1936

Fig. 1

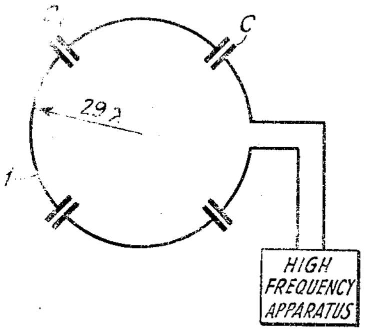


Fig. 2

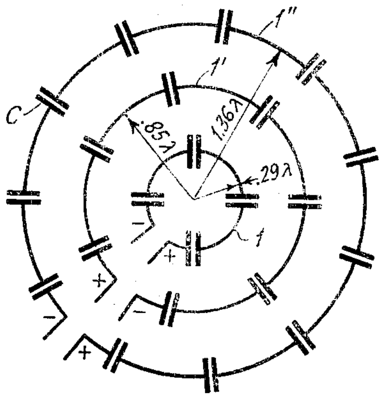


Fig. 3

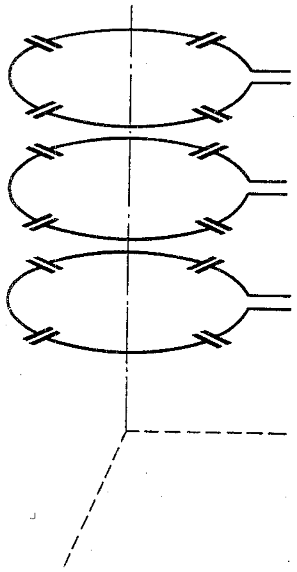


Fig. 4

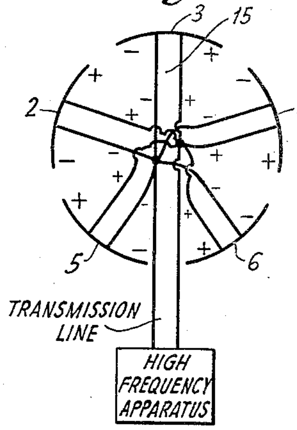


Fig. 5

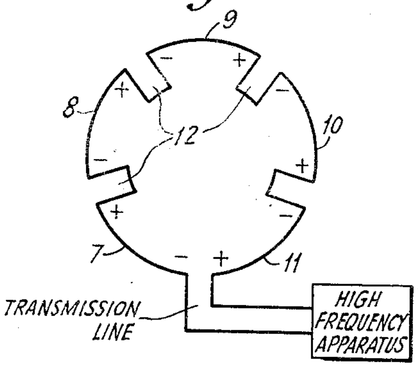
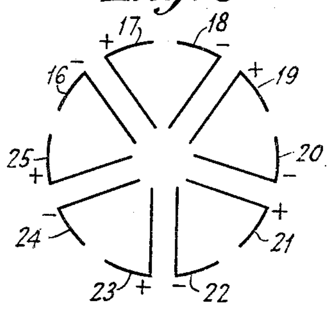


Fig. 6



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Application February 15, 1936, Serial No. 64,021

14 Claims. (Cl. 250—33)

This invention relates to antennas, and particularly to an antenna for broadcasting horizontally polarized waves uniformly in all horizontal directions.

In broadcasting at extremely short wave lengths, such as when using television, it is desirable to use horizontally polarized waves. It is also required, in such case, that radiation be substantially equal in all horizontal directions. These desiderata cannot be achieved by using the well known simple horizontal linear radiator which produces a radiation pattern in the form of a figure 8. A small loop antenna is also undesirable because it gives poor efficiency and low latitudinal concentration, although it does give equal radiation in all horizontal directions.

The present invention provides a highly desirable type of antenna which makes possible substantially equal radiation in the horizontal plane with considerable latitudinal concentration.

I have found that for a horizontal circular loop with a given current, the field strength of the radiated wave in a horizontal direction is proportional to the first order Bessel function of the first kind $J_1(2\pi a/\lambda)$ with the argument $(2\pi a/\lambda)$, where a is the radius and λ the wavelength. The field is therefore a maximum when $J_1(2\pi a/\lambda)$ is a maximum or minimum. The invention is based on an understanding of this principle, and employs one or more concentric horizontal loops having radii which are maxima or minima of the function $J_1(2\pi a/\lambda)$.

