

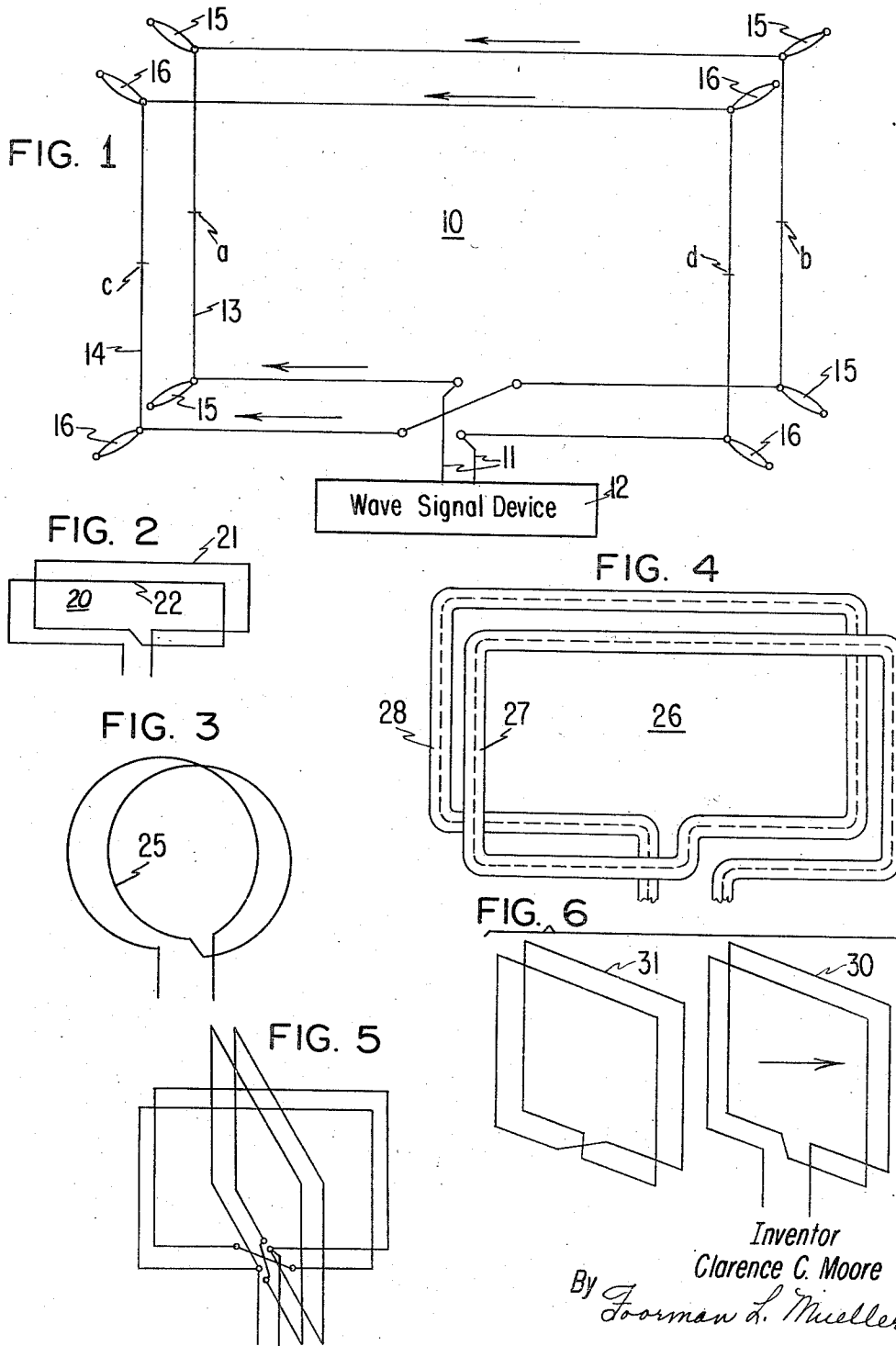
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C. C. MOORE

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Inventor
Clarence C. Moore
By *Joorman L. Mueller*
Attorney

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Clarence C. Moore, Elkhart, Ind.

