

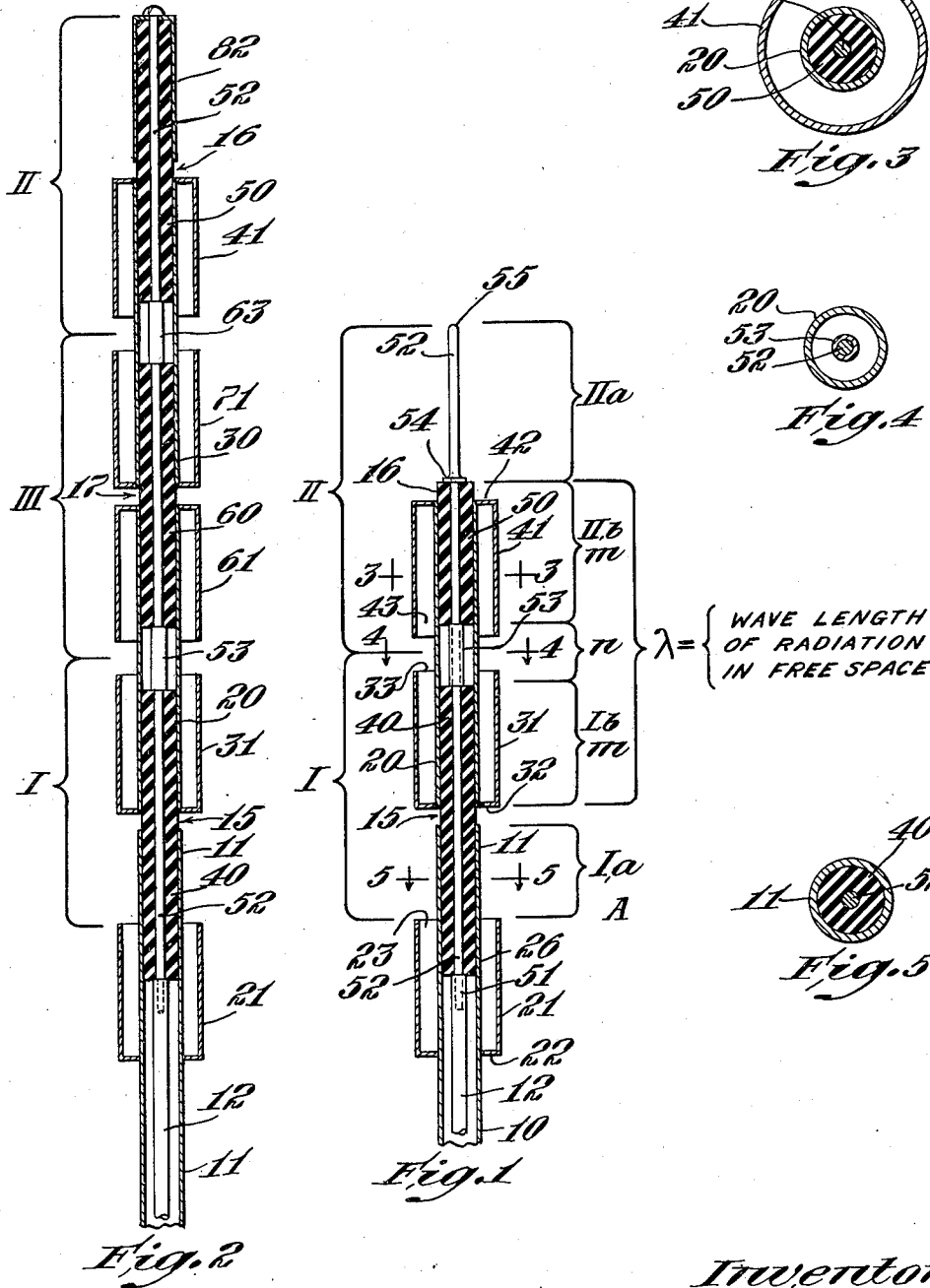
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G. G. GREENE

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ANTENNA

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Inventor  
Gardiner G. Greene  
by Robert Cushman Grover  
Att'ys.

