United States Patent

Grant

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[45] **Oct. 3, 1972**

[54] **BROADSIDE LOG PERIODIC ANTENNA**

[72] Inventor: **Ronald D. Grant,** Urbana, Ill.

[73] Assignee: **JFD Electronics Corporation,** Brooklyn, N.Y.

[22] Filed: **Aug. 27, 1970**

[21] Appl. No.: **69,063**

Related U.S. Application Data

[63] Continuation of Ser. No. 685,093, Nov. 22, 1967, abandoned.

[52] **U.S. Cl.** **343/792.5,** 343/797, 343/810, 343/793

[51] **Int. Cl.**.....**H01q 11/10**

[58] **Field of Search**...343/792.5, 793, 912, 796, 797, 343/798, 809, 810

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Saxfield Chatman, Jr.
Attorney—Ostrolenk, Faber, Gerb & Soffen

[57] **ABSTRACT**

This invention teaches an antenna array of the broadside type in which dipoles of differing electrical lengths are stacked vertically above and below an imaginary plane with electrical lengths increasing with increasing distance in moving above and below the imaginary plane. The antenna has symmetry in that for each dipole of the array below the imaginary plane, for example, there is a dipole of substantially equal electrical length and spacing approximately the same distance above the imaginary plane.

Transposed feeder harness means are employed for joining adjacent dipoles and common output (input) terminals are provided in a position substantially at the location of the imaginary plane. Directional characteristics are obtained by means of Veeing the dipole arms and/or providing a vertically aligned ground screen positioned behind the antenna stack array.

In another embodiment a similar array may be positioned immediately behind the first array in place of the ground screen. Directional characteristics may be obtained through coupling an output (input) utilization means to one and then the other of the arrays which are coupled at their feed terminals by means of a transposed feeder section. The array may also be joined with a conventional endfire array, for example, to form a broadside VHF endfire array and an endfire UHF array or conversely, a broadside UHF array and an endfire VHF array.

Omnidirectional characteristics may be introduced if such an application is either desired or required by bending or otherwise forming the dipole arms so as to provide a substantially U-shaped configuration for each dipole.

As another embodiment the ground screen may be replaced by parasitic elements arranged in a vertically stacked array with the parasitic element being provided for each dipole in the broadside array and being positioned in substantially behind its associated dipole.

25 Claims, 15 Drawing Figures

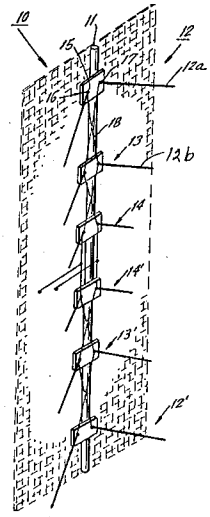


FIG. 1

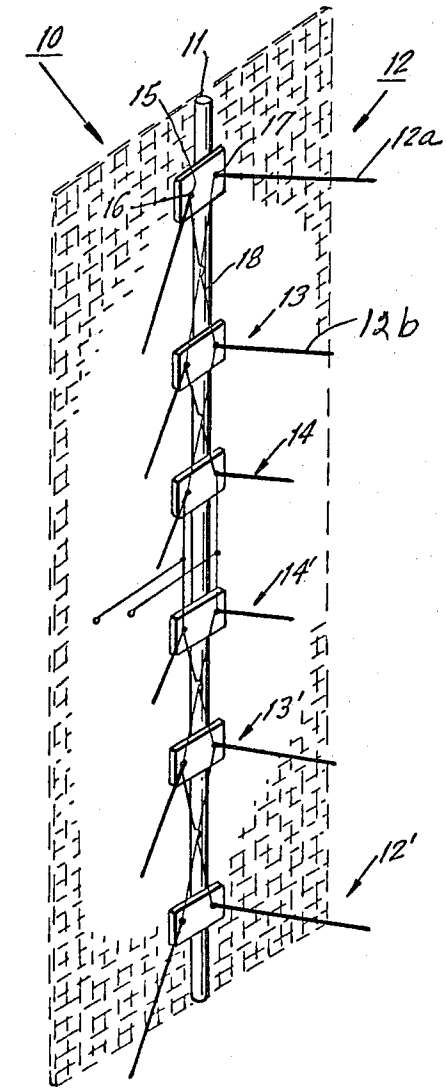


FIG. 1a

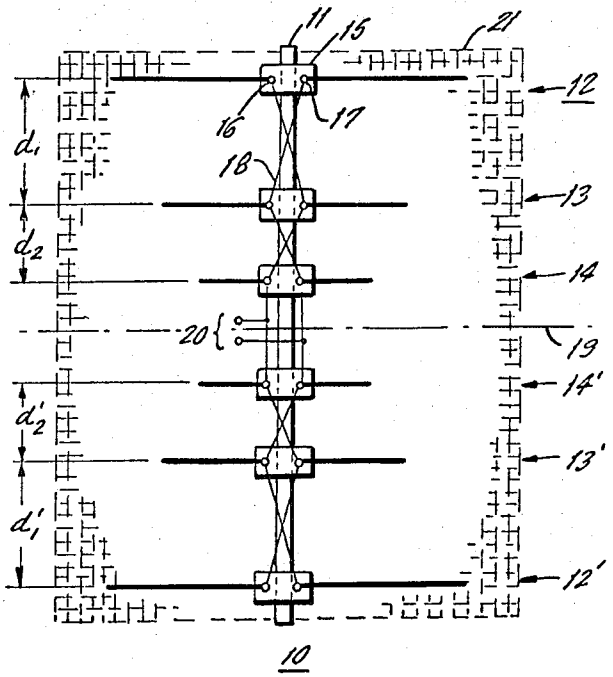
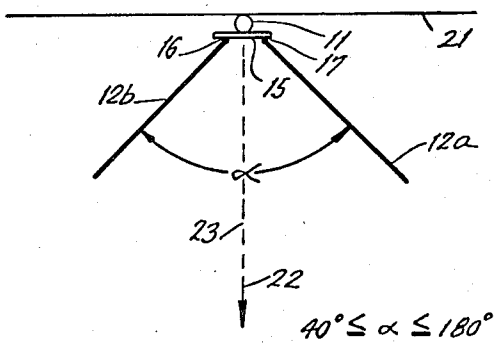


FIG. 1b



$40° \leq \alpha \leq 180°$

INVENTOR.
RONALD D. GRANT

BY
Ostrolenk, Faber, Gerb & Soffen
ATTORNEYS

FIG. 2.