According to one embodiment of the invention, there is employed an array of concentric loops broken up by series condensers, the radii of these loops corresponding to maximums and minimums of the first order Bessel function of the first kind $J_1(2\pi a/\lambda)$, successive radii having lengths approximately equal to 0.29, 0.85, 1.36, 1.86 etc., wavelengths. Condensers are employed at proper intervals in the loop to provide uniform current distribution. Adjacent loops are energized in phase opposition.

A better understanding of the invention may be had by referring to the following detailed description which is accompanied by drawing, wherein:

Figs. 1 to 6, inclusive, illustrate different embodiments of the invention.

Fig. 1 shows a single radiator consisting of a single turn horizontal loop **1** with four or more series condensers c, c and having a radius equal to 0.29 wavelength, the first maximum of the first order Bessel function above named. Condensers c, c partially tune the self inductance of the loop and enable the current in different parts of loop **1** to be in phase and of nearly equal amplitude. The lengths of the wire sections between condensers are made not greater than one-half wavelength. If desired, the lengths of the wire sections may be made not to exceed one-quarter wavelength in order to obtain substantially equal currents at all points.

Fig. 2 shows an array of concentric loops **1**, **1′**, **1″** in the same horizontal plane, having radii respectively, of 0.29, 0.85 and 1.36 wavelengths. These radii are of such values as to make the Bessel function of the first kind, i. e., $J_1(2\pi a/\lambda)$ a maximum or a minimum. Successive loops are energized in phase opposition, as shown, and thus produce a system which gives a considerable increase in latitudinal concentration of radiation over that of Fig. 1. The spacings between radiator loops give maximum field strength of the radiated wave in all horizontal directions.

Fig. 3 shows several single loops of the type shown in Fig. 1, placed one above the other in pancake style and energized cophasally in order to obtain greater concentration of radiation latitudinally. If desired, several of the arrays shown in Fig. 2 may be arranged in the same manner. These loops are spaced ordinarily at least one-half wavelength apart.

Fig. 4 shows a modification where the circular loop is broken up into several distinct radiating elements **2**, **3**, **4**, **5** and **6**, each energized by a separate feed line **15**. Fig. 5 is a further modification wherein distinct radiating elements **7**, **8**, **9**, **10** and **11** around a circle are connected in series through folded line sections **12** of proper length to give approximately uniform current in the same direction around the circle in all radiating elements. In these two figures the radii of the loops should be in accordance with the principles hereinabove set forth for best operation. In each of the cases of Figs. 4 and 5 in the manner shown in the drawing, the length of each radiating element should in no case exceed one-half wave, irrespective of the length of the radius, in order to prevent phase reversal of the current in a radiator.

Fig. 6 shows a still further embodiment disclosing still another way of feeding separated radiating elements **16**, **17**, **18**, **19**, **20**, **21**, **22**, **23**, **24**, and **25**. Here also each of these elements should not be greater than one-half wavelength.

If desired, arrays of systems like Figs. 4, 5 and 6 may be stacked one above the other in the same manner as shown in Fig. 3. It is evident that where a sufficient number of radiating elements like those shown in Figs. 4, 5 and 6 are employed, the individual elements may be straight instead of curved and thus the loop will depart from a true circle. In the systems of Figs. 4, 5 and 6 it is important that the currents in all the radiating elements travel along the circle in the same direction. The instantaneous polarities indicated on these figures indicate one manner in which these elements should be energized to effect this result. If the radius of the circle in the systems of Figs. 4, 5 and 6 is substantially 0.29 wavelength, then it is preferred that there be four separated radiating elements. If the radius of the circle is 0.85 wavelength, it is preferred that there be eleven separated radiating elements, and in the case of a radius of 1.36 wavelengths it is preferred that the number of elements be eighteen. These numbers are preferred because they give the smallest number of radiating elements possible for a particular radius without producing a current reversal in the elements.