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## ANTENNA

Gardiner G. Greene, Waban, Mass., assignor to  
Workshop Associates, Inc., Newton Highlands,  
Mass., a corporation of Massachusetts

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This invention relates to an antenna, and more particularly to a compact multi-element colinear coaxial arrangement of radiators driven from one end.

Colinear coaxial arrangements of radiators in an antenna can be used when an omnidirectional radiation pattern is desired in planes perpendicular to the direction of polarization of the antenna. With conventional antennas the means of electrically exciting the antenna and those for supporting it mechanically have interfered to a greater or lesser extent with obtaining a good omnidirectional pattern in planes perpendicular to the polarization of the antenna and at the same time have interfered with obtaining the optimum pattern in the planes containing the antenna.

Some of the objects of this invention are to provide a colinear coaxial array of radiators in an antenna which avoids these difficulties, to provide such an antenna which is especially compact, to provide an antenna of this type which has an integral means of electrical excitation, to provide such an antenna which has an optimum pattern in planes perpendicular to the polarization of the antenna, to provide such an antenna which has an optimum pattern in planes containing the antenna, and to provide an antenna of this type whose mechanical construction is compact and rigid and does not interfere with the electrical pattern of the antenna, and which offers little wind resistance.

In one aspect of the invention, the antenna constructed in accordance with its principles consists of several radiating dipole units each directly fed in series connection to the generator and each having two elements furnishing a desirable radiation pattern based on a certain mechanical distance between the approximate radiation centers of the units, while maintaining control of this pattern, and maintaining the necessary electrical characteristics. This is accomplished by equipping the antenna with a series feeding arrangement within the antenna structure which does not disturb the radiation patterns, but permits any desired selection of the phase relation of the electrical energy at the respective units.

Another aspect of the invention is the arrangement of two or more radiators in series directly upon the feed line, for example a coaxial conductor which may then serve as or contribute to the mechanical support of the dipoles. In yet another aspect of the invention, the above mentioned improvements are accomplished by spac-

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ing the centers or two dipoles such a free space or mechanical distance apart, while maintaining favorable electrical characteristics, that the radiation patterns of these dipoles reinforce each other in part, and in part totally interfere with each other. The result of such interaction is a long, narrow radiation pattern in a plane containing the antenna. One practical embodiment of antennas according to the invention has a radiation pattern characterized by an effective angle of  $30^\circ$  between the half power points and by the practical absence of the side lobes in a plane containing the antenna.

In a further aspect, the antenna according to the invention comprises a plurality of center-fed dipole radiating elements spaced along a transmission line supplying them in series combination, the free space or mechanical distance between the dipole centers being selected (for example from about 0.5 to 1.0 times the free space wave length of radiated energy) to provide, together with a certain difference of the phases of the radiator energy (for example  $\pm 40^\circ$ ), a desired radiation pattern.

These and other objects, aspects and features will appear from the following description of two typical practical embodiments illustrating the novel characteristics of my invention. This description refers to a drawing in which

Fig. 1 is an axial section through an antenna according to my invention, with two co-axial center-fed dipoles;

Fig. 2 is a similar section through an antenna incorporating three dipoles and of somewhat modified mechanical structure; and

Figs. 3, 4 and 5 are sections on lines 3—3, 4—4, and 5—5 respectively of Fig. 1.

In Fig. 1, a co-axial transmission line supplying the antenna is indicated as comprising the outer conductor 10 and the inner conductor 12. Conventional means for mechanically supporting the line, and with it the antenna proper will be provided but are not shown in order to simplify the drawing. Within the antenna proper, the outer conductor 10 terminates at 15 to provide a feed area in the manner to be explained below. At a certain distance below gap 15, the conductors are coaxially surrounded by a metal cylinder 21 which is fastened to outer conductor 10 by means of a metal end disc 22 which is fastened to, for example welded, to parts 10 and 21.

If preferred, the electrically open end 23 may be mechanically closed with dielectric material. The cylinder 21 is approximately a quarter wave in length and represents a choke having very

high, practically infinite, impedance at the point 23, thus defining the outer end of an approximately quarter wave radiating section, next to the generator feeding into the line, constituted by the outer conductor extending from the point 23, as indicated at 1a. This quarter wave section comprises one element of the first half wave dipole unit marked I in Fig. 1.

