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N. E. LINDENBLAD

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RADIAL RADIATING SYSTEM FOR SHORT-WAVE COMMUNICATION

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Fig. 1

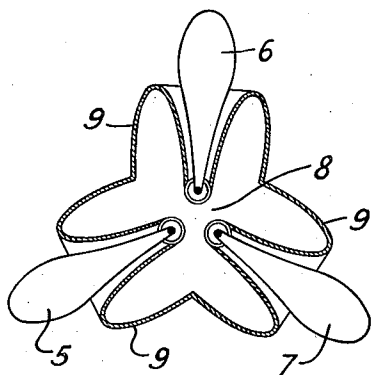


Fig. 2

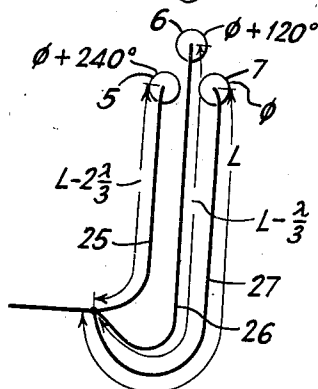


Fig. 3

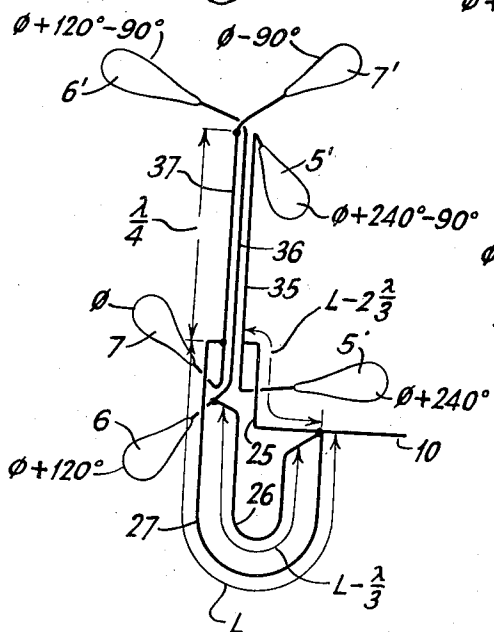
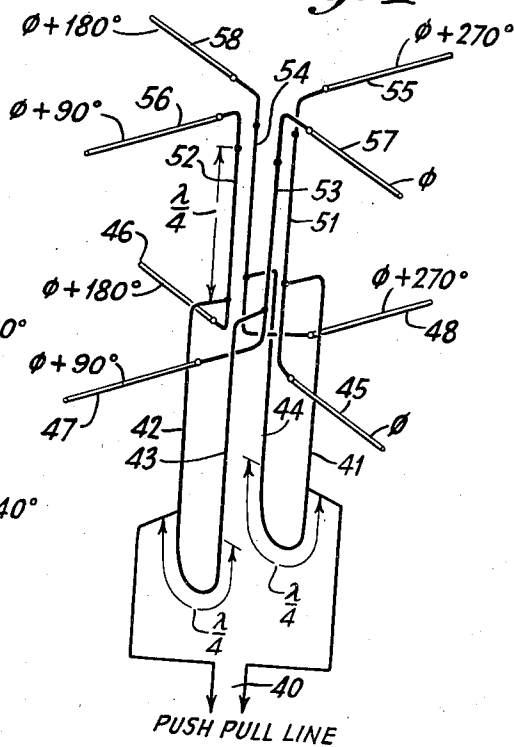


Fig. 4



BY

INVENTOR.
NILS E. LINDENBLAD

ATTORNEY.

UNITED STATES PATENT OFFICE

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RADIAL RADIATING SYSTEM FOR SHORT-WAVE COMMUNICATION

Nils E. Lindenblad, Rocky Point, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

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15 Claims. (Cl. 250—33)

The present invention relates to antennae and, more particularly, to short wave radial radiator systems for radiating a rotating field.

An object of the present invention is the provision of a radial radiating system with a progressive phase connection between the elements thereof for radiating a rotating field.

Another object of the present invention is the vertical combination of a plurality of radial radiating systems as aforesaid, in order to increase the vertical directivity of the system.

Still another object is the vertical combination of radial radiating systems, as aforesaid, in such a manner as to gain band width as well as vertical directivity.

A further object of the present invention is the combination of a plurality of radial radiating systems, as aforesaid, in such a manner that the systems mutually compensate for any reflection into a transmission line connected thereto.