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The present invention relates to an antenna and more particularly to an antenna for use with wave signal devices whether adapted to radiate wave signals or receive wave signals.

In recent years, there has been a great deal of work done in connection with antennas of all sorts. Various arrangements and expedients have been resorted to decrease losses, increase the power output in the case of an antenna for a transmitter, improve the reception or transmission pattern and the like. In connection with antennas used at high altitudes or antennas used to broadcast large amounts of power, there has been considerable loss due to various factors dependent primarily upon the voltage of the antenna. For example, there has been a considerable loss due to corona which takes place at high voltages and is due to the partial ionization of the air about the antenna causing the air to become a partial conductor and carry current. The corona does not begin to take place except at a certain definite voltage which varies greatly in dependence upon the shape and size of the antenna conductors as well as on the condition of the medium surrounding the antenna as, for example, the altitude at which the antenna is disposed. Once the critical voltage for a particular location is exceeded, a large amount of energy loss may take place due to corona. This phenomenon is to a certain extent a limitation upon the amount of power which may be radiated by an antenna since for an antenna of certain dimensions, the greater the power applied thereto the greater must be the voltage and hence, the greater the corona loss. Consequently, for a particular transmitting antenna there is a limit to the power input beyond which it is inadvisable to go because a large amount of power is wasted due to corona loss and little is gained as far as power radiated is concerned. In certain parts of the world, where elevations above sea level are great, as for example, in many parts of South America, the corona problem is particularly bad even at relatively low values of power radiated. It would be desirable to provide an antenna wherein the corona problem would be substantially eliminated at all altitudes and also where large amounts of radio frequency power are to be radiated. It would furthermore be desirable to provide an antenna in which the voltage problem was eliminated so that the expense of insulators for supporting the same could be greatly reduced and whereby ice and snow would have substantially no deleterious effect as far as the operating characteristics of the antenna are concerned.

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Accordingly, it is an object of the present invention to provide a new and improved antenna for wave signal devices.

It is another object of the present invention to provide a loop antenna having a distributed voltage whereby the corona problem is substantially eliminated and, due to the low voltages involved, no expensive insulators are required and no deleterious effect from ice and snow is experienced.

It is another object of the present invention to provide a new and improved antenna having circular polarization whereby fading effects are reduced.

It is another object of the present invention to provide an improved antenna having some of the desirable characteristics of rhombic antennas without the loss of power characteristic of such antennas in the termination impedance thereof.

It is another object of the present invention to provide an antenna for wave signal devices in which reversal of the conductor in the antenna occurs at the place where phases would normally reverse so that all currents in the antenna flow in the same direction at the same instant whereby the benefits of stubs are obtained without requiring the provision thereof.

It is a further object of the present invention to provide a loop antenna having an even number of turns of a length of one or more wave lengths around each turn in which substantially no voltage components are present and the only voltage existing is that due to the impedance between the adjacent loops.

Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the present invention, reference may be had to the accompanying drawings in which:

Fig. 1 is a schematic diagram of an antenna embodying the present invention;

Figs. 2, 3 and 4 illustrate other embodiments of the invention;

Fig. 5 illustrates the antenna in accordance with the invention so positioned to provide a non-directional pattern; and

Fig. 6 illustrates an antenna array in accordance with the invention which provides a unidirectional pattern.