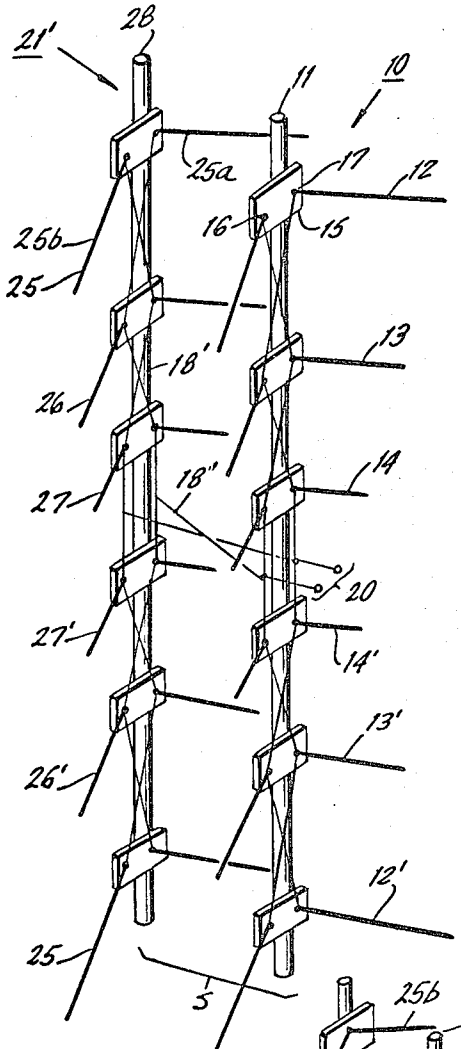
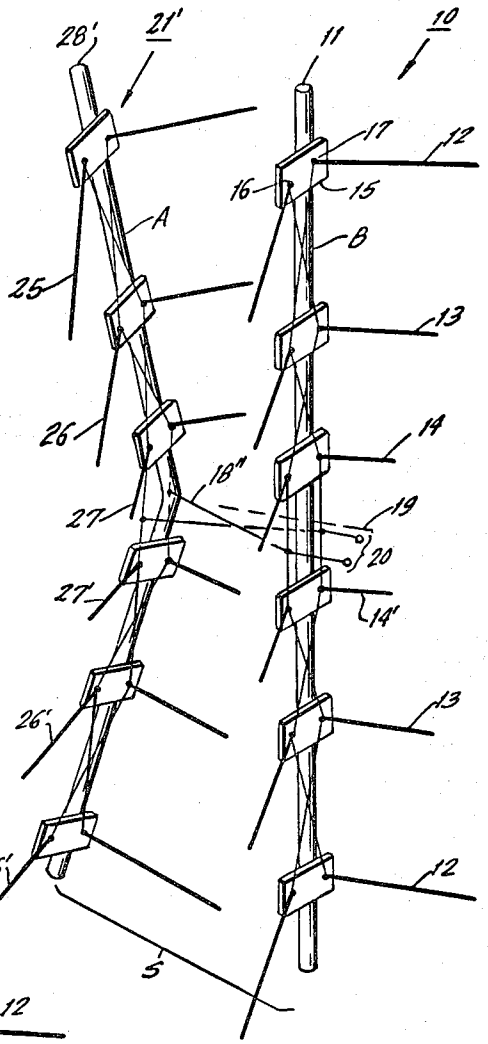


FIG. 3.



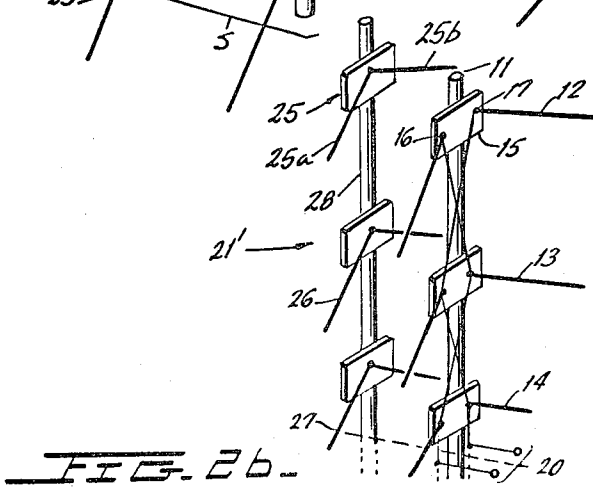


FIG. 2b.

FIG. 2a.

INVENTOR.
RONALD D. GRANT

BY
Ostrolenk, Faber, Gerb & Soffen

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FIG. 4.

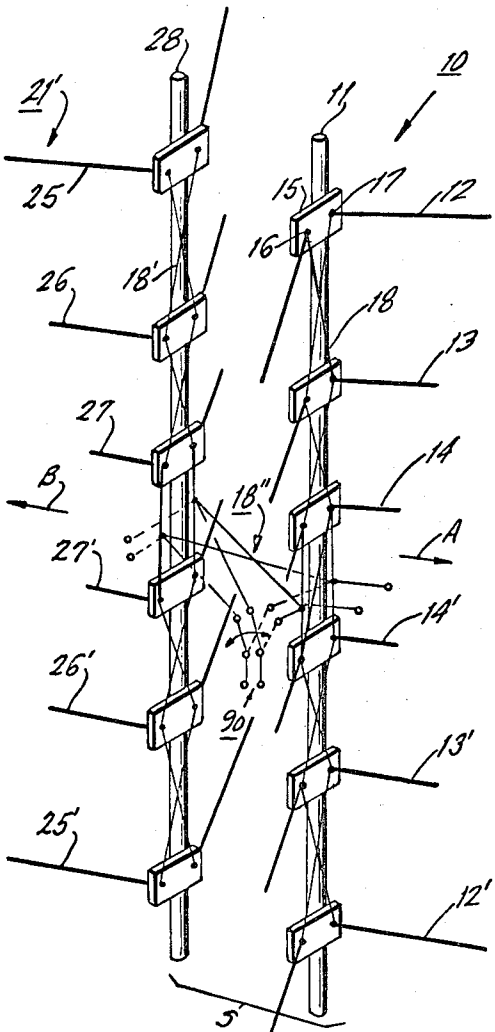
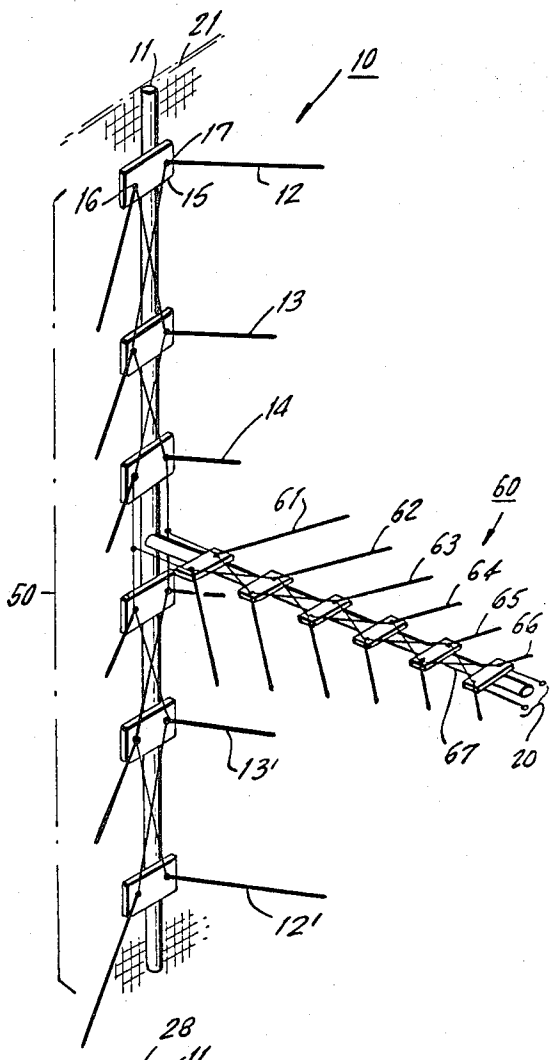


FIG. 5.



