Sept. 22, 1964 R. L. CARREL ETAL 3,150,376

MULTI-BAND LOG PERIODIC ANTENNA

Filed April 3, 1964 2 Sheets-Sheet 1

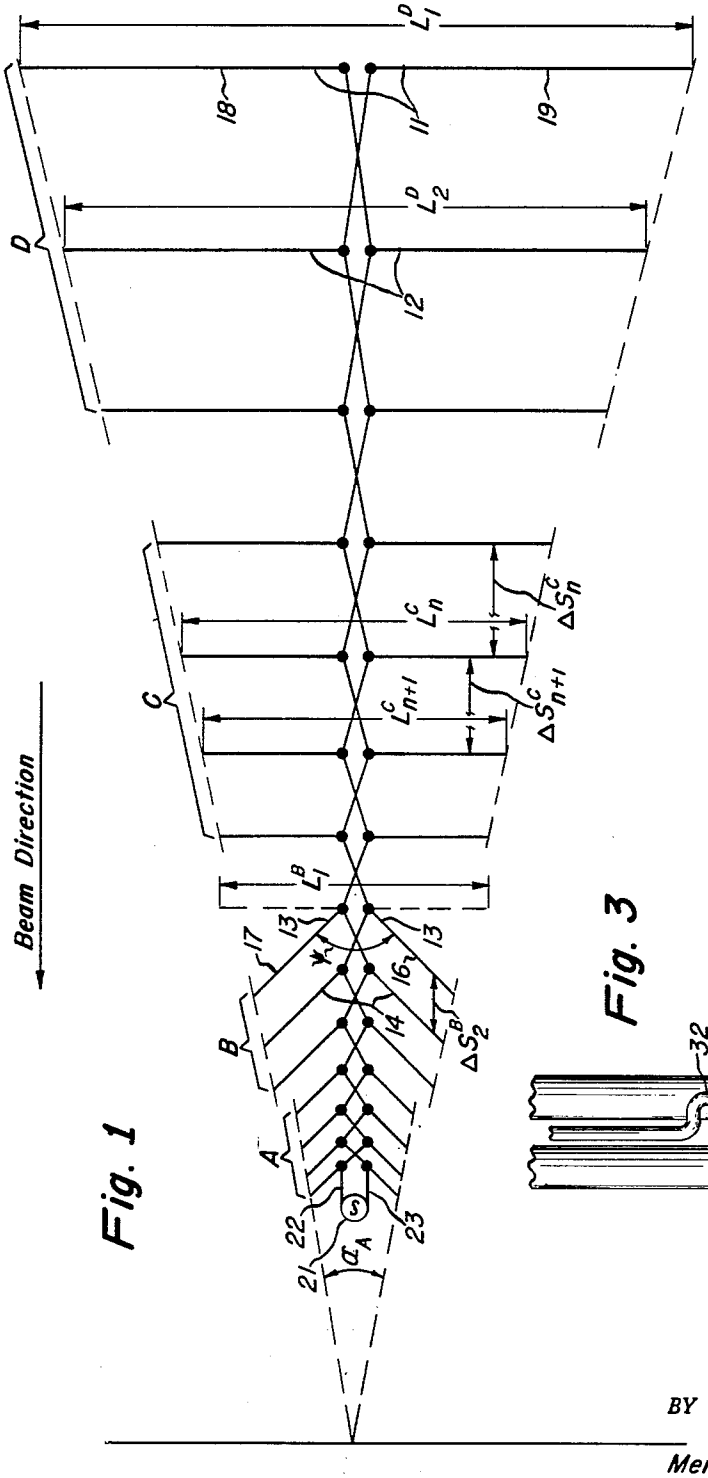


Fig. 1

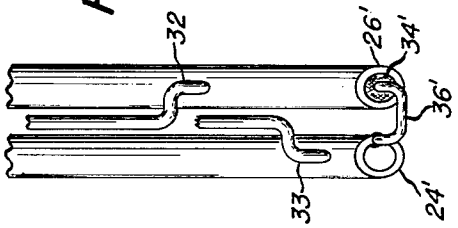


Fig. 3

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Filed April 3, 1964 2 Sheets-Sheet 2