In accordance with the invention, I provide an antenna having at least four series portions which

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are one-half wave length long and so positioned that the instantaneous currents in the various portions are all in the same direction. As the basic antenna will have four portions I have chosen to call this antenna a "quad." Tests made

of antennas of various configurations which fulfill the above requirements have indicated in every case that the voltage of the antenna is uniformly distributed along the antenna so that there is substantially no voltage difference between any two adjacent portions of the antenna. It should be understood that the present invention is applicable to antennas for use with wave signal receivers or wave signal transmitters. It is a generally accepted fact that any good transmitting antenna is also a good receiving antenna, especially when receiving the frequency for which it is designed. Accordingly, although in the following description reference is primarily made to transmitting antennas, it should be understood that the invention is equally applicable to receiving antennas and a transmitting antenna is described by way of example only.

Referring now to Fig. 1 of the drawings, there is illustrated a loop antenna embodying the present invention generally designated at 10 which is illustrated as being connected to a transmission line 11 which is in turn connected to a wave signal device 12 as, for example, a transmitter. Essentially, the antenna of the present invention is a loop antenna comprising an even number of conductor turns, namely, two, four, six or more. As illustrated, the antenna 10 comprises two turns 13 and 14 suitably supported at the corners thereof by insulators 15 and 16, respectively. Since the antenna has substantially no voltage points such as the characteristic voltage antinodes of prior art antennas, the insulators 15 and 16 can be relatively inexpensive and in a particular installation insulators of the ordinary ten cent store variety were found to be very satisfactory even with a transmitting antenna for transmitting large amounts of radio frequency energy.

Although the antenna of the present invention may have various shapes as will become apparent from the following description, the antenna 10 of Fig. 1 is illustrated as comprising conductors 13 and 14 in the form of a square having an electrical length of approximately one-quarter ($\frac{1}{4}$) wave on each side so as to produce a total length around the loop of one full wave length. The four one-half wave portions required to make up the "quad" antenna are provided by the sections between *a* and *b*, *b* and *c*, *c* and *d* and from *d* back to *a* through the wave signal device. The spacing of the conductors 13 and 14 is determined by the surge impedance desired and preferably is such as to have the same surge impedance as the transmission line 11 connected thereto. It will be understood that additional pairs of conductors such as 13 and 14 may be added in series, thereby increasing the radiation resistance of the antenna and the power generated thereby. For a particular installation for a broadcasting antenna for broadcasting radio frequency signals having a frequency of the order of 28 megacycles, an antenna embodying the square loops formed of conductors 13 and 14 having a length of eight feet on the side was found to be very satisfactory and capable of beaming a powerful signal comparable, if not superior, to prior art antennas while requiring less space and being considerably less expensive than such prior art antennas.

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The currents flowing in the antenna are indicated by the arrows associated with the parallel arms thereof, and it is noted that these currents are in phase due to the fact that the conductor is reversed at the point where the phases of the currents would normally reverse. That is, the current reverses every half wave and, therefore, the current in the portion between *b* and *c* will be opposite to that between *a* and *b*, but as the wires of the two sections are reversed, the currents will be in the same direction. Consequently, all currents flowing in the conductor at a particular instant are in the same direction. By virtue of the distributed current and voltage in the antenna 10, it is possible for the antenna to be opened and fed at any point which is a desirable characteristic from the standpoint of mounting the same. It is also pointed out that the antenna is re-entrant and does not require a terminating resistor as does the usual rhombic and other loop antennas. This eliminates the energy loss of the terminating resistor and also reduces the cost of the antenna.

As previously stated, the voltage of the antenna has been found to be substantially uniformly distributed about the antenna. It is believed that the reason for this is that the turns of the antenna are close-spaced and form, in effect, a balanced transmission line, and the currents flowing in the various radiating portions thereof at any instant all flow in the same direction. However, in a transmission line the currents in the two conductors are substantially 180 degrees out of phase while in the "quad" antenna as disclosed the currents are substantially 360 degrees out of phase or in phase. Any difference in the phase relationships in the adjacent turns of the antenna tend to be corrected by the interrelation between the electromagnetic fields produced by the turns. It is well known that when two electromagnetic fields operate in close proximity with each other with a slight phase difference between the fields, there is produced a tremendous interaction of power which tends to cause the fields to correct each other. This is generally similar to the action of two generators which are connected to the same line and in which generators rapidly tend to be drawn into phase. It is pointed out that although the currents in the various turns of the antenna are in the same direction, they are out of time phase by one cycle in each successive turn.