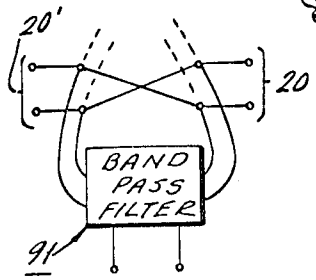
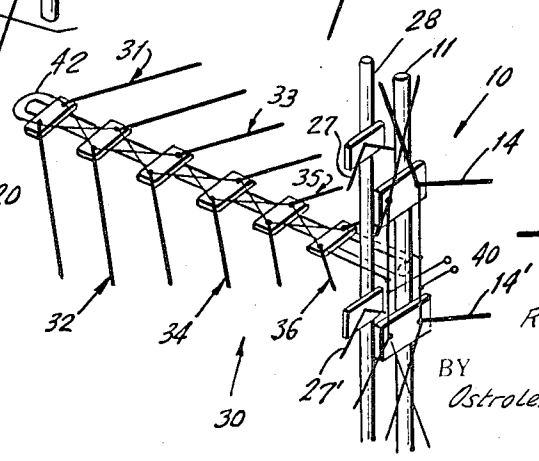


FIG. 4a.



INVENTOR.
RONALD D. GRANT

BY
Ostrolenk, Faber, Gerb & Soffen
ATTORNEYS

FIG. 7.

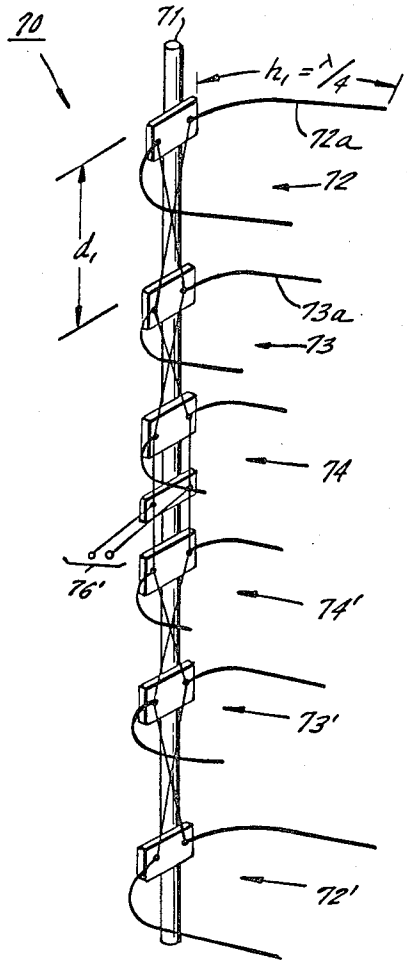
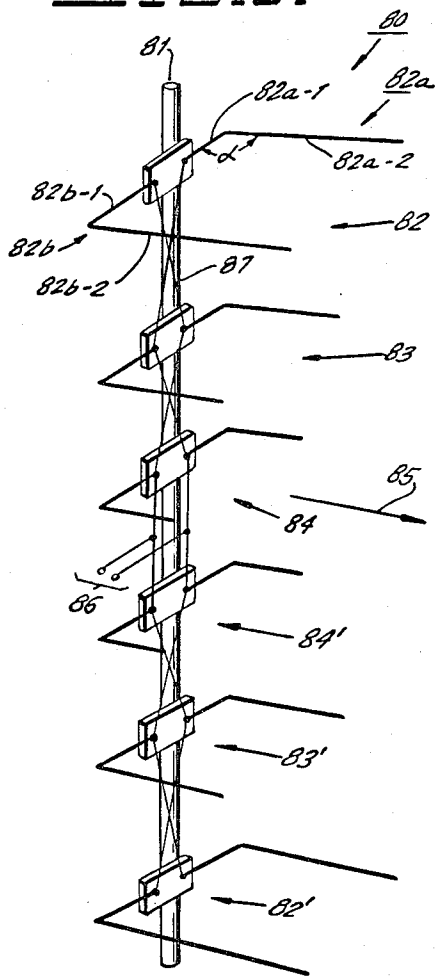


FIG. 8.



E PATTERN OMNIDIRECTIONAL
H PATTERN BIDIRECTIONAL

FIG. 9a.

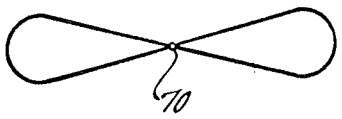
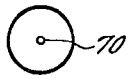


FIG. 9b.



INVENTOR.
RONALD D. GRANT

BY

Ostrolenk, Faber, Gerb & Soffen
ATTORNEYS

BROADSIDE LOG PERIODIC ANTENNA

This application is a continuation of application Ser. No. 685,093, filed Nov. 22, 1967, now abandoned.

The instant invention relates to antennas, and more particularly to a broadside antenna of the log periodic type yielding extremely high gain and providing a superior radiation pattern through the use of a relatively small number of dipole elements.

Antennas of the log periodic type are presently gaining widespread prominence due to their inherent ability to provide high gain and superior radiation patterns over a substantially broad band of operating frequencies. For example, such log periodic antennas presently in use cover the entire VHF band; the entire UHF band; and a combination of both the UHF and VHF bands through the use of a composite log periodic antenna array. Such present-day log periodic antennas are of the endfire array category. In order to increase the gain of such antennas appreciably, a substantially appreciable number of dipoles and/or parasitic elements must be added to the array, thereby substantially increasing the weight of the array, length of the array and presenting significant problems as regards structural strength of the antenna as well as of the antenna mounting element.

The instant invention is characterized by providing a log periodic antenna of the broadside array category wherein the increase of the number of dipoles to the array has been found to be directly linearly related to the gain. Thus, if the number of active elements (i.e., dipoles) is doubled, the antenna gain is likewise doubled, thereby yielding a much more efficient antenna for the number of dipole elements employed.

The instant invention is comprised of a vertical supporting means for positioning and supporting a plurality of dipoles. Each of the dipoles mounted to the supporting means is comprised of a pair of dipole arms lying substantially within a horizontal plane being substantially equal in length and being oriented or V'd at an angle lying substantially within the range from 40° to 180°. Moving downwardly from the topmost dipole, the succeeding dipoles are arranged at spaced intervals along the supporting means, with each of the V'd dipoles pointing substantially in the same direction as the topmost dipole. The arms of succeeding dipoles preferably differ in length from the dipole positioned immediately above by a factor γ wherein γ varies from 0.78 to 0.99. The spacing between the dipoles diminishes preferably by the amount γ_1 such that the spacing between the second and third dipoles, counting down from the top, is γ_1 times the spacing between the topmost and next to the topmost dipole. It should be understood that the factors γ and γ_1 need not be equal to one another.