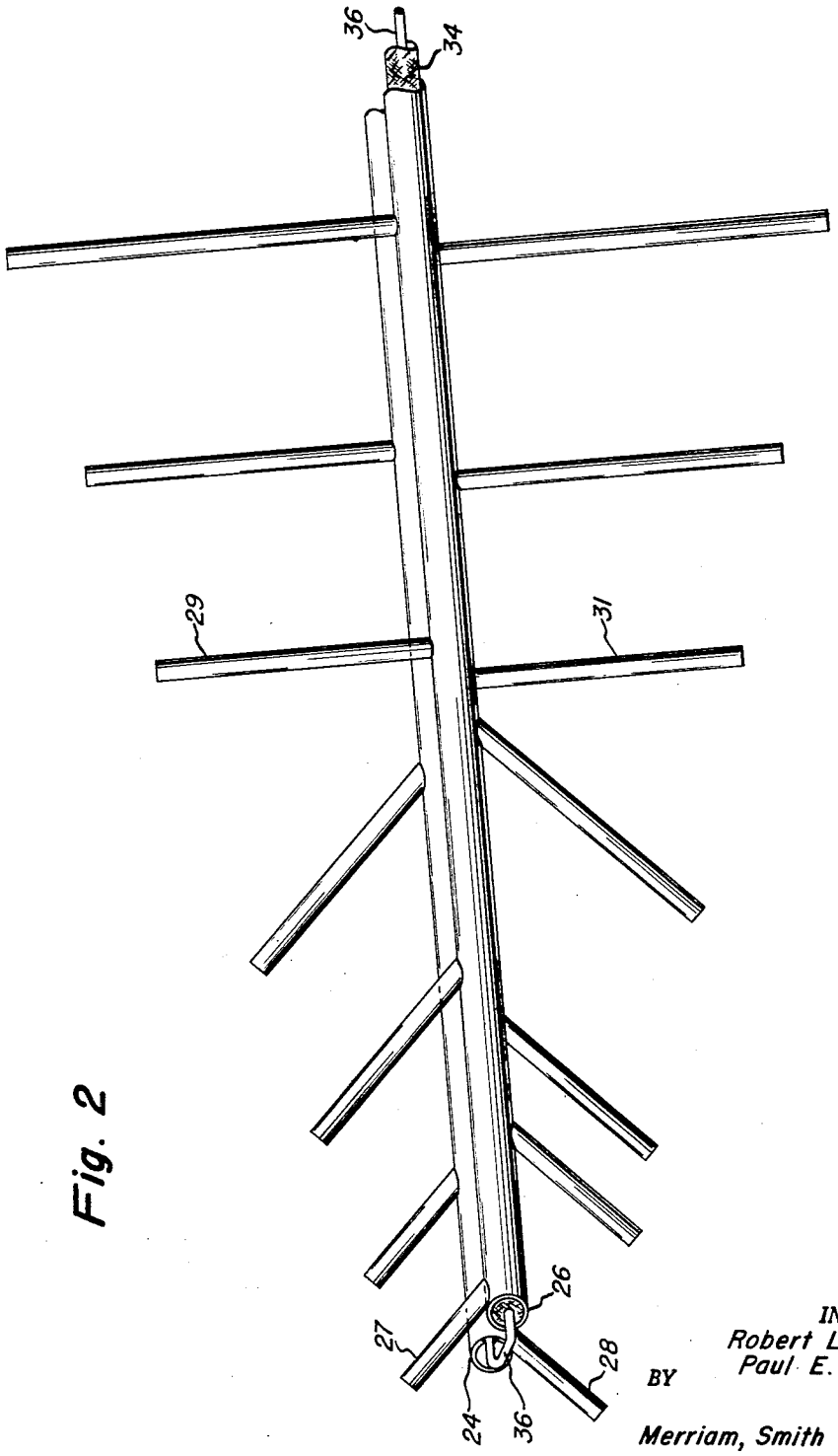


Fig. 2

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United States Patent Office 3,150,376 Patented Sept. 22, 1964