Still a further object is the provision of a novel system of connecting a plurality of radial radiating systems to a transmission line.

It has been heretofore disclosed in a prior application No. 112,037, filed November 21, 1936, by P. S. Carter, and assigned to the assignee of the present application, that in a balanced transmission line any irregularity in the impedance of said line such as caused by an insulator may be compensated for by placing a similar insulator of like construction an odd multiple, including unity of a quarter of a wavelength away from the first insulator. Similarly, any capacitive or inductive effect of a radiator connected to the transmission lines may be compensated for by connecting a similar radiator to the transmission line at a distance substantially equal to an odd multiple, including unity, of a quarter of the wavelength away from the first radiator.

In my prior co-pending application No. 208,573, filed May 18, 1938, I have shown a plurality of radiating members connected to a transmission line with a quarter wavelength spacing between the points of connection. By this connection not only is the phase relationship required for a rotating field obtained, but the radiators mutually compensate one for the other for any reflection into the transmission line which might otherwise be caused.

The present invention contemplates the connection of a plurality of radial radiating systems to a transmission line in such a manner that the lengths of the connections differ by an odd multiple including unity of a quarter of the length of the operating wave whereby the said systems mutually compensate for reflections into the transmission line. In the case of a wide band system, the mid-frequency of the band is ordinarily taken as the operating frequency for purposes of calculating the lengths of the connections. Optimum compensation is, of course,

obtained with a purely resistive load at the desired frequency and exact phase quadrature connection. In case there is a slight residual reactance the spacing may be made slightly more or less than a quarter wave depending upon whether the reactance is inductive or capacitive. Furthermore, in some cases, it may be desirable to compensate more on one side of the mid-band frequency than on the other. In this case the differential line lengths will differ from an exact quarter wave in the direction to give the desired characteristic. Also, the angular displacement of one radial system with respect to the other will be adjusted in a corresponding sense in order to give the proper spatial phase relationship.

The invention will be better understood by reference to the following detailed description which is accompanied by a drawing in which Figure 1 and Figure 2 show a cross-sectional view and a wiring diagram of a single three phase radiating system; Figure 3 shows the application of my invention to a vertical combination of a plurality of three phase radiators and Figure 4 shows the application of my invention to a phase quadrature system.

In Figure 1 I have shown a horizontal cross-sectional view of a three-phase radial radiating system having a progressive phase connection in order to provide for a rotating field. Radiating elements 5, 6 and 7 are supported within hub structure 8. Hub structure 8 has a plurality of sleeve portions 9 which surround a portion of the radiating members 5, 6 and 7, as described in more detail in my prior co-pending application Serial No. 208,573, filed May 18, 1938. In order to obtain a rotating field the length of the feed lines to the radiators 5, 6 and 7 progressively differ from each other by a third of the length of the operating wave. This connection is shown in more detail in Figure 2 wherein it is seen that line 27 is the longest, having a length L . Line 26 has a length

$$L - \frac{\lambda}{3}$$

where λ is the length of the operating wave, and conductor 25 has a length

$$L - \frac{2\lambda}{3}$$

Due to this progressive difference in length, at any instant of time, the phase of energy in radiator 6 will lead that in radiator 7 by 120 electrical degrees and the energy in radiator 5 will lead that in radiator 7 by 240 degrees.

While I have shown three radiating elements for a three phase system this number, it is to be clearly understood, is only illustrative and any number may be used to obtain a rotating field as long as the branches are made to differ from

each other by a corresponding fraction of a wavelength. The difference between the longest and shortest branch is always less than a whole wavelength. Since any combination other than phase quadrature connection results, as I have explained before, in less compensating effect against reflection back to the main transmission line, I have shown in Figure 3 how this difficulty may be overcome when using groups of vertical radiating systems in a vertical array.