The decreasing length of the dipole arms and decreasing spacing continues until the central or feed point of the antenna array is reached, at which time the succeedingly lower dipole arms positioned beneath the feed point increase in spacing and in length of dipole arms in accordance with the γ factors mentioned above. A transposed feeder harness couples the feed point to each of the dipole arms for providing proper phasing of the dipoles. A ground plane or reflecting plane, preferably in the form of a metallic grid or metallic screen, is positioned behind the broadside array so that a vertically aligned imaginary plane which is the bisector of the angle formed between each dipole is substantially perpendicular to the surface of the ground plane.

The spacing between adjacent dipoles moving downwardly from the topmost dipole decreases in a substantially regular fashion until a center point or feed point is reached at which the spacing then increases moving downwardly from the central point to the bottom-most dipole. In a like manner, the length of dipole arms from the topmost dipole to the central feed point decreases in a substantially regular fashion, whereas dipole arm length increases in a regular fashion, moving downwardly from the central feed point to the bottom-most dipole. The preferred antenna array is substantially symmetrical to an imaginary horizontal plane passing through the central feed point such that dipole arms located at equal distances above and below the imaginary plane have equal arm length.

A feeder line is coupled from the central feed point both upwardly and downwardly along the array by means of a transposed feeder harness in order to assure that all signals fed from the feed point to each dipole, or conversely, fed from each dipole back toward the central feed point, are all in phase.

As an alternative embodiment, the ground plane may be replaced by a plurality of parasitic elements, each being arranged behind an associated dipole. Each parasitic element may be V'd, either forwardly or rearwardly, or may be straight. The spacing of each parasitic element relative to its associated dipole and the electrical length of each parasitic element is selected so as to reflect substantially all of the energy impinging on the element toward its associated dipole.

Experimentation with the antenna has proven that the array provides extremely high gain operation over a broad band of operating frequencies as well as yielding an extremely highly directive radiation pattern. Providing additional dipoles has been found to increase gain of the antenna array in a linear fashion, thereby providing very significant additional amounts of gain per dipole stacked to the array, especially when compared with endfire log periodic arrays.

By appropriate selection of dipole arm lengths and spacings, the antenna is capable of providing extremely good performance as a UHF antenna, a VHF antenna (covering both the low band and high band VHF), a combined VHF and UHF antenna, as well as being capable of being employed with endfire arrays to provide a combined UHF-VHF antenna. For example, the stacked array of the instant invention may be combined with a standard VHF endfire log periodic antenna for providing transmission or reception over the entire VHF and UHF bands. As another alternative, a stacked broadside array designed in accordance with the principles of the instant invention for operation as a VHF antenna may be combined with an endfire array covering the UHF band so as to incorporate the unique advantages of the stacked broadside array described herein with standard endfire arrays.

Modification of the above embodiment through either alternative of giving each arm of the dipoles a curved configuration, or an L-shaped configuration, and through omission of the ground plane or parasitic elements yields an antenna similar in all characteristics

to the antenna described above, but with the differing feature of providing an omnidirectional radiation pattern yielding high gain over the operating frequency range.

It is, therefore, one object of the instant invention to provide a novel log periodic antenna of the broadside type for use in transmission and reception applications.

Another object of the instant invention is to provide a novel stacked broadside log periodic antenna comprised of a plurality of dipoles stacked in a vertical fashion with the dipoles being arranged in an asymmetric pattern relative to a horizontal plane passing through the central feed point of the antenna.

Yet another object of the instant invention is to provide a novel stacked broadside log periodic antenna comprised of a plurality of dipoles stacked in a vertical fashion with the dipoles being arranged in an asymmetric pattern relative to a horizontal plane passing through the central feed point of the antenna and wherein the array is further provided with a vertically aligned reflecting means arranged behind the dipoles for improving the radiation pattern and performance of the antenna array.

These and other objects of the instant invention will become apparent when reading the accompanying description and drawings in which:

FIG. **1** is a perspective view showing one preferred embodiment of the instant invention.

FIGS. **1***a* and **1***b* are front and top views, respectively, of the embodiment of FIG. **1**.

FIGS. **2**, **2***b*, **3**, **4**, **5** and **6** are perspective views showing alternative embodiments of the instant invention.

FIG. **2***a* is a top view of another preferred embodiment of the invention.

FIG. **4***a* is a schematic diagram of another feature of the invention.

FIGS. **7** and **8** are perspective views showing further alternative embodiments for the instant invention.

FIGS. **9***a* and **9***b* show H and E-plane radiation patterns for the antenna arrays of FIGS. **7** and **8**.

Referring now to the drawings, and more particularly to FIGS. **1** through **1**b, there is shown therein an antenna array **10** designed in accordance with the principles of the instant invention and which is comprised of a vertical pole or mast **11** adaptable for mounting to any suitable support, and which is, in turn, designed to have strength suitable for supporting the dipoles **12–14** through **12′–14′**, respectively. Each dipole is secured to mast **11** by a support bracket **15**, preferably formed of a suitable insulating material and having a pair of mounting terminals **16** and **17** secured thereto for the purpose of mechanically and electrically coupling the inboard ends of dipole arms **12***a* and **12***b*, as well as the terminals of a transposed feeder harness **18**.

The dipole arms **12***a* and **12***b* are V'd (i.e., bent forward) so as to form an angle α lying in the range from 40° to a maximum of 180°. Each of the dipoles, such as, for example, the dipole **12**, is coupled at its inboard ends to a mounting bracket **15**, preferably formed of an insulating material, and is secured by suitable fastening members **16** and **17**. These fastening members also secure the end terminals of a transposed feeder harness **18** which is provided for the purpose of maintaining phase synchronism of signals fed to and/or received from each of the dipoles.

The dipole arms of dipoles **12** through **14** are of decreasing length moving from dipole **12** to dipole **14**. The length of the dipole arms is preferably determined by the equation

$$h_2 = \gamma h_1$$

where

h_2 = the length of each of the dipole arms **13***a* and **13***b*;

h_1 = the length of either the dipole arms **12***a* and **12***b*; and

γ has a value preferably in the range of from 0.78 to 0.99.

The distance d_2 between dipoles **13** and **14** is related to the distance between dipoles **12** and **13** by the equation

$$d_2 = \gamma_1 d_1$$

where

γ_1 is preferably in the range from 0.80 to 0.99. However, it should be noted that it is not absolutely necessary that the γ factor determining distance between adjacent dipoles be the same as the factor γ_1 for determining associated dipole arm lengths.