The inner conductor 12 ends at 26 within choke 21, where it has a tapped central hole 51 into which a somewhat thinner inner conductor 52 is screwed, forming a shoulder at 26. An axially perforated rod 40 of dielectric material is threaded over conductor 52.

The second half or element Ib of the first dipole unit I is formed by another quarter wave choke 31 which is preferably but not necessarily of the same material and dimensions as the choke 21 and has an electrically closed inner end 32 adjacent to the cut-away portion 15, and an electrically open end 33 which may be mechanically closed with a solid dielectric. The open end 33 of the choke 31 defines the outer end of the second radiating half Ib of the first dipole I.

Body 31 is mounted on a metallic sleeve 20 which fits dielectric body 40 and constitutes with outer conductor 10, a feed gap at 15. Fixed to sleeve 20, which constitutes part of the feed line, is further a third dipole element formed by cylinder body 41 with disk 42. The open ends of cylinders 31 and 41 face each other across a gap which corresponds to a gap, defined by metal spacer 53, between dielectric body 40 and a second dielectric body 50 inserted in sleeve 20 and somewhat protruding therefrom at 16. The inner ends of elements 31 and 41 are thus connected by sleeve 20.

The inner conductor 52 extends beyond dielectric body 50.

The above described structural elements may be mechanically held together by any suitable means; in the present instance, conductor 52 is provided with a shoulder 54 which firmly presses rods 40 and 50 and spacer 53 against shoulder 26 when the threaded end of 52 is screwed into, or fastened in any other suitable manner to the above mentioned tapped hole 51. The sleeve 20 may be press fitted and cemented to plugs 40 and 50.

It will be noted that sleeve 20 constitutes a continuation of outer conductor 10, cut-away portion 15 being the above mentioned feed area.

Cylinder 41 constitutes a third choke preferably similar to the chokes 21 and 31. The electrically open end 43 defines the outer end of the first quarter wave section IIB of the second dipole unit II. The free end of conductor 52, extending from the cut-away portion 16 constitutes the second quarter-wave section IIA of the second dipole unit II. The free space distance between portion 16 and the end 55 of conductor 52 is about a quarter wave. The widths of the cut-away portions, 15, 16 are chosen to match the antenna and line impedances in known manner. These cut-away portions are also preferably electrically symmetrical, that is, they are of equal width and the inner conductor is surrounded by the same dielectric material, preferably a solid dielectric as herein described. It will further be understood that the impedance value of the antenna as a whole and that of its feeding line have to be matched according to conventional principles.

It will now be evident that the present system operates with radiating units which are connected in the feed line for direct excitation or energy

supply therefrom, that is they are not merely in series with each other but actually fed in series from the generator.

Generally speaking, the phase difference between the energy at the two radiating units should be zero; the mechanical distance between the units is given an optimum value, determined empirically or mathematically according to known methods.

In the present embodiment, the phase difference between the dipole centers 15 and 16 is approximately zero degrees, although it may vary within  $\pm 40^\circ$ .

The proper values for the mechanical distances and the electrical phase relation between the two dipole units I and II are in the present embodiment provided by filling the space between the inner and outer conductors of the transmission line between dipole centers partly with air and partly with a dielectric material, as indicated in Fig. 1. The relative lengths of the air-filled section  $n$  and the sections  $m$  filled with dielectric material, which may be regarded as the sections effective for purposes of calculation, can be determined from the simultaneous equations

$$n + 2m = a \quad (1)$$

$$n + 2m\sqrt{\epsilon} = b \quad (2)$$

wherein  $a$  is the free space, or mechanical, distance in units of wave length, and  $b$  is

$$1 + \frac{\phi}{360}$$

likewise in wave length with  $\phi$  the phase difference between radiators measured in electrical degrees.

These furnish

$$m = \frac{b - a}{2(\sqrt{\epsilon} - 1)} \quad (3)$$

Using the preferred values 0.7 for  $a$  and 1.0 for  $b$  and the resin Styraloy (made by Dow Chemical Company) with the dielectric constant  $\epsilon$  of 2.4, the dimension  $m$  is  $0.275\lambda$  and  $n$  is  $0.15\lambda$ .