In Figure 3 I have shown a pair of three phase radiating systems, one of which comprises radiators 5, 6 and 7 and the other of radiators 5', 6' and 7'. In order to obtain maximum vertical directivity as disclosed in my prior application, Number 208,373, the vertical spacing between the different radiating systems is arranged to be approximately a half wave-length. Radiators 5, 6 and 7 are fed from transmission line 10 in the same way as described before with reference to Figure 2. The same reference numerals are used in this figure as were used in Figure 2. The second group of radiators 5', 6' and 7' are connected to transmission lines 25, 26 and 27 by additional transmission lines 35, 36 and 37. The length of each of these transmission lines 35, 36 and 37 is adjusted to a quarter of the length of the operating wave, or any odd multiple thereof. Since any pair of radiating elements fed from a single conductor such as 7 and 7' have a total length of connecting line from transmission line 10 to the radiators, which differs in length by a quarter of the length of the operating wave, a maximum cancellation effect against reflection back to the common transmission line 10 is thus obtained and the benefit from phase quadrature connection, before described, is restored. A similar advantage, of course, likewise exists with respect to radiators 5, 5' and 6, 6'. Due to the added length of transmission lines 35, 36 and 37, the phase rotation of the group of radiators 5', 6' and 7' fed through the longer branches will lag a quarter of a wave beyond the group fed through the shorter branches 25, 26 and 27. This phase lag is corrected for by advancing the spatial phase relationship of radiators 5', 6' and 7' 90 degrees in the direction of its phase rotation. Thus it will be seen that radiator 5' is advanced 90 degrees with respect to radiator 5. Likewise, radiator 6' is advanced 90 degrees with respect to radiator 6 and similarly for radiators 7' and 7.

In Figure 4 I have illustrated the connections for a combination of phase quadrature turnstiles in which the benefit to be obtained by using connection lines differing in length by a quarter of the length of the operating wave is utilized to the utmost. In this figure I have illustrated a pair of transmission lines 40 carrying radio frequency energy in a phase opposing relationship. One of the conductors is connected to a looped transmission line comprising conductors 41 and 44. The lengths of these conductors 41 and 44 differ by a quarter of the length of the operating wave. To the upper end of conductor 41 is connected a radiating element 45 and also a radiating element 55 through the medium of a connection 51 which has a length a quarter of the length of the operating wave longer than the connection to radiating element 45. Likewise, to the upper end of conductor 44 is connected radiating element 48 and through the medium of a connection 54 a quarter of the length of the operating wave in length, radiating element 58. In the same way the other side of the push-pull line 40 is connected to a looped transmission line 42, 43, the

upper end of line 42 being connected to radiating elements 46 and 55 by connections differing in length by a quarter of the length of the operating wave. The upper end of connection 43 is connected to radiating elements 47 and 57 through connections differing in length by a quarter of the length of the operating wave. Thus it will be seen that at each junction there are connected two similar loads by connections differing in length by a quarter of the length of the operating wave thus obtaining maximum cancellation effect as far as reflections back into the main line is concerned.

As described with reference to Figure 3, since the radiators in the upper radial system are fed by energy which lags the energy fed to the lower system by a quarter of the length of the operating wave, the upper system must be advanced in a spatial phase relationship by 90 degrees in order that the energy in each radiator of the upper system may be in phase with the energy in the radiator of the lower system immediately below it. This is readily apparent from the drawing wherein conductor 55 is advanced 90 degrees with respect to radiating element 45 and likewise for each of the other pairs of radiating elements.

Furthermore, each of the systems as shown in Figures 3 and 4 may be duplicated and the second group vertically stacked with respect to the first. Then the transmission lines connecting the two groups are again made to differ in length by a quarter of the length of the operating wave and the proper spatial phase adjustment made. It will thus be seen that by proper combination and adjustment, as outlined heretofore, any number of radial radiating systems may be combined without anything other than beneficial results.

While I have particularly shown and described an embodiment of my invention, it is to be clearly understood that my invention is not limited thereto but modifications may be made within the scope of the invention.

I claim:

1. An antenna comprising a plurality of omnidirectional radiating systems of similar characteristics located in different parallel planes spaced apart a distance other than a quarter of the length of the operating wave and transmission lines for connecting said systems to a source of radio frequency energy, the length of said transmission lines differing by an odd multiple including unity of a quarter of the length of the operating wave, said systems being so oriented with respect to one another and said planes so spaced that their radiation is additive in all horizontal directions.

2. An antenna comprising a plurality of horizontally disposed omnidirectional radiating systems of similar characteristics, said systems being arranged in different parallel planes spaced apart a distance equal to a half of the operating wavelength, transmission lines for connecting each of said systems to a source of radio frequency energy, the lengths of said transmission lines differing by an odd multiple including unity of a quarter of the length of the operating wave.

3. An antenna comprising a plurality of horizontally disposed omnidirectional radiating systems of similar characteristics, said systems being arranged in different parallel planes, transmission lines for connecting each of said systems to a source of radio frequency energy, the lengths of said transmission lines differing by an odd multiple including unity of a quarter

of the length of the operating wave, said systems being so oriented with respect to one another and said planes so spaced that their radiation is additive in a radial direction.