Although the antenna disclosed in Fig. 1 is illustrated as having a square loop configuration with a length on each side of one-quarter wave length, it should be understood that other configurations thereof may be employed. For example, in Fig. 2 of the drawings there is disclosed a similar loop antenna in which the top and bottom conductors of Fig. 1 are squeezed together. In other respects the antenna 20 of Fig. 2 is identical with the antenna 10 of Fig. 1 and includes at least two turns comprising conductors such as 21 and 22. It is noted that this antenna also fulfills the requirement stated for a "quad" antenna, that is, four radiating portions each one-half wave long and arranged so that the currents in all portions are in the same direction.

Very satisfactory results may be obtained for other configurations of the loop such as the circular loop antenna 25 of Fig. 3 of the drawings. It should be understood that various other configurations are possible as long as the basic requirements set forth are adhered to. The principles involved in these various configurations are

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substantially identical and no further discussion thereof is included herein.

In Fig. 4 of the drawings there is illustrated an antenna 26 similar to the antenna 10 of Fig. 1 except that the turns of the loop antenna are defined by coaxial cables 27 and 28. Such an antenna is suitable for underground use. Due to the absence of high voltage points on the antenna, the "quad" antenna in accordance with the invention is particularly adapted for underground or underwater use.

It will be understood that although a loop antenna with the plane of the loop disposed in a vertical plane is illustrated in Figs. 1 to 4 of the drawings, antennas in accordance with the invention may equally well be employed with the plane of the loop disposed in some other plane than the vertical plane. This will, of course, change the radiation pattern of the antenna. It should also be understood that when the antenna comprises four or six or more loop conductors that an integral number of wave lengths per loop is required so that the currents in the adjacent loop portions are in phase. In a single loop, it may be desirable to have an integral number of wave lengths greater than one.

In the antennas described thus far the bi-directional characteristics of loop antennas are obtained. In the event that it is desired to provide a non-directional antenna embodying the present invention, configurations such as illustrated in Fig. 5 of the drawings may be employed, Fig. 5 showing a pair of square loop antennas such as 10 of Fig. 1 connected in parallel but displaced from each other by 90 electrical degrees so that the lobes of the two antenna patterns will be displaced by 90 degrees and the over-all antenna pattern will be substantially non-directional. It is apparent that various other arrangements can be provided in which a plurality of antennas are used to provide a non-directional pattern.

The "quad" antenna in accordance with the invention may be used in various well known antenna arrays. In Fig. 6 there is illustrated an arrangement in which an antenna 30 which is identical to the antenna 10 of Fig. 1 is used in combination with a reflector 31 which is also an antenna of the "quad" type but which is not driven. Reflector 31 will tend to reverse the lobe on the left side of the antenna 30 in Fig. 6 to provide a uni-directional pattern in the direction indicated by the arrow in the figure. Satisfactory results have been obtained by spacing the reflector a distance corresponding to one-quarter ($\frac{1}{4}$) of a wave length from the antenna 30. The reflector can be positioned closer to the antenna if desired, spacings of from .1 to .15 of a wave length having been found satisfactory. It is obvious that more complicated arrays using a plurality of reflectors and directors can be used in accordance with well known principles.

The theory underlying the present invention is not too well understood but extensive tests have demonstrated that an antenna is provided having substantially no high voltage points thereon whereby a very satisfactory antenna is provided for use in high altitudes where the corona problem is particularly serious and also for antennas employed to radiate large amounts of radio frequency energy. Furthermore, with this arrangement the insulation problem for the antenna is greatly reduced and as a result, the cost of the antenna is much lower than that of similar prior art antennas. Also, the ice and snow problem which has caused so much diffi-

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culty recently with antennas employed in connection with frequency modulation and television, is substantially eliminated due to the fact of the distributed voltage around the antenna with substantially no voltage points thereon.