The dipole arm relationship and dipole spacing for dipoles **12′** through **14′** is substantially identical to the relationships existing amongst dipoles **12** through **14**. Also, the dipole arm lengths of dipoles **12** through **14** are equal to those of dipoles **12′** through **14′**, respectively. In addition, the dipoles **12** through **14** are spaced a distance from an imaginary horizontal plane **19** of the antenna array by an amount equal to the distances from the dipoles **12′** through **14′**, respectively, to the imaginary plane **19**. The feeder terminals **20** for coupling the antenna array **10** to a receiver (or transmitter) facility are located substantially in the plane **19** of the array. A transposed feeder harness arrangement is provided for electrically coupling dipoles **12′** through **14′** to the feeder terminals **20** in substantially the same manner as the coupling between feeder terminals **20** and dipoles **12** through **14**.

The ground plane or reflecting plane **21** of the array is preferably formed of a suitable conductive material arranged in a grid-like fashion so as to form a reflecting screen for the purpose of reflecting energy which impinges upon the ground plane substantially in the direction shown by arrow **22** in FIG. **1***b*. The reflecting plane **21** is arranged so as to be substantially perpendicular to imaginary vertical plane **23** which is the bisector of the angle formed by the dipole arms such as, for example, the arms **12***a* and **12***b*. It should be noted that all of the dipole arms are V'd to form substantially the same angle and are further arranged so that all of the dipole arms **12***a* through **14***a* and **12***a′* through **14***a′* lie substantially within one plane and the arms **12***b*–**14***b* and **12***b′*–**14***b′* lie substantially within a second plane which intersects the first plane forming an angle α, where α, as was previously described, lies within the range from 40° to 180°.

In one exemplary embodiment, an antenna array of the type shown in FIGS. **1** through **1***b*, comprised of six dipoles, was designed for use in the UHF range encompassing UHF channels **14** through **83** in the frequency range from approximately 450 to 900 megacycles per second. The length of the dipole arms **12***a* and **12***b* are

such that their electrical length, when measured from tip-tottip (with the arms unbent or straight), is equal to $3\lambda/2$, where λ is the wavelength for a signal of a frequency of 470 megacycles. Thus, tip-to-tip length is equal to $3\lambda/2$ is equal to 20.0 inches.

Selecting a γ equal to 0.70, the tip-to-tip developed lengths of dipoles **13** and **14** are 14.0 and 9.80 inches, respectively.

The spacing relationships again employing γ_1 equal to 0.70 are all based upon the spacing d_1 which is determined by the equation:

$$d_1 = \sigma h_1 \qquad (4)$$

where

$$\sigma = 0.05 \rightarrow 1.0$$

For the present embodiment $d_1 = \lambda/4$
where

λ = the wavelength for the operating frequency of 470 megacycles.

Thus d_1 is equal to 7 inches. With a γ_1 of 0.70, d_2 is equal to 4.9 inches; and d_3 (the distance between dipole **14** and feed point **20**) is equal to 3.5 inches.

It is to be noted that the distances d_1' through d_3' are equal, respectively, to the distances d_1 through d_3, as are the lengths of dipoles **12'** through **14'** equal, respectively, to dipoles **12** through **14**.

The antenna array incorporating the above designed parameters was found to give broad band frequency response over the entire UHF range with a unilobe radiation pattern having a beam width 35°. Secondary lobes were quite small and about 9 db down from the main lobe.

A second experimental model was exhaustively tested in which the spacings d_1 and h_1 were substantially equal to those given in the above exemplary embodiment, with the modification being a selection of γ_1 equal to 0.79. This selection resulted in the following parameters:

$h_1 = 20$ inches	$d_1 = 7.00$ inches
$h_2 = 15.8$ inches	$d_2 = 5.54$ inches
$h_3 = 12.4$ inches	$d_3 = 4.37$ inches
$h_4 = 9.8$ inches	$d_4 = 3.45$ inches

The antenna of this second embodiment can be seen to have included two additional dipoles when compared with the first experimental embodiment with the same design concepts being maintained throughout; namely, the symmetrical aspect of the antenna, the decreasing dipole lengths moving from the outer limits toward the center of the antenna, and the decreasing spacing between dipoles moving from the outer limits of the antenna toward the center thereof. The addition of two dipoles to the array was found to result in a significant increase in gain. The increase in the broadside aperture of **2** results in a doubling in power gain (i.e., 3db). These results are not obtainable with endfire arrays. Also, this broadside array gives frequency independent response and a greater bandwidth.

Further alternative embodiments of the instant invention are shown in FIGS. **2** through **6**. Considering FIG. **2***b*, there is shown therein an antenna array substantially similar to that shown in FIGS. **1** through **1***b*, except that the ground or reflecting plane **21** is replaced by an array **21'** of parasitic elements **25** through **27** arranged along a second vertical supporting means **28** such that the arms of each of the parasitic elements, for example, the arms **25***a* and **25***b*, are electrically coupled to one another at their inboard ends and are electrically insulated from the active elements **12–14** and **12'–14'**, as well as being electrically insulated from the transposed feeder harness **18**. The lower half of the antenna array of FIG. **2***b* has been omitted for purposes of brevity, it being understood that the lower half of the array is substantially the mirror image of the upper half of the array depicted.

Each parasitic element is positioned substantially directly behind an associated dipole such that the associated dipole and parasitic elements, for example, dipole **12** and parasitic element **25**, lie substantially within a horizontal plane. In the top view embodiment of FIG. **2***a*, the parasitic elements **25** through **27** and **25'** through **27'** are shown as being a single straight element. FIG. **2***b* differs from FIG. **2***a* in that the parasitic elements **25** through **27** are V'd at an angle β wherein β lies substantially within the same range as the angle at which the dipole arms are V'd.

The vertical supporting means **28** is positioned behind the support **11** by a distance s so as to space each of the parasitic elements from their associated dipoles by a distance

$$\frac{\lambda_m}{10} \leq S \leq \frac{3\lambda_m}{4}$$

where

λm is the wavelength for the midband frequency of the frequency band to be covered.

The electrical lengths of the parasitic element may vary between being slightly smaller to slightly greater than their associated dipoles without causing any significant decrease in the quality of performance.

The parasitic elements decrease in length and in spacing in substantially the same manner as do the associated dipoles.

The V'd parasitic elements in the embodiment of FIG. **2***b* provide improved operation as compared with the straight parasitic elements such that the front-to-back ratio is significantly improved and higher mode operation is improved.

FIG. **2** shows still another embodiment of the instant invention wherein a second broadside active element array **21'** comprised of elements **25–27** and **25'–27'** are secured at spaced intervals along supporting means **28**. Again it can be seen that the dipole arrays **10** and **21** are substantially identical to that shown in FIGS. **1** through **2***a*, with each of the associated dipoles lying substantially within a horizontal plane. The feeder harnesses **18** and **18'** of the arrays **10** and **21'**, respectively, are substantially identical to the feeder harness **18** described with respect to FIGS. **1** and **1***a*. The midpoints of these harnesses are connected by an additional transposed section **18''**. The feed points **20** are located on array **10** as shown.