With this spacing there are no vertical side lobes, assuming that the antenna is placed vertically; the main vertical lobe is of maximum length and covers  $30^\circ$  between the half power points.

An increase of the free space distance between the dipole centers renders the main vertical lobe narrower and shorter while at the same time vertical side lobes are introduced. If the spacing is appreciably more than  $0.8\lambda$ , the side lobes become undesirably large.

By decreasing the free space distance between the dipole centers the vertical lobe is shortened and widened. This spacing should not be appreciably less than  $0.5\lambda$ . With this spacing of  $0.5\lambda$ , the quarter wave chokes 31 and 41 should be shortened  $\frac{1}{4}\lambda$  to provide a  $\frac{1}{8}\lambda$  spacing between their open ends.

It should be noted that the lengths  $m$  and  $n$  in Equations 1 to 3 may be divided in other combinations of equal or unequal parts.

Instead of one solid dielectric material, as above described, various materials or combinations of materials may be used. The respective lengths of the various portions of dielectric may be calculated from the simultaneous equations

$$n_1 + n_2 + \dots + n_i + 2m_1 + 2m_2 + \dots + 2m_i = a \quad (4)$$

$$n_1 + n_2 + \dots + n_i + 2m_1\sqrt{\epsilon_1} + 2m_2\sqrt{\epsilon_2} + \dots + 2m_i\sqrt{\epsilon_i} = b \quad (5)$$

The space between the outer conductor 10 and

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the inner conductor 12 of the coaxial transmission line between dipole centers from 15 to 16 on Fig. 1, may be filled with a single dielectric material. Then,

$$a\sqrt{e}=b \quad (6)$$

Where, as mentioned above,  $a$  is the free space or mechanical distance in wave lengths,  $b$  is

$$1+\frac{\Phi}{360}$$

measured in wave length, with  $\Phi$  the phase difference between radiators measured in electrical degrees, and  $e$  is the dielectric constant of dielectric material. From this,

$$e=\left(\frac{b}{a}\right)^2 \quad (7)$$

Substituting in (7) the preferred values 0.7 for  $a$  and 1.0 for  $b$ , the quantity  $e$  is found to be 2.04. Generally, the range of values of  $e$  for dielectric materials from 1.25 to 90.00.

Instead of a pair of dipoles as shown in Fig. 1, a larger number may be used, as for example shown in Fig. 2.

This figure contains all the components described with reference to Fig. 1, as indicated with identical numbers, with the addition of a dipole system or unit III, feed line sleeve 30, dielectric body 60, and unit elements provided by cylinders 61 and 71, forming a radiation gap 17. Sleeves 20 and 30 connect the inner ends of elements 61 and 71 to those of the adjacent elements 31 and 41, respectively. Instead of using the bare inner conductor 52 as last element in unit II, Fig. 2 indicates the possibility of continuing plug 50 beyond gap 16 and covering it with a sleeve 82 connected to inner conductor 52.

With the distances 15 to 17 and 17 to 16 mechanically  $0.7\lambda$ , and the phase difference about  $0^\circ$ , the main radiation lobe was in a practical embodiment even narrower than that of a two unit antenna according to Fig. 1, namely about  $20^\circ$  between half power angles. With increasing frequency, the units become mechanically shorter and the use of five and more coaxial dipoles arranged according to the invention becomes feasible, yielding an antenna of higher gain.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. System for radiating electro-magnetic energy comprising two radiators each incorporating two elements coaxially extending on either side of a center, a feed line, means for feeding each of said radiators directly in series with the other from said line substantially at said centers, said elements incorporating dielectric medium other than air, and means for coaxially mounting said radiators such that the electrical phase relation of said centers is substantially zero degrees whereas their mechanical distance is substantially less than one wave length of radiated energy in free space, due to said dielectric medium.

2. System for radiating electro-magnetic energy comprising two center fed radiators, a feed line, means for arranging said radiators coaxially along said line for feeding them substantially at their centers in direct series connection in the line, the electrical phase relation of said centers being substantially zero degrees, and dielectric means associated with said radiators for render-

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ing the mechanical distance of said centers less than about 0.8 of a wave length of the radiated energy in free space.

3. System for radiating electro-magnetic energy comprising several coaxially arranged members adapted to radiate fields of substantially the same power and configuration each of said members having two centrally fed substantially quarter wave length elements connected directly in series and each of said members including a dielectric transmission medium, and means for mounting said members at a certain distance of their centers, said medium and said mounting means putting said members electrically in phase but placing them mechanically closer than one wave length.

4. System for radiating electro-magnetic energy comprising several coaxially arranged members adapted to radiate fields of substantially the same power and configuration each of said members having two substantially quarter wave length elements connected directly in series to be centrally fed and each of said members including a dielectric transmission medium, and means for mounting said members at a certain distance of their centers, said medium and said mounting means putting said members electrically in phase, said dielectric medium being selected to make the mechanical distance of said centers from substantially 0.6 to 0.8 wave lengths.

5. An antenna comprising a coaxial feed line and two center fed half wave radiators coaxially spaced along said line; the radiator nearest to said line including a quarter wave section of the outer surface of said line, a quarter wave choke mounted coaxially on said line, defining that end of said section which is opposite to its feed point with the electrically open end of the choke, and a quarter wave choke mounted coaxially on said line with its electrically closed end adjacent said radiator feed point; the other radiator including a quarter wave choke mounted coaxially on said line with its electrically closed end adjacent its feed point, and a quarter wave conductor constituted by the electrically closed end of said line; the mechanical distance between said dipole centers being from 0.5 to 0.8 wave length of free space radiation, and their electrical phase between plus and minus forty degrees.

6. An antenna according to claim 5, wherein the mechanical distance between said dipole centers is approximately 0.7 of the wave length of free space radiation, and their electrical phase is approximately zero degrees.

7. System for radiating electro-magnetic energy comprising a feed line, a plurality of radiating dipole units each having two elements, means for mounting said units along said line, means for serially connecting in said line the inner ends of the two elements constituting each of said dipole units thus providing series excitation, and phase adjusting means in said units for providing a given phase difference of the electric energy at the respective units.

8. System for radiating electro-magnetic energy comprising a feed line, a plurality of radiating dipole units each having two hollow elements, means for mounting said units along said line with said elements surrounding the line, means for serially connecting in said line the inner ends of the two elements constituting each of said dipole units thus providing series excitation, and phase adjusting means in said units for providing a given phase difference of the electric energy at the respective units.

9. System according to claim 8, wherein said feed line is coaxial, said elements are tubes coaxially surrounding said line, said connecting means are tubes within said elements, and said phase adjusting means include tubes of dielectric material coaxially arranged on the line.

10. System for radiating electro-magnetic energy comprising a feed line, a plurality of half wave length radiating dipole units each having two elements, means for mounting said units along said line, means for serially connecting in said line the inner ends of the two elements constituting each of said dipole units thus providing series excitation, said units being mounted so that the mechanical distance of the effective radiating centers of two adjacent units is within the range of 0.5 to 0.8 times the free space wave length, a selected value of said distance defining with a selected phase relation of the electric energy at said units a radiation pattern of selected configuration, and phase adjusting means in said units for providing said phase relation.

11. System according to claim 10 wherein said mechanical distance is substantially 0.7 of the

free space wave length and said phase difference is substantially zero.

GARDINER G. GREENE.

# REFERENCES CITED

The following references are of record in the file of this patent:

## UNITED STATES PATENTS

| Number    | Name               | Date          |
|-----------|--------------------|---------------|
| 2,111,636 | Lindenblad         | Mar. 22, 1938 |
| 2,201,857 | Dome               | May 21, 1940  |
| 2,274,389 | Von Baeyer         | Feb. 24, 1942 |
| 2,298,449 | Bailey             | Oct. 13, 1942 |
| 2,321,454 | Brown              | June 8, 1943  |
| 2,323,641 | Bailey             | July 6, 1943  |
| 2,400,127 | McGuigan           | May 14, 1946  |
| 2,455,224 | Bulchealter et al. | Nov. 30, 1948 |

## OTHER REFERENCES

FM and Television, January 1946, "FM Broadcasting and Communications Handbook," by James A. Craig. (Pages 36, 37, 40 to 45.)