While there have been shown and described particular embodiments of the present invention, it is not desired for the invention to be limited to the exact arrangement shown but it is intended in the appended claims to cover all those modifications which fall within the true spirit and scope of the present invention.

I claim:

1. A loop antenna system for a wave signal device operating at a predetermined frequency comprising, an even number of conductor turns each having an electrical length substantially equal to a wave length at said predetermined frequency, and a conductor having low impedance connecting said conductor turns in series, said turns being spaced with respect to each other at a distance very small as compared with said wave length and being spaced to provide a predetermined impedance, whereby the instantaneous currents in all corresponding close-spaced portions of said turns are substantially in phase and a substantially uniformly distributed voltage exists around said loop, and the maximum effectiveness of said antenna is in the directions perpendicular to the plane of said loop.
2. An antenna for a wave signal device operating at a predetermined frequency comprising, elongated conductor means having substantially uniform impedance per unit length thereof, said conductor means being formed to provide a loop having two series connected turns, each of said turns having an electrical length substantially equal to a wave length at said predetermined frequency, said turns being spaced with respect to each other at a distance very small as compared with said wave length, whereby the instantaneous currents in all corresponding close-spaced portions of said turns are substantially in phase and a substantially uniformly distributed voltage exists around said loop, and a transmission line connected to said loop for coupling said loop to the wave signal device, the spacing of said turns being such that the impedance of said loop is substantially equal to the impedance of said transmission line.
3. An antenna for a wave signal device operating at a predetermined frequency comprising, a loop having two complete turns connected in series, each of said turns being in the form of a square each side of which has an electrical length substantially equal to a quarter wave length at said predetermined frequency, the spacing between said turns being small as compared with the length of said sides of said turns, whereby the instantaneous currents in all corresponding close-spaced portions of said turns are in phase and a distributed voltage exists around said loop, and a transmission line connected to said loop for coupling said loop to the wave signal device, the spacing of said turns being such that the impedance of said loop is substantially equal to the impedance of said transmission line.
4. A loop antenna system for a wave signal device operating at a predetermined frequency comprising, an even number of conductor turns connected in series, each of said turns having an electrical length substantially equal to a whole number of wave lengths at said predetermined frequency, said turns being spaced with respect to each other at a distance very small as com-

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pared with said wave lengths, whereby the instantaneous currents in all corresponding close-spaced portions of said turns are in phase and a distributed voltage exists around said loop, and a transmission line connected to said loop for coupling said loop to the wave signal device, the spacing of said turns being such that the impedance of said loop is substantially equal to the impedance of said transmission line.

5. An antenna system for a wave signal device operating at a predetermined frequency comprising, a pair of loop antennas positioned at right angles with respect to each other and connected in parallel, each of said loop antennas including a continuous conductor formed to provide an even number of close-spaced turns connected in series, each of said turns having an electrical length substantially equal to a wave length at said predetermined frequency, said turns of each antenna being spaced with respect to each other at a distance very small compared with said wave length, whereby the instantaneous currents in all corresponding close-spaced portions of said turns of each loop are substantially in phase and a substantially uniformly distributed voltage exists around each of said loops.

6. A loop antenna system for a wave signal device operating at a predetermined frequency comprising, a first loop including an even number of conductor turns connected in series, each

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of said turns having an electrical length substantially equal to a whole number of wave lengths at said predetermined frequency, said turns being spaced with respect to each other at a distance small compared with said wave length, and a second closed loop having the same axis as said first loop and including an even number of conductor turns having substantially the same configuration and spacing as said conductor turns of said first loop, said second closed loop being spaced from said first loop by a distance substantially equal to a quarter of said wave length.

CLARENCE C. MOORE.

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