The arrangement of FIG. **3** is such as to maintain uniform spacing between the frontward driven elements or dipoles and their associated rearward elements in terms of electrical wavelengths such that the ratio of spacing between dipole **12**, for example, and its

associated dipole **25**, when compared with the spacing between dipole **13** and its associated dipole **26**, is substantially 1:1. The embodiment of FIG. **3** is identical in every other respect to the embodiment of FIG. **2**. Whereas the embodiment of FIG. **3** shows the dipoles in the array **21'** as being V'd forward in the same direction and at the same angle as its associated dipole elements of array **10**, it should be understood that the dipoles of array **21'** may be substituted by straight dipoles (i.e., $\alpha = 180°$) of substantially equal electrical length.

The antenna array of FIG. **3** provides optimum operation with the experimental data showing that the optimum front-to-back ratio over entire band is obtained as a result of the V'ing of supporting mast **28'**.

In the embodiment of FIG. **2***b*, the mast **28** supporting the parasitic elements **25–27** may be V'd backwards about its mid-point (i.e., imaginary plane **19**) in the same manner as the active array **21'** of FIG. **3** to improve the front-to-back ratio of the composite array.

FIG. **4** shows still another embodiment wherein the dipole array **21''** is comprised of a plurality of dipole elements **25–27** and **25'–27'** secured to a vertical support means **28** which is positioned closer to support means **11** so that the spacing *s* therebetween is less for this embodiment than for any of the embodiments shown in previously described Figures. As a further alternative to minimizing spacing S, the vertical support means **28** may be removed altogether and the dipoles **25–27** and **25'–27'** may be secured directly to the mast **11** and on the opposite side of the mast from that side on which the dipoles or active elements **12–14** and **12'–14**πo are secured. The dipoles **25–27** and **25'–27'** are V'd in the rearward direction forming an angle β which lies in the range between 40° and 180°. This rearward V'ing of the parasitic elements permits extremely close spacing of the supporting means **28** and **11**, as well as permitting the use of a single support means **11** as a substitute for twin support means.

The feeder harnesses **18** and **18'** are substantially identical in design and operation to those shown in FIGS. **1** and **1***a*. They are joined at their mid-points by transposed section **18''**. Feed points **20** are positioned at the mid-point of array **10**. Transposed section **18''** acts to maintain the front-to-back ratio with the direction of maximum gain being that indicated by arrow A. The composite array of FIG. **4** may be made bidirectional by providing array **21'** with a pair of feed terminals **20'** (shown in dotted fashion). A two-position switch **90** may be switched between the feed terminals **20** and **20'** so that when connected to terminals **20**, the direction of maximum gain is designated by arrow A, and when connected to terminals **20'**, the direction of maximum gain is designated by arrow B.

The switch **90** may be replaced by bandpass filter means **91**, shown in FIG. **4***a*. The bandpass filter may be designed to pass signals lying within a first band of frequencies from array **10** while attenuating the signals lying within the first band of frequencies from array **21'**. Alternatively, the bandpass filter may be further designed to pass all signals lying within a second band of frequencies from array **21'** while attenuating those signals from array **10** which lie in the second band of frequencies. Thus, bidirectional operation may be obtained automatically without the need for operating a switch (**90**).

The parasitic elements **25–27** of FIG. **26**, in addition to having their arms either straight or V'd forward, may also be V'd in the rearward direction in the same manner as the dipole elements **25–27** and **25'–27'** of the array **21'** shown in FIG. **4**.

As still a further modification of the antenna design of the instant invention, the broadside array may be combined with endfire arrays to provide a composite broad band antenna structure. For example, considering the embodiment of FIG. **5**, there is shown therein a standard VHF endfire array **30** combined with an array **10** designed in accordance with the principles of the instant invention, and which is provided with stacked dipole elements dimensioned and spaced for providing coverage of the entire VHF band.

The VHF array **30** is comprised of a plurality of active elements **31** and **35**, each having electrical lengths so as to resonate at discrete frequencies within the VHF band. For example, the dipole **31** which is shown V'd forward at an angle α lying between 40° and 180° as an electrical length of $\lambda/2$, wherein λ is the wavelength for the operating frequency of channel 2, for example. Thus, in accordance with log periodic principles, the dipole **31** will resonate at odd half-wavelength multiples and more particularly will operate at $3\lambda/2$ so as to provide a resonant condition for the VHF high band substantially at a frequency equal to, or very nearly equal to the frequency for channel 8 which lies in the VHF high band. The remaining dipoles **32** through **36** are designed in a like manner. The dipoles are electrically coupled to the feed point **40** by means of a transposed feeder harness **41** to provide a good front-to-back ratio. The rearmost dipole **31** is shortened at its inboard ends by a shorting stub **42**.

The spacing between dipoles and the electrical length of the dipole arms in endfire array **30** gradually decreases from the left toward the right-hand end of the array **30**, preferably in accordance with the factor previously described. The design principles and operating characteristics of an endfire VHF log periodic antenna are covered in greater detail in U. S. Pats. re Nos. 25740; 3,150,376; and copending U. S. applications Ser. No. 345,691, now U.S. Pat. No. 3,276,028, issued Sept. 27, 1966; Ser. No. 225,311, now U.S. Pat. No. 3,228,257, and Ser. No. 523,477, now U.S. Pat. No. 3,466,655, issued Sept. 9, 1969.

The specific design considerations of the endfire log periodic antenna will be omitted herein for purposes of simplicity, and reference should be made to the above mentioned copending applications and U. S. patents regarding the specific design features to be employed.

The broadside array **10** is an antenna array substantially as shown in FIG. **1**, for example, and having dipole elements **12–14** and **12'–14'**, respectively, which are dimensioned in space so as to provide operation over the entire UHF band and having a reflector array **21** comprised of reflectors such as **27** and **27'**.

FIG. **6** shows still another manner in which a broadside array may be combined with an endfire array. In the combined UHF–VHF antenna array of FIG. **6**, there is shown therein a broadside VHF array comprised of active elements **12–14** and **12'–14'** and a ground or reflecting plane **21**. Each of the antenna array **10** is substantially as shown in FIG. **1**, the exception being that the dipole elements are so dimensioned

and spaced as to provide operation over both the lower and upper VHF bands. If desired, the ground or reflecting plane **21** may be replaced by parasitic elements arranged in any one of the manners as shown in FIGS. **2–4**.

The central feed point **50** which is coupled to the dipole elements **12–14** and **12'–14'** in the same manner as shown in FIGS. **1** through **1***b* is further electrically coupled to an endfire array **60** comprised of a plurality of dipole arms **61** through **66** which are electrically coupled through a balanced feeder line **67** forming a transposed feeder harness to provide the 180° phase shift, as was previously described. The endfire array **60** is preferably designed in accordance with the principles described in U. S. Pat. No. 3,210,767 mentioned previously such that the dipoles are of decreasing electrical length moving from the left to the right-hand end of array **60** and such that the spacing between dipoles decreases, moving in the same direction. The endfire array **60** is designed so as to provide operation over the entire UHF band.