3,150,376

MULTI-BAND LOG PERIODIC ANTENNA

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Filed Apr. 3, 1964, Ser. No. 357,226
18 Claims. (Cl. 343—792.5)

This invention relates to antennas. More particularly it relates to antennas having unidirectional radiation patterns that are essentially independent of frequency over wide bandwidths. Still more particularly, the antennas of the invention are designed to cover intermittent bands of frequencies which cover a wide range from the lowest frequency band to the highest.

In the copending application of Dwight E. Isbell, Serial No. 26,589, filed May 3, 1960, and in application of the inventors herein, Serial No. 59,671, filed September 30, 1960, now U.S. Patent No. 3,108,280, dated October 22, 1963, there are described certain antennas comprising coplanar arrays of dipoles or V-elements having unusually wide bandwidths performance characteristics over which bandwidths the antennas are essentially frequency independent. These antennas have input impedances which are nearly constant with unidirectional patterns and directivities comparable to yagi arrays. As described in the applications above named, the arrays comprise a number of elements which may be linear dipoles of V-elements, arranged in side-by-side relationship in a plane. The lengths of the dipoles or the developed lengths of the V-elements (i.e., the length when the sides of the V-elements are rotated to form a linear dipole) and the spacing between adjacent dipoles or V-elements are designed to vary by approximately chosen scale factors according to a definite mathematical formula, with each of the elements being fed at its midpoint by a common feeder which has appropriate phasing between successive elements. The elements which are used to make up the arrays vary progressively in length in accordance with the scale factor selected.

In the linear dipole version, described in the aforementioned Isbell application, the length of the longest dipole element corresponds to about ½ wavelength at the low frequency limit of the antenna's effective range, while the shortest element has a length corresponding to about ⅜ of a wavelength at the upper frequency limit. On the other hand, the antennas described in the present inventors' copending application, Serial No. 59,671, in which the elements are V-shaped, have increased directivity at frequencies above the ½ wavelength mode of operation and therefore have effective frequency ranges which are greater than those of a comparable linear dipole antenna.

The antennas of the instant invention are related to those described above, but differ therefrom in that the former are designed so that their effective frequency range is not continuous from the high limit to the low limit but is rather broken up into a number of discrete bands within which bands the antenna performs satisfactorily. There are a number of instances in which antennas of this type will be found particularly useful. For example, the frequencies assigned to VHF and UHF television transmission are divided into a number of discrete frequency bands. Thus, television channels 2, 3, and 4 of the lower VHF range cover frequencies from 54 to 72 mcs., the mid-VHF band containing television channels 5 and 6 extends from 76 to 88 mcs. and the upper VHF band, including television channels 7–13, extends from 174 to 216 mcs., while television channels 14–83 of the UHF band extend from 470 to 890 mcs.

An antenna made in accordance with the present invention can effectively cover all of the above frequency bands, but not the intervening ranges between the bands of interest, and this antenna is considerably smaller in overall size and weight and, therefore, less expensive than an antenna designed to cover continuously the entire range of television frequencies from 54 to 890 mcs. Furthermore, the directive gain increases in the higher modes which are used to cover the higher frequency bands, thus making more effective use of the size of the structure.

Another application of the invention occurs in antennas designed for use by amateur radio operators whose transmissions are restricted by law to certain frequency bands. The "ham" radio operator is, therefore, interested in an antenna which performs effectively in those ranges in which he is free to operate and which need not be effective in the intervening frequency bands. Such an antenna can also be made in accordance with the invention in a smaller version than has been heretofore possible, without sacrificing bandwidth or directivity.

The invention will be better understood from the following detailed description thereof taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic plan view of an antenna made in accordance with the principles of the invention;

FIGURE 2 is a perspective view of a practical antenna embodying the invention; and

FIGURE 3 is a fragmentary view of an improved and preferred form of an antenna similar to that shown in FIGURE 2, as seen from a point directly in front of and above the narrow end of the antenna.