In the case of Fig. 5, assuming that the radiating elements are of the same length, a condition most practical and preferably to be used in all of the systems shown in Figs. 1–6, inclusive, then the electrical length of any one U section of line between radiating elements should be equal to one wavelength minus the length of a radiating element.

It will be understood that the invention is not limited to the precise arrangements shown and described, since various modifications may be made without departing from the spirit and scope of the invention. For example, the invention may be used to obtain uniform radiation in all directions in the plane of the loop regardless of the angle of the loop with respect to the horizontal. Of course, it will be appreciated that the principles of the invention are equally applicable to receiving antennae and that the invention is not limited solely to transmitting systems.

It should also be understood that the term "loop" used in the appended claims is deemed to include either one continuous electrical connection, as shown in Figs. 1, 3 and 5, or a plurality of spaced elements arranged around a circle and whose adjacent ends are insulated from one another, as shown in Figs. 4 and 6.

What is claimed is:

1. An antenna comprising a loop having a radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is radius, λ the wavelength, and $J_1(2\pi a/\lambda)$ is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$.

2. An antenna comprising a circular loop hava radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$, is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$, and a plurality of serially connected condensers in said loop for tuning out, at least partially, the self-inductance of the loop, the lengths of the wire sections between condensers being not greater than one-quarter wavelength.

3. An antenna comprising a circular loop hava radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$, is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$, and means serially connected in said loop for providing substantially uniform current distribution.

4. An antenna comprising a circular horizontal loop having a diameter equal approximately to 0.60 wavelength, and means for producing substantially cophasal current in the antenna elements constituting the loop.

5. An antenna comprising a plurality of horizontal circular loops, one above the other, each having a radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$ is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$, and means for producing substantially cophasal current in the antenna elements constituting each loop.

6. An antenna comprising a plurality of concentric horizontal loops, in the same plane, having, successively, respective radii of approximately 0.29, .85 and 1.36 wavelengths, and means for energizing adjacent loops out of phase, and the elements of each loop in such manner that the current is substantially cophasal throughout the loop.

7. An antenna in accordance with claim 6, including a plurality of serially connected condensers in each loop for providing substantially uniform current distribution, the sections of wire of each loop between successive condensers being not greater than one-quarter wavelength.

8. An antenna comprising a plurality of horizontal circular loops, one above the other, each having a radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength,, and $J_1(2\ {}_1a/\lambda)$ is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$, and means for energizing said loops cophasally.

9. An antenna comprising a plurality of separated radiating elements, each not exceeding one-half wavelength, substantially in the form of a circle, and means for producing currents which flow in the same direction around said circle in all of said elements, the radius of said circle corresponding to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$ is the first order Bessel function of the first kind.

10. An antenna comprising a plurality of separated dipoles arranged substantially in the form of a circle, each of said dipoles not exceeding one-half the length of the communication wave, and a pair of leads extending from the center of each dipole to high frequency apparatus, whereby currents flow in the same direction around said circle in all of said dipoles, the radius of said circle corresponding to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$ is the first order Bessel function of the first kind.

11. An antenna comprising a horizontal loop having a radius which is substantially equal to 0.85 times the length of the communication wave, and means for producing substantially cophasal current in the antenna elements constituting the loop.

12. An antenna comprising a horizontal loop having a radius which is substantially equal to 1.36 times the length of the communication wave, and means for producing substantially cophasal current in the antenna elements constituting the loop.

13. An antenna comprising a horizontal loop having a radius which is substantially equal to 0.85 times the length of the communication wave, a plurality of spaced, serially connected condensers in said loop, the sections of loop between

successive condensers having lengths not exceeding half the length of the operating wave.

14. An antenna comprising a plurality of horizontal circular loops, one above the other, each having a radius which corresponds to a maximum or a minimum of the function $J_1(2\pi a/\lambda)$, where a is the radius, λ the wavelength, and $J_1(2\pi a/\lambda)$ is the first order Bessel function of the first kind with the argument $(2\pi a/\lambda)$, said loops being spaced at least one-half wavelength apart, and means for energizing said loops cophasally.

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