It can, therefore, be seen from the foregoing description that the instant invention provides a novel broadside array yielding extremely effective operation over a broad frequency range and wherein design is such as to provide substantially linear increases in antenna gain as additional dipole elements are added so long as the symmetrical arrangement of the array is substantially adhered to in designing the antenna.

As an alternative embodiment to the highly directional broadside arrays of FIGS. **1** through **6**, the embodiments of FIGS. **7** and **8** may be employed in cases where good all-channel omnidirectional radiation patterns are desired. Considering first FIG. **7**, there is shown therein a frequency independent omnidirectional antenna array **70** comprised of an elongated support means **71** and a plurality of dipoles **72–74** and **72'–74'** which are arranged so as to be symmetrical about a line of symmetry **75** passing through the location of the feed point terminals **76**. As was previously the case with the embodiments of FIGS. **1** through **6**, the dipoles **72–74**, while curved, nevertheless adhere to the general design of the previously described arrays in that, for example, each dipole arm **72***a* and **72***b* of dipole **72** has an electrical length equal to $\lambda/4$ where λ is the wavelength for the lowest operating frequency for the frequency range in which the array operates. Thus, the total tip-to-tip electrical length measured along the arms of the dipole **72** is equal to $\lambda/2$. The length of dipoles moving downwardly from dipole **72** vary in accordance with the factor γ such that h_2 (the length of dipole arm **73***a*) is equal to h_1 (the electrical length of arm **72***a*) times the factor γ where γ is a constant in the range from 0.78 to 0.99. The decreasing electrical lengths are controlled by the γ factor until the dipole closest to and above the line of symmetry **75** is reached, at which time the remaining dipoles positioned below the line of symmetry increase in electrical length in the manner shown in FIG. **7** so as to provide a substantially symmetrical array with the line of symmetry for the array being the line **75**. The inboard ends of the dipole arms are coupled by a transposed feeder harness **77** in the same manner as was previously described with reference to FIGS. **1** through **6**. The dipoles may be mounted to suitable brackets **78**, each being provided with suitable mounting means (not shown) for securing each dipole to the vertical support means **71** and for electrically connecting the transposed feeder harness to the inboard ends of the dipole arms.

It should be noted that neither a reflecting plane nor a parasitic element array is employed in the arrangement of FIG. **7** in order to provide an omnidirectional pattern for the antenna. FIG. **9***b* shows the horizontal E radiation pattern obtained with the antenna array **70**, it being understood that the antenna, while represented by a dot in FIG. **9***a*, would be directed vertically upward out of the plane of the paper.

FIG. **9***a* shows the horizontal H radiation pattern which indicates that a substantially bidirectional H pattern is obtained.

The antenna of FIG. **7** has extremely advantageous use in both UHF and VHF reception in that it can be employed as a home receiving antenna providing excellent all-channel reception and being omnidirectional so that it is immaterial as to how the antenna is mounted insofar as its angular orientation is concerned due to its omnidirectional characteristics. Thus, it is possible through this design to provide the user with an antenna which requires no rotating mechanism in order to assure the use of good signal reception.

Insofar as spacing between dipoles is concerned, the spacing d_1 between dipoles **72** and **73** (and likewise between dipoles **72'** and **73'**) is determined by the equation

$$d_1 = 4\,\delta h_1$$

with δ being a constant lying in the range from 0.125 to 0.25. d_1 thereby lies within the range from $\lambda/8$ to $\lambda/4$ wherein λ is equal to the wavelength of the lowest frequency in the operating frequency range of the array. Spacings between subsequent dipoles are determined by the factor γ such that, for example, d_2 is equal to d_1 times γ, wherein d_2 is the spacing between dipoles **73** and **74** (and likewise the spacing between dipoles **73'** and **74'**).

FIG. **8** shows an alternative arrangement which may be substituted for the embodiment of FIG. **7** wherein the curved or arcuate shaped dipole arms of each of the dipoles is replaced by a substantially L-shaped arm, as shown in FIG. **8**, wherein the broadside array **80** is comprised of a vertical support means **81** and dipoles **82–84** and **82'–84'**. The ratio of lengths of dipole arms moving from dipoles **82** toward **84** (and hence from dipoles **82'** to **84'**, respectively) is determined by the constant γ in the same manner as was previously described. Likewise, spacing gradually decreases between adjacent dipoles moving from the uppermost (or lowermost) end toward the center of the array in accordance with the factor γ. The dipole arms, however, for example, dipole arms **82***a* and **82***b*, are comprised of inboard sections **82***a***–1** and **82***b***–1**, respectively, and outboard sections **82***a***–2** and **82***b***–2**, respectively, wherein the electrical length of the inboard sections **82***a***–1** and **82***b***–1** is of the order of $\lambda/12$ to $\lambda/20$ and is preferably $\lambda/10$ where λ is the wavelength for the lowest frequency within the operating frequency range of the antenna.

The outboard sections **82***a***–2** and **82***b***–2** are preferably 1.5 to 3.0 times as long as their associated

inboard sections so as to substantially be of a length within the range from $3\lambda/20$ to $\lambda/4$.

The angle α formed between the inboard and outboard sections such as, for example, the sections **82***a*–**1** and **82***a*–**2** preferably is a right angle, but may lie within the range from 70° to 110°.

The dipoles **82**–**84** (and hence **82'** and **84'**) are coupled to the feeder point terminals **86** by means of a transposed feeder harness **87** in a similar fashion to that described with respect to the embodiments of FIGS. **1**–**7**.

The antenna embodiment of FIG. **8** has also been found to provide an excellent frequency independent omnidirectional antenna yielding operating characteristics comparable to those achievable through the use of the embodiment of FIG. **7**.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited not by the specific disclosure herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. An antenna array comprised of

elongated support means;

a plurality of active elements positioned at spaced intervals along said support means;

a pair of feed terminals positioned intermediate the ends of said support means for coupling energy between said active elements and utilization means;

said active elements being comprised of a plurality of dipoles;

half of said dipoles being positioned at predetermined spaced intervals along said support means between said feed terminals and one end of said support means;

each of said dipoles being comprised of first and second arms lying on opposite sides of said support means;

a transposed feeder harness coupling the inboard ends of said dipoles to said feed terminals;

the remaining half of said dipoles being positioned along said support means between said feed terminals and the opposite end of said support means to form an antenna array which is substantially symmetrical about an imaginary horizontal plane passing through the point of connection of said feed terminals and said feeder harness;

said transposed feeder harness further coupling the remaining dipoles to said feed terminals.

2. The antenna array of claim **1** wherein the first arms and the second arms of all of said dipoles lie substantially in first and second respective planes which are parallel to said support means; and which intersect forming an angle within the range from 40° to 180°.

3. The antenna array of claim **1** further comprising reflection means positioned adjacent said support means for enhancing the directional characteristics of said array.

4. The antenna array of claim **3** wherein said reflection means is comprised of a substantially planar conductive screen having a grid-like pattern.

5. The array of claim **3** wherein said reflection means is comprised of second elongated support means positioned side by side with respect to said first support means;

a plurality of parasitic elements positioned at spaced intervals along said second support means and being secured to said support means at a point substantially equidistant from their outboard ends;

the spacing between adjacent parasitic elements and the electrical lengths of said parasitic elements being selected to provide a symmetrical pattern about said feed terminal point comparable to the symmetrical pattern of said dipoles.

6. The antenna array of claim **5** wherein each of said parasitic elements is positioned along said second support means so as to be substantially coplanar with an associated dipole.

7. The antenna array of claim **5** wherein each of said parasitic elements is bent at its point of securement to said second support means to form an angle lying in the range from 40° to 180°.

8. The antenna array of claim **7** wherein the dipoles and parasitic elements are aligned so that one imaginary plane defines the common disector of the angles formed by the first and second arms of said dipoles and parasitic elements.

9. The antenna array of claim **1** wherein said electrical lengths of the longest dipoles are substantially equal to $n/2$ where n is any real integer and λ is the wavelength of the lowest frequency for the operating frequency range of the antenna array.

10. The antenna array of claim **9** wherein the ratio of the electrical lengths of any dipole of said selected dipoles is given by the formula

$$l_{n+1}/l_n=\tau$$

where l_n is the electrical length of the larger dipole and l_{n+1} is the electrical length of the smaller adjacent dipole, and n is the nth arm running in an order from the dipole furthest from the feed terminals toward said feed terminals, and τ is a constant in the range from 0.78 to 0.99;

the ratio of the electrical lengths of said remaining dipoles being determined in the same manner as that employed for the selected dipoles.

11. The antenna array of claim **9** wherein the spacing between adjacent dipoles measured along said first support means is determined by the formula

$$d_{n+1}/d_n=\tau$$

where d_n is the spacing between the dipole having the electrical length l_n and the adjacent larger dipole; d_{n+1} is the spacing between the dipole having the electrical length l_n and the adjacent smaller dipole and τ is a constant lying in the range from 0.78 to 0.99.

12. The antenna array of claim **5** wherein the

ratio of the electrical lengths of any parasitic element from the feed terminals to one end of said array is given by the formula

$$l_{n+1}/l_n=\tau$$

where l_n is the electrical length of the larger parasitic element and l_{n+1} is the electrical length of the smaller adjacent parasitic element, and n is the nth arm running in an order from the parasitic element furthest from the

feed terminals toward said feed terminals, and τ is a constant in the range from 0.78 to 0.99;

the ratio of the electrical lengths of the remaining parasitic elements being determined in the same manner as that employed for the parasitic elements between said feed terminals and one end of said array.

13. The antenna array of claim 12 wherein

the electrical length of the longest parasitic element l_n at either outer end of the array is determined by the equation

$$l_1 = L(1+0.05L)$$

where L is the electrical length of the longest dipole associated with the longest parasitic element.

14. The antenna array of claim 5 wherein said second elongated support means is bent at a point near the feed terminals of said array so that the upper and lower halves thereof form equal angles with said first support means so as to space each parasitic element a distance s away from its associated dipole determined by the equation

$$\frac{\lambda}{10} \leq S \leq \frac{3\lambda}{4}$$

where λ = wavelength to which the associated dipole is attuned to resonate.

15. The antenna array of claim 5 wherein said parasitic elements are V'd in a direction opposite from that of said dipoles.

16. The antenna array of claim 1 wherein the dipole first and second arms are curved so that the outboard ends thereof extend in a direction generally perpendicular to the inboard ends.

17. The antenna array of claim 16 wherein the electrical lengths of the first and second arms of the longest dipole are each in the range from 0.4 λ to 0.6 λ where λ is the wavelength of the lowest frequency in the operating frequency range of the array.

18. The antenna array of claim 1 wherein the first and second arms of each dipole are comprised of an inboard section and an outboard section;

said inboard and outboard sections being substantially straight; integral with one another and forming an angle at their juncture point lying in the range from 40° to 180°.

19. The antenna array of claim 18 wherein the ratio of lengths of each outboard section l_{out} to its associated inboard section l_{in} is given by the equation

$$l_{out} = Kl_{in}$$

where K is a constant lying in the range from $1.5 \leq K \leq 3.0$;

the total electrical length of the longest dipole arms each being in the range from 0.4 λ to 0.6 λ where λ is the wavelength of the lowest frequency in the operating frequency range of the antenna array.

20. A composite antenna array

comprised of first and second antenna arrays of the type described in claim 1 and being arranged so that their support means are arranged substantially in spaced parallel fashion and directions of maximum gain are coincident and point in opposite directions;

a transposed feeder section coupling their feed terminals;

the feed terminals of one of said arrays being adapted to be coupled to suitable utilization means.

21. A composite antenna array

comprised of first and second antenna arrays of the type described in claim 1 and being arranged so that their support means are arranged substantially in spaced parallel fashion and their directions of maximum gain are coincident and point in the same direction;

transposed feeder section coupling their feed terminals;

the feed terminals of one of said arrays being adapted to be coupled to suitable utilization means.

22. A composite antenna array

comprised of first and second antenna arrays of the type described in claim 1 and being arranged so that their support means are arranged substantially in spaced parallel fashion and their directions of maximum gain are coincident and point in opposite directions;

a transposed feeder section coupling their feed terminals;

means coupled between said feed terminals for altering the directional characteristic of the composite array.

23. The composite array of claim 22 wherein said switching means is comprised of two-position switch means for coupling one or the other of said feed terminals to suitable utilization means.

24. The composite array of claim 22 wherein said switching means is comprised of bandpass filter means coupled between the feed terminals of said first and second arrays for passing the signals of one of said arrays which lie in one frequency band while attenuating the signals from the remaining array which lie in said one frequency band;

said one frequency band being smaller than the frequency range for which said arrays are designed to operate.

25. An antenna array comprised of

elongated support means;

a plurality of active elements positioned at spaced intervals along said support means;

a pair of feed terminals positioned intermediate the ends of said support means for coupling energy between said active elements and utilization means;

said active elements being comprised of a plurality of dipoles;

half of said dipoles being positioned at predetermined spaced intervals along said support means between said feed terminals and one end of said support means;

each of said dipoles being comprised of first and second arms lying on opposite sides of said support means;

a transposed feeder harness coupling the inboard ends of said half of said dipoles to said feed terminals;

the remaining half of said dipoles being positioned at predetermined spaced intervals along said support means between said feed terminals and the opposite end of said support means to form an anten-

na array which is substantially symmetrical about a horizontal plane passing through the point of connection of said feed terminals and said feed harness whereby associated dipoles positioned on opposite sides of said feed terminals are separated from the feed terminals by equal distances;

said transposed feeder harness further coupling the remaining half of said dipoles to said feed terminals.

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