Referring to FIGURE 1, it will be seen that the antennas of the invention are composed of a plurality of elements, which may either linear dipoles, e.g., **11** and **12**, or V-shaped elements, e.g., **13** and **14**, or a combination of both as shown, arranged in side-by-side relationship. The elements are arranged in a number of zones, or groups, e.g., A, B, C, and D. The distinguishing characteristic of the zones found in the antenna is the fact that the ends of the elements within a zone fall on a pair of converging straight lines, as shown in the drawing. It is also characteristic of the antennas of the invention that the converging lines defining the ends of the elements in a given zone are not collinear with the corresponding converging lines associated with another zone of the antenna having the same type (i.e., linear dipole or V-element) of element. Thus, for example, since zones C and D are both comprised of linear dipoles, the converging lines defining their terminals are not collinear. This is also true of zones A and B which are also composed of similar elements. When adjacent zones are composed of dissimilar elements, however, as in the case of zones B and C, wherein B has V-elements and C has linear elements, the converging lines passing through the terminals of the elements of the zone may or may not be collinear. Furthermore, the angle formed by these converging lines, e.g., α_A in FIGURE 1, may or may not be equal for each zone, although all such angles preferably have values between about 20° and about 100°. In the antenna shown in FIGURE 1, α_A is represented as the angle defined by the converging lines passing through the outer ends of the elements in zone A. This angle might or might not be equal to that angle which would be formed on extending the lines passing through the ends of the elements of zone B to a meeting point. Similar considerations could be had relative to the angle which would result were a line to be drawn past the ends of all elements of zones C and D.

It will be seen from FIGURE 1 that zones A and B are composed of a plurality of V-elements, each of which consists of a pair of arms, e.g., **16** and **17**, defining an apex in the middle of the V-element, said V-elements

being arranged in a herringbonelike pattern. The arms of a given V-element are equal in length and the related arms of the several V-elements within a zone, i.e., the arms on the same side of a line passing through the apexes of the V-elements, are preferably substantially parallel to each other.

In a similar manner the linear dipoles which constitute zones C and D of the antenna of FIGURE 1 are each composed of a pair of arms, e.g., **18** and **19**, which are equal in length and which are preferably substantially parallel to the corresponding arms of the other dipoles within the zone. With respect to all zones, i.e., both those consisting of V-elements and those formed of linear dipoles, it is preferred that the antenna be symmetrical about a line passing through the midpoints of the linear dipoles and the apexes of the V-elements, respectively, as shown.

The antenna is fed at its narrow end from a conventional source of energy, depicted in FIGURE 1 by way of illustration only as alternator **21**, by means of a balanced feeder line consisting of conductors **22** and **23**. It will be seen that the crossed feeder lines **22** and **23** are twisted between connections to consecutive or adjacent elements of the antenna.

The length of an element (dipole or V-element) in the antenna shown in FIGURE 1 is designated herein as L_n^X, where n is used to designate any element in the zone which is designated as X. Thus, for example, the longest element in the antenna of FIGURE 1, which is the longest dipole of group D, is designated as L_1^D, meaning element No. 1 of zone D. Thus, in general, the subscript (n) indicates the order of the particular element in the group designated by the superscript (X). It will be further seen that in the case of V-elements, such as those of zone B, the effective length of a V-element is taken to be the length which the arms of the V-element have when developed so that these arms are collinear. As shown, the length L_1^B is the developed length of V-element **13**.

The lengths of the elements in the antennas of the invention, and the spacing between these elements are related by a scale factor τ which is constant within a given zone and is defined by the following equations:

$$\tau^X = \frac{L_{(n+1)X}}{L_n^X} = \frac{\Delta S_{(n+1)X}}{\Delta S_n^X}$$

where τ^X is a constant having a value less than 1, L_n^X is the length of a dipole (or the developed length of a V-element) in zone X of the antenna, $L_{(n+1)}{}^X$ is the corresponding length of the adjacent smaller element in group X, $\Delta S_n{}^X$ is the spacing between the element having the length L_n and the adjacent larger element in group X, and $\Delta S_{(n+1)}{}^X$ is the spacing between the element having the length L_n and the adjacent smaller element in group X.

In the foregoing, it will be observed that the same scale factor, τ, may be used to determine both dipole length and spacing. This will, under normal conditions, represent optimum operational conditions. However, if efficiency of a lesser degree can be tolerated, it is, at times, possible to operate with a different scale factor for determining the dipole length from that which determines spacing. At such times, a scale factor τ_1 may be used to determine the dipole length and a scale factor τ_2 may be used to control spacing the dipole sections.

Each dipole and the feeder connecting thereto in the region between one dipole pair and the next adjacent dipole pair may be regarded as a "cell." The lengths of dipoles and the spacings then are so selected by the determined scale factors that the combination of dipole lengths and spacings, when combined as here described, provide the desired substantially uniform wideband responses in the desired frequency ranges.

As noted above, the elements comprising the antennas of the invention may be either linear dipoles or V-elements. With respect to the latter, the arms of the individual V-elements are inclined to point in the direction of decreasing element size so that the apex of each of the V-elements points in a direction away from the angle formed by the lines passing through the extremities of the individual elements. The angle, ψ, formed at the apexes of the V-elements by the arms thereof, preferably has a value between about 50° and 150°.

It will be noted that in FIGURE 1 the angle α_A is that formed by the lines passing through the extremities of the elements in zone A. In a similar manner, although not shown in the drawing, the lines passing through the extremities of the elements in zones B, C, D, etc., could be extended to form similar angles α_B, α_C, α_D, respectively. Each of these angles α_B, α_C, α_D, etc., may be equal to each other, and in the preferred embodiment of the antenna are equal, but this is not a necessary condition. In any event, it is preferred that these angles, whether or not they are equal to each other, have values within the range from about 20° to 100°.

The advantages of the antennas of the invention stem from the discovery that when a given antenna is in operation at a certain frequency there are involved only a few of the elements of which the antenna is formed. It has been found possible, therefore, to remove from the antenna structure those elements which are not involved at this frequency and bring the adjacent parts of the antenna together to close the gap which would exist, and it has been further found that this modification of the antenna is possible without affecting the performance on either side of the excluded region. Taking the antenna of FIGURE 1 as an example, the element which would have formed the fourth element of Zone D is not required when the antenna is operated at a frequency which is dependent on the lengths of elements **1**, **2** and **3**. Accordingly, and since the antenna is not intended to operate at a frequency represented by this hypothetical fourth element, the element can be omitted from the antenna with a consequent saving in size, weight, and cost, without, however, adversely affecting the operation of the remaining elements in the antenna at their characteristic frequencies. In a similar manner the elements which would normally have appeared in the antenna between zones A and B have been omitted with no adverse effects on the operation of the antenna at the frequencies corresponding to the elements found in zones A and B.

The antennas of the invention contain a plurality of zones or groups as defined above, all of which may contain linear dipoles and some V-elements as desired. The use of V-elements in the antennas of the invention rather than dipoles increases the directivity of the antennas and also permits more effective utilization of a given antenna, since the same structure can be used in several frequency modes to achieve coverage of different frequency bands. In the case of an antenna zone or group consisting entirely of straight dipoles, the effective frequency range of such a zone is that in which the low limit corresponds to the frequency at which the largest element in the zone is about ½ wavelength long, and the upper frequency limit to the frequency at which the smallest dipole in the group is about ⅜ wavelength long. In general, therefore, it may be said that the frequency range of a straight dipole group of elements corresponds to the mode of operation in which the lengths of the dipoles in the group are about ½ wavelength long. As the frequency is raised above the upper limit of the ½ wavelength mode in the group, the elements will also be found to radiate or receive effectively at frequencies in which the dipoles are about ⅔ wavelengths long (the ⅔ wavelengths mode), ⅝ wavelengths long (the ⅝ wavelengths mode), and so on. At frequencies above the ½ wavelength mode, however, the pattern of a straight dipole group becomes multilobed and is therefore of limited usefulness. By inclining the arms of the dipoles to form V-elements, it has been found

that a single lobe of improved directivity may be obtained as the frequency is raised from the ½ wavelength mode through the intervening ranges to the ⅝ wavelengths mode and beyond. For each mode of operation there exists an optimum value for the angle ψ, ranging from about 114° for the ⅝ wavelength mode to about 62° for the ⅝ wavelengths mode. By using a compromise value for ψ within this range, however, a zone of V-elements can be made to achieve acceptable performance over several modes of operation, thereby increasing its effective range. This result is possible since many of the elements forming the antenna array are used at more than one frequency.

The construction of a practical antenna made in accordance with the invention is shown in FIGURE 2. In this antenna the balanced line consists of two closely spaced and parallel electrically conducting small diameter tubes 24 and 26, to which are attached the arms which form the V-elements and the straight dipoles. It will be noted that each of the arms making up one straight dipole, e.g., 29 and 31, or one V-element, e.g., 27 and 28, is connected to a different one of said conductors 24 and 26. Moreover, considering either one of conductors 24 and 26, consecutive arms along the length thereof extend in opposite directions. It will be seen that this construction has the effect of alternating the phase of the connections between successive elements, as depicted schematically in FIGURE 1. Although the elements of the antenna of FIGURE 2 are not precisely coplanar, differing therefrom by the distance between the parallel conductors 24 and 26, in practice this distance is usually small so that the arms of the elements are substantially coplanar and the advantages of the invention are maintained. In some instances, however, it may be advantageous to bend the individual arms, e.g., 32 and 33 in FIGURE 3, close to the point of attachment to the feeder lines 24′ and 26′, so as to position all the arms in the same plane. The antennas of FIGURES 2 and 3 may be conveniently fed by means of a coaxial cable, e.g., 34 and 34′ positioned within conductor 26 or 26′, the outer conductor of the cable making electrical contact with the conductor 26 or 26′ and the central conductor 36 or 36′ of the cable extending to and making electrical connection with conductor 24 or 24′ as shown.

In addition to the type of construction shown in FIGURES 2 and 3, practical antennas made in accordance with the invention can use a balanced feeder line which is twisted between connections to successive dipoles or V-elements. Other suitable means for accomplishing the desired phasing, such as transmission line loops or stubs, can also be used.

As an example of the invention, an antenna was constructed in a manner similar to that shown in FIGURE 3 containing two zones of elements, a group of V-elements, such as group A in FIGURE 1, and a group of linear dipoles, such as group C. The antenna was made using 0.125″ diameter tubing for the balanced line and 0.050″ diameter wire for the arms of the elements. The arms were soldered to the feeder line and the array was fed by a miniature coaxial cable inserted into one of the conductors of the balanced line. The antenna had a total of 12 elements, of which 6 were contained in a zone of linear dipoles partially defined by $\tau=0.90$. The linear dipoles ranged in length from about 7.5 inches to about 4.4 inches, the zone having a length of about 2 inches. The antenna also contained a group of six V-elements ($\psi=70°$) ranging in developed length from about 3.3 inches to about 2.6 inches, the group of elements having a length of about 1.1 inches, and being further defined by $\tau=0.95$. This antenna was a scale model of one designed to cover the 15 meter, 10 meter, 6 meter and 2 meter bands of amateur radio transmission. For the 15 and 10 meter bands the antenna was operated in the ½ wavelength mode as a linear dipole array. The 6 meter band was covered by the V-elements of the antenna in the ½ wavelength mode and the 2 meter band was covered by the same V-elements in the ⅝ wavelength mode. This antenna was found to perform acceptably over this range, although the performance in the 6 meter band was somewhat inferior to the other bands which were covered. This deficiency, however, could have been rectified by providing an additional large element in the group of V-elements.

It is believed evident from the above description that the antennas of the invention can be designed to cover discrete frequency bands within a wide overall range as desired. By using the principles of the invention, the antenna can be made smaller in length and consequently cheaper to construct that has heretofore been possible, without, however, sacrificing performance within the desired frequency bands.

This application constitutes a continuation-in-part of U.S. patent application Serial No. 76,075, filed by the inventors herein named on December 15, 1960, now abandoned, and a continuation-in-part of U.S. patent application Serial No. 299,715, also filed by the inventors herein named and carries a filing date of August 5, 1963, now abandoned.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. A broadband unidirectional antenna covering an intermittent range of frequencies comprising an array of a plurality of substantially coplanar elements, said elements being arranged in a plurality of zones, the ends of the elements in each of said zones falling on a pair of converging lines, the lines passing through the ends of the elements in any zone being non-collinear with at least one pair of the corresponding lines associated with any other zone, the elements within any zone being arranged in substantially parallel side-by-side relationship and progressively increasing in length and spacing, the ratio of the lengths of any two adjacent elements within any one of said zones being given by the formula

$$\frac{L_{n+1}}{L_n}=\tau$$

where L_n is the length of the larger of said adjacent elements, L_{n+1} is the length of the adjacent smaller element, and τ is a constant having a value less than 1, the spacing between the elements of any zone being given by the formula

$$\frac{\Delta S_{n+1}}{\Delta S_n}=\tau$$

where ΔS_n is the spacing between the element having the length L_n and the adjacent larger element, ΔS_{n+1} is the spacing between the element having the length L_n and the adjacent smaller element, and τ has the significance previously assigned, said elements being fed by a common feeder which alternates in phase between successive elements.

2. The antenna of claim 1 in which the elements in at least one of said zones are parallel dipoles.

3. The antenna of claim 1 in which the elements in at least one of said zones are V-elements arranged in a herringbonelike arrangement, each of said elements having a pair of equal arms defining an apex, the apexes of said V-elements lying on a straight line, the corresponding arms of said elements being parallel.

4. The antenna of claim 3 wherein the angle formed by the arms of any V-element at the apex thereof has a value within the range from about 50° to about 150°.

5. The antenna of claim 1 wherein the angles formed by the lines passing through the ends of the elements in said zones have values within the range from about 20° to about 100°, and the values of the constant τ associated

with said zones lie within the range from about 0.8 to about 0.95.

6. A broadband unidirectional antenna covering an intermittent range of frequencies comprising an array of a plurality of substantially coplanar conducting elements, said elements being arranged in a plurality of zones, the ends of the elements in each of said zones falling substantially on a pair of converging lines, the lines passing substantially through the ends of the elements in any zone being non-collinear with at least one pair of the corresponding lines associated with any other zone, the elements within any zone being arranged in substantially parallel side-by-side relationship and progressively increasing in length, the ratio of the lengths of any two adjacent elements within any one of said zones being determined by a zonal scale factor established by the ratio of the length of one conducting element to the length of the next adjacent and longer conducting element to establish the length scale factor, the spacings of one conducting element to the next smaller element and the spacing of the same conducting element to the next longer conducting element with each zone establishing the spacing scale factor, and where each scale factor in each zone is a constant, and a common two-conductor feeder connected to all of the elements with adjacent conductor elements being connected to different conductors of the feeder.

7. The antenna of claim 6 in which the elements in at least one of said zones are parallel dipoles extending in a direction substantially perpendicular to the axis of the feeder.

8. The antenna of claim 6 in which the elements in at least one of said zones comprises V-elements arranged in a herringbonelike arrangement, each of said elements having a pair of equal arms defining an apex, the apexes of said V-elements lying on a straight line, the corresponding arms of said elements being parallel, and in which at least one other zone comprises dipole elements extending substantially normal to the feeder axis.

9. An aerial system for wide-band use over selected intermittent frequency ranges comprising a plurality of substantially coplanar elements arranged in a plurality of zones, at least one zone comprising a plurality of herringbonelike conducting V-elements arranged to terminate in planar relationship, at least one other zone comprising a plurality of parallel dipoles, a two-conductor balanced feeder connected to the elