April 20, 1965 J. M. BUZBEE 3,179,943

LOG PERIODIC MONOPOLE ARRAY AND IMAGE GROUND PLANE ELEMENTS ALTERNATELY CONNECTED TO PLURAL FEED LINES

Filed Feb. 12, 1962 2 Sheets-Sheet 1

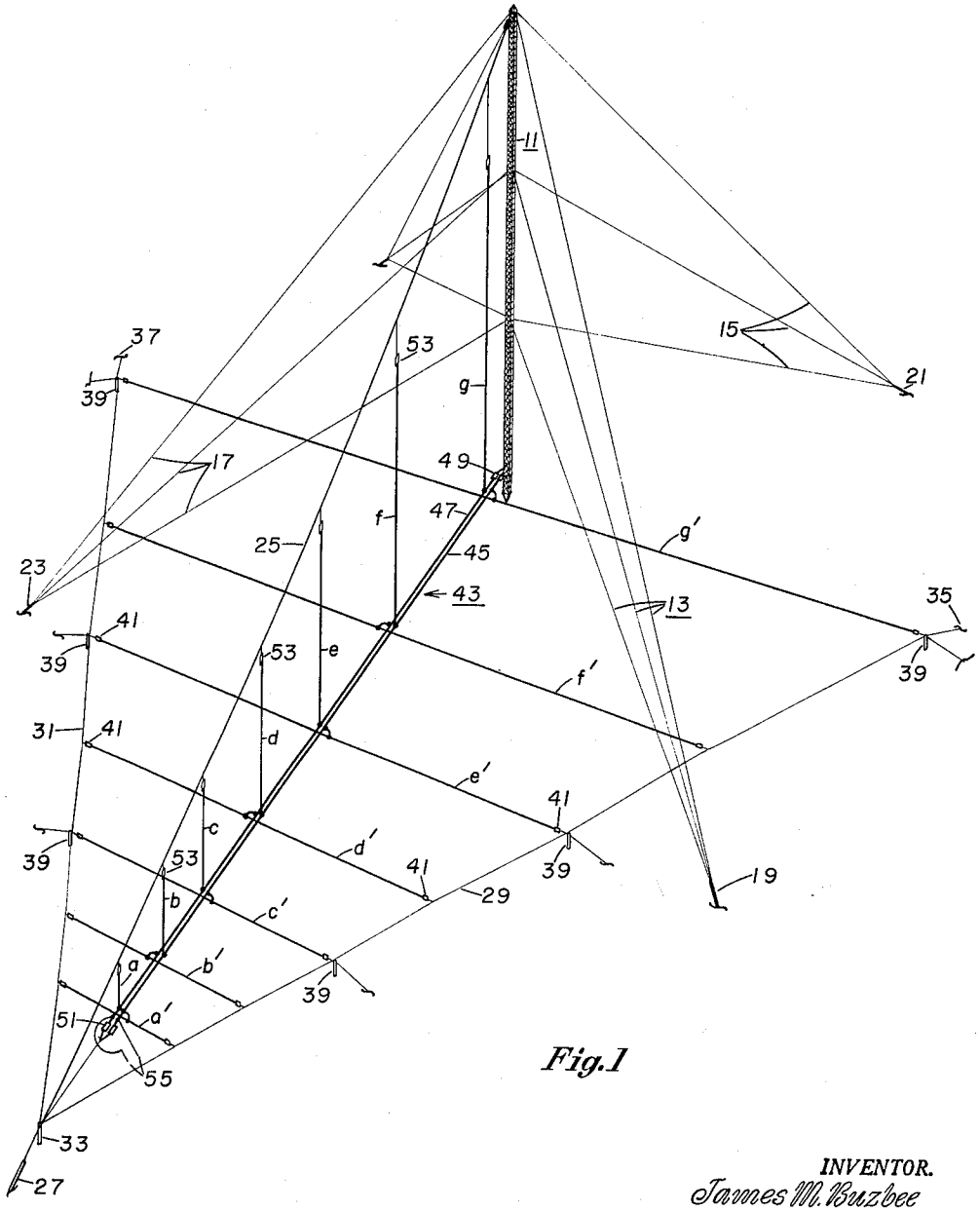

Fig.1