4. An antenna comprising a plurality of omnidirectional radiating systems having a common vertical axis, but arranged in different horizontal planes spaced apart a distance equal to a half of the operating wavelength, all of said systems having similar characteristics, transmission lines for connecting said systems to a source of radio frequency energy, the lengths of said transmission lines differing by an odd multiple including unity of a quarter of the length of the operating wave, said systems being so oriented with respect to one another that their radiation is additive in a horizontal direction.

5. An antenna comprising a plurality of radial radiating systems, each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel, said planes being so spaced as to obtain maximum directivity in the direction of said planes, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections having a length equal to an odd multiple including unity of a quarter of the length of the operating wave between corresponding conductors of each radial system and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees.

6. An antenna comprising a plurality of radial radiating systems, each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections having a length equal to an odd multiple including unity of a quarter of the length of the operating wave between corresponding conductors of each radial system and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees, successive radial systems along said connections being advanced 90 degrees with respect to the preceding system.

7. An antenna comprising a plurality of radial radiating systems each comprising a member N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections between corresponding conductors of each radial system, and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees, said transmission lines being connected to said connections at such points that there is a difference in length of path for energy of a quarter of the length of the operating wave between corresponding conductors of said system.

8. An antenna comprising a plurality of radial radiating systems each comprising a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections between corresponding conductors of each radial system and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees, said transmission lines being connected to said connections at such points that there is a difference in length of path for energy of a quarter of the length of the operating wave between corresponding conductors of said system, successive radial systems along said connections being advanced 90 degrees with respect to the preceding system.

9. An antenna comprising a plurality of radial radiating systems each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system, means for maintaining radio frequency energy on the conductors of one of said systems, the phase relationship between adjacent conductors being $360/N$ electrical degrees and connections between corresponding conductors of each system, said connections having a length equal to an odd multiple, including unity, of a quarter of the length of the operating wave.

10. An antenna comprising a plurality of radial radiating systems each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system, means for maintaining radio frequency energy on the conductors of one of said systems, the phase relationship between adjacent conductors being $360/N$ electrical degrees and connections between corresponding conductors of each system, said connections having a length equal to an odd multiple, including unity, of a quarter of the length of the operating wave, successive systems being advanced 90 degrees with respect to the preceding system whereby the lag due to the length of the said connections is compensated.

11. An antenna comprising a plurality of radial radiating systems each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system, means for maintaining radio frequency energy on the conductors of one of said systems, said means comprising individual transmission lines from a source of energy to each conductor of said system, said transmission lines differing in length $360/N$ electrical degrees, and connections between corresponding conductors of each system, said con-

nections having a length equal to an odd multiple, including unity, of a quarter of the length of the operating wave.

12. An antenna comprising a plurality of radial radiating systems each including a number N of quarter wave conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system, means for maintaining radio frequency energy on the conductors of one of said systems, said means comprising individual transmission lines from a source of energy to each conductor of said system, said transmission lines differing in length $360/N$ electrical degrees, and connections between corresponding conductors of each system, said connections having a length equal to an odd multiple, including unity, of a quarter of the length of the operating wave successive systems being advanced 90 degrees with respect to the preceding system whereby the lag due to the length of said connections is compensated.

13. An antenna comprising a plurality of poly-phase radial radiating systems of similar characteristics arranged about a common vertical axis, and spaced along said axis a distance equal to a half of the operating wavelength transmission lines for connecting said systems to a source of radio frequency energy, the lengths of said transmission lines differing by an odd multiple including unity of a quarter of the length of the operating wave, said systems being so oriented with respect to one another that their radiation is additive in a direction normal to said axis.

14. An antenna comprising a plurality of radial radiating systems, each including a number N of conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections having a length equal to an odd multiple including unity of a quarter of the length of the operating wave between corresponding conductors of each radial system and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees.

15. An antenna comprising a plurality of radial radiating systems, each including a number N of conductor elements disposed radially about a central axis and in a common plane, the planes of said systems being parallel and spaced apart a distance equal to a half of the operating wavelength, each conductor being spaced $360/N$ degrees from adjacent conductors of the same system and means for energizing said antenna comprising connections having a length equal to an odd multiple including unity of a quarter of the length of the operating wave between corresponding conductors of each radial system and individual transmission lines from a common source of energy to each of said connections, said transmission lines differing in length by $360/N$ electrical degrees, successive radial systems along said connections being advanced 90 degrees with respect to the preceding system.

NILS E. LINDENBLAD.