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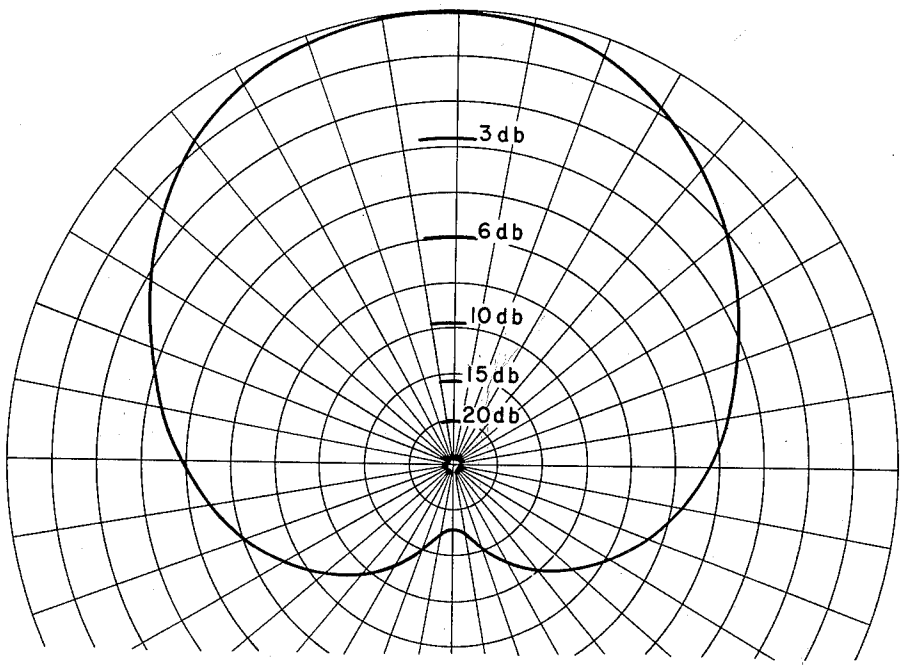

Fig. 2

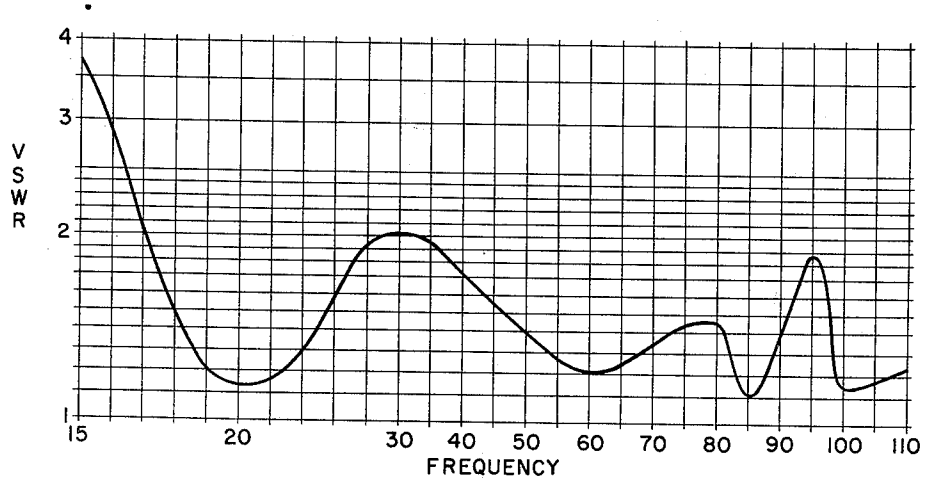

Fig. 3

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LOG PERIODIC MONOPOLE ARRAY AND IMAGE GROUND PLANE ELEMENTS ALTERNATELY CONNECTED TO PLURAL FEED LINES

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My invention relates to antennas, and more particularly to log-periodic monopole arrays. As background to aid in the understanding of my invention, it is convenient to refer to two important concepts which have contributed to significant advances in the antenna art in recent years. First, the concept that important properties of an antenna are determined by its shape and by its dimensions evaluated in wave length. If by an arbitrary scaling, an antenna is transformed into a structure equal to the original one, its properties will be independent of the frequency of operation. The antenna then satisfies the "angle" condition, so that its form can be specified entirely by angles, and not by any particular dimension. (See V. H. Rumsey, "Frequency Independent Antennas," IRE National Convention Record, Part I, pages 114–118, 1957.) Second, the concept that if an antenna structure becomes equal to itself by a particular scaling of its dimensions by some ratio tau, it will have the same properties at the frequency *f*, and at a frequency tau times *f*. Consequently, the impedance, or any other characteristic, is a periodic function of the logarithm of the frequency. Antennas obtained from utilization of this principle are called "log-periodic." (See R. H. Du Hamel and D. E. Isbell, "Broadband Logarithmically Periodic Antenna Structures," IRE National Convention Record, Part I, pages 119–128, 1957.)

Since the above-mentioned concepts were introduced, there have been numerous types of "log-periodic" antennas devised. One class of "long-periodic" antennas which should be mentioned is that of log-periodic dipole arrays (see D. E. Isbell, "Log Periodic Dipole Arrays," IRE Transactions on Antennas and Propagation, volume AP–8, May 1960, No. 3). While the log-periodic dipole array has the operational advantage of being broadband and the structural advantage of being planar, it has the disadvantage of large size when utilized for frequencies at the lower end of the radio spectrum. In order to reduce the required antenna size, log-periodic monopole arrays have been proposed (see D. G. Berry and F. R. Ore, "Log Periodic Monopole Array," IRE International Convention Record, Part I, Antennas and Propagation, pages 76–85, 1961). The log-periodic monopole antenna is of course generally only half the size of its dipole counterpart. These monopole arrays must, however, be worked with an image reflecter, either earth or some sort of counterpoise. Normally, a monopole element may be fed in a simple manner, for example, from a transmission line whose characteristic impedance is half of that used to feed a dipole, or balanced, version of the antenna used; one side of the transmission line being connected to a ground plane, usually earth, and the other side being connected to the radiating element. Unfortunately, however, such a simple scheme is not practical for the case of log-periodic antenna arrays, as will be immediately apparent from inspection of the illustrations contained in the Isbell article above mentioned. Because of the fact that the energy to be transmitted is fed to the log-periodic array at the front or small end, it must progress past the high frequency portion of the antenna (the portion containing the shorter radiating elements) in order to reach the longer lower frequency radiating elements. In the design suggested by Isbell, the transmission line is transposed between adjacent radiating elements in order to obtain a reversal of direction for the radiating field. This must be done in order to prevent excitation of the longer elements at higher modes of oscillation. If it were attempted to modify the Isbell array into a monopole array by replacing half of the dipole elements by a connection to ground, the path through the ground between alternate connections would represent a shunt conductance to the transmission line. As frequency decreases, the magnitude of this conductance will become intolerable, and a high VSWR will result.

There have been many attempts at solution of the problems involved in feeding a log-periodic monopole array; some of them workable, some not, and some with more advantages than others, but none of them have been ideal. Most of the proposed schemes have been summarized in the Berry and Ore article above mentioned. One proposed scheme has been to use an unbalanced transmission line with transformers between each radiating element to reverse phase. Another proposed scheme uses resonant loading of an unbalanced transmission line to obtain the necessary phase shift between elements. Still another proposed scheme consists of an unbalanced transmission line electromagnetically coupled to quarter wave radiation elements.

While all of the proposed schemes above mentioned provide workable solutions to the problem, they all have disadvantages. First, they require an unbalanced transmission line feed, and since many balanced transmission lines are in general use in the industry, use of these antennas requires the changeout of such transmission lines at considerable expense to the user. Furthermost, all of these antennas utilize the earth as the reflecting, or image plane. Most of these antennas however, do utilize some configuration of conductors to improve the conductivity of the earth. Thus, in spite of the fact that there have been many attempts at solutions, the problems outlined above still remain.

Accordingly, it is the general object of the present invention to provide an improved log-periodic monopole antenna array wherein the disadvantages above mentioned are obviated.

Another object of the present invention is to provide a log-periodic monopole antenna array which can be conveniently fed from a balanced transmission line.

Another object of the present invention is to provide an improved log-periodic monopole antenna array wherein structural problems are minimized.

Another object of the present invention is to provide an improved log-periodic monopole antenna array wherein the phase shift feed problem is conveniently solved.

Another object of the present invention is to provide a log-periodic monopole antenna array that is readily erected and easily portable.

Another object of the present invention is to provide a log-periodic monopole antenna array which can be practically utilized for transmission at frequencies near the lower end of the HF portion of the radio frequency spectrum.

These and other object are effected by my invention as will be apparent from the following description, taken in accordance with the accompanying drawings, forming a part of this application, in which:

FIG. 1 is a schematic perspective view showing a log-periodic monopole antenna array in accordance with a preferred embodiment of my invention;

FIG. 2 is a graph showing an actual plot of the radiation pattern measured on an experimental model antenna constructed in accordance with a preferred embodiment of the present invention; and

FIG. 3 is a graph showing a plot of VSWR versus frequency (megacycles), as measured for an actual experi-

mental model antenna array constructed in accordance with a preferred embodiment of the present invention.

My invention, in accordance with a preferred embodiment thereof, contemplates use of one half of the radiating elements of a log-periodic dipole array design (for example, such as the ones discussed in the Isbell article hereinbefore mentioned), disposing these radiating elements vertically, and replacing the elements of the other half of the dipole array with horizontal elements which are attached to the feed line in the same manner as the original elements. These horizontal elements must be insulated from each other and from surrounding objects and should, in general, extend a quarter wave length from the antenna vertical elements in each direction away from same, though they may extend further. Referring to FIG. 1 of the drawings, the antenna vertical elements are designated *a* through *g*, while the horizontal elements are designated as a prime through *g* prime. A conventional type mast **11** is held vertically in place by a system of guys **13, 15, 17**, which are suitably anchored in earth at **19, 21, 23**. A catenary line or support cable **25** is fixed to the mast adjacent its upper end and extends downwardly and outwardly to a suitable anchor in earth at **27**. The horizontal elements *a* prime through *g* prime are disposed in spaced parallel relation and are supported in a horizontal plane above the earth plane by means of side lines or cables **29, 31** which diverge from a support **33** at the small end of the array to respective ground anchors **35, 37** at the large end of the array. Suitable intermediate supports **39** are provided to hold the side cables in a substantially horizontal plane. The horizontal elements are connected at their ends to respective insulators **41**, which in turn are connected to the side support cables. A feed line **43** in the form of a pair of conductors **45, 47** is connected at one end to insulators **49** which are in turn connected to the mast **11** at a level just above the plane of the horizontal elements; and is connected at its other end to insulators **51** which are in turn connected to the ground support **33** immediately above the junction of the side support cables **29, 31**. Thus, the feed line **43** bisects the angle formed by the side support cables. The antenna vertical elements are connected at their upper ends to respective insulators **53** which are in turn connected to the catenary **25**. The lower ends of the vertical elements are connected respectively to alternate sides of the feed line **43**. Similarly, the horizontal elements are connected at their center points to alternate sides of the feed line, with each horizontal element being connected to the side of the feed line opposite to the side to which the corresponding vertical element is connected. In other words, vertical elements *a, c, e, g* are connected to one side **47** of the feed line, while vertical elements *b, d, f* are connected to the other side **45**. At the same time, horizontal elements *a* prime, *c* prime, *e* prime, *g* prime, are connected to the same side **45** of the feed line as are vertical elements *b, d, f*, while horizontal elements *b* prime, *d* prime, *f* prime are connected to the same side **47** of the feed line as are vertical elements *a, c, e, g*. The antenna is fed from a balanced transmission line represented by leads **55** connected to the feed line **43** adjacent the small end of the array.

It is understood, of course, that the lengths of both the horizontal elements and the vertical elements of the array, as well as their spacing, is chosen in accordance with a suitable logarithmic ratio, and in accordance with log-periodic design principles. It is also understood that the number of array elements shown by FIG. 1 is for illustrative purposes only, and in practice would be chosen for a particular array in accordance with log-periodic design principles. It is, however, not necessary that the tolerance on element dimensions be extremely close. As examples, it has been found that all elements in the array may be of uniform diameter if extreme bandwidth is not required. Furthermore, the tips of the elements may describe an exponential curve such as a catenary. Such departures from strict log-periodic design principles are commonly employed in practical log-periodic antenna design.

Log-periodic monopole antenna arrays constructed in accordance with the principles of the present invention provide a number of desirable advantages. The elevated horizontal elements of the array provide a good image plane for the vertical elements with which they are associated, and the image plane is relatively independent of the lossy earth. Being insulated from each other, the horizontal elements do not constitute a shunt conductance to the feed line. Since the array does not utilize buried components, it can be made easy to erect and readily portable. It is generally realized by those skilled in the antenna art that the use of a counterpoise instead of the earth as an image reflecter provides an appreciable improvement in antenna efficiency for monopole type antennas. It is thought that a similar improvement can be expected for the case of the log-periodic monopole antenna array wherein the counterpoise arrangement is used instead of the earth as the image reflecter.

The log-periodic monopole antenna array constructed in accordance with the principles of my invention has the further advantage of having a balanced feed point similar to that of the log-periodic dipole array. This allows the use of standard balanced transmission lines to transfer energy from the transmitter to the antenna array or from the antenna array to the receiver.

It should be pointed out that the incidental conductive connection between alternate horizontal elements provided by the feed line is of no importance. The insulation between horizontal elements as referred to herein means that there is no connection which would allow circulating currents to flow between elements such as would be the case through the earth if a conductive connection were made directly to a common ground plane at alternate horizontal elements.

The log-periodic monopole antenna array constructed in accordance with my invention may be used near the earth reflecting plane, or it may be used in free space since its operation is substantially independent of the earth reflecting plane. Of course, as with any antenna array, the earth will affect the far field pattern of the antenna, but the antenna is still useful in a free space environment. In effect, the antenna of the present invention provides a balanced array similar to the log-periodic dipole array, but which has a physical configuration which makes it suitable for disposition near ground, with resulting height and structural advantages when compared to other types of balanced antennas.

The antenna array shown in the drawings and described herein as the preferred embodiment of my invention is only one of a number of configurations which may be constructed to operate in accordance with the principles of my invention. Any of the common radiating elements may be substituted for the wire elements of FIG. 1; for example, conical elements, sheet elements, overtone mode elements etc. Furthermore, the horizontal elements (sometimes also referred to herein as complementary or image elements) may be located as shown in FIG. 1, or they may be disposed in any other manner which maintains symmetry of their location with respect to the plane which contains the vertical radiating elements. Also, since the antenna array is essentially independent of earth, the antenna itself may be disposed in other planes, such that horizontal polarization, or intermediate degrees of polarization may be obtained. As previously stated, the array may be fed from the front or small end with a balanced transmission line, or it may receive its energy from the rear through a coaxial transmission line which proceeds through one wire of the balanced transmission line to the front of the array, so as to form an "infinite balun" of the type employed by other log-periodic arrays.

The impedance of the two wire feed line which is part

of the antenna may be varied to produce different feed point impedances in the same manner as is commonly used in the design of log-periodic dipole arrays. Of course, any suitable materials may be used for the construction of antenna arrays in accordance with the principles of my invention. The elements of the antenna array may be self-supporting, or they may be supported by an external structure as shown in FIG. 1. Furthermore, antenna arrays constructed in accordance with the principles of my invention are suitable for scaling to any part of the radio frequency spectrum. While the antenna arrays herein described are most useful in the high frequency (HF) portion of the radio spectrum, they are useful in all parts of the spectrum, and may be particularly so in cases where antenna arrays must be operated in conjunction with a ground plane type of environment, such as aboard an aircraft, missile, ship at sea, etc. One very significant advantage of antenna arrays constructed in accordance with the principles of my invention is its reduction in height compared to that of a log-periodic dipole array. It therefore would prove to be most useful at the lower radio frequenies. As an example, a log-periodic dipole array designed to cover the high frequency part of the radio spectrum (from two to thirty megacycles) might have a dimension across the rear, parallel to the longest element, of approximately two hundred and forty feet. The length of the array might be as much as three to five hundred feet. While the antenna of the present invention does not provide a reduction in length for comparable characteristics, it does provide a halving of height of the radiating elements when used for vertical polarization. It will be noted that the lengths of the horizontal elements in typical log-periodic monopole arrays of the present invention are the same as for the radiating elements of the log-periodic dipole array. However, since the horizontal elements in the log-periodic monopole array of the present invention may be parallel to and located relatively near the ground plane, they present little structural difficulty compared with the situation wherein the elements of this same length must be vertically disposed.

The foregoing disclosure and the showings made in the drawings are merely illustrative of the principles of this invention and are not to be interpreted in a limiting sense.

I claim:

1. A log-periodic monopole antenna array comprising: a plurality of radiating elements having central axes disposed in a plane with the length and spacing of said elements progressively increasing from one end of said array in accordance with a logarithmic function; an image element for each said radiating element and extending symmetrically and laterally outwardly from said plane on either side of said respective radiating element from a point substantially at an end thereof, with each side of each said image element having a minimum length substantially equal to that of the corresponding radiating element; a feed line for said array including first and second conductors disposed near the adjacent ends of said radiating elements and the center points of said image elements; means for electrically connecting said respective adjacent radiating elements to opposite sides of said feed line, and means for electrically connecting each respective image element to the feed line conductor opposite that to which the corresponding radiating element is connected.

2. The invention as set forth in claim 1, wherein said radiating elements and said reflector elements are conductive wires.

3. A log-periodic monopole antenna array comprising: a plurality of radiating elements having central axes disposed in a vertical plane with the length and spacing of said elements progressively increasing from one end of said array in accordance with a logarithmic function; an image element for each said radiating element and extending symmetrically outwardly in a horizontal plane on either side of said respective radiating element from a point substantially at the lower end thereof, with each side of each said image element having a minimum length substantially equal to that of the corresponding radiating element; a feed line for said array including first and second conductors extending near the lower ends of said radiating elements and the center points of said image elements; means for electrically connecting said respective adjacent radiating elements to opposite sides of said feed line, and means for electrically connecting each respective image element to the feed line conductor opposite that to which the corresponding radiating element is connected.

4. A log-periodic monopole antenna array comprising: a plurality of radiating elements having central axes lying in a vertical plane and disposed in spaced parallel relation with the lower ends of said elements lying on a straight line with the length and spacing of said elements progressively increasing from the small end of said array in accordance with a logarithmic function; a counterpoise element for each said radiating element and extending in a horizontal plane symmetrically outwardly on either side of said respective radiating element from a point substantially at the lower end thereof, with each side of each said counterpoise element having a minimum length substantially equal to that of the corresponding radiating element; a feed line for said array including first and second conductors extending near the lower ends of said radiating elements and the center points of said counterpoise elements; means for conductively connecting said respective adjacent radiating elements to opposite sides of said feed line, and means for conductively connecting each respective counterpoise element to the feed line conductor opposite that to which the corresponding radiating element is connected.

5. The invention as set forth in claim 4, wherein said radiating elements and said counterpoise elements are wires, and including means for supporting said array with said counterpoise elements above and adjacent a ground plane.

6. A log-periodic monopole antenna array comprising: a plurality of radiating elements, with the length and spacing of said elements progressively increasing from one end of said array in accordance with a logarithmic function; an image element for each said radiating element and extending laterally outwardly on either side of said respective radiating element from a point substantially at an end thereof, with each side of each said image element having a minimum length substantially equal to the corresponding radiating element; a feed line for said array including first and second conductors disposed near the adjacent ends of said radiating elements and said image elements; means for electrically connecting said respective adjacent radiating elements to opposite sides of said feed line, and means for electrically connecting each respective image element to the feed line conductor opposite that to which the corresponding radiating element is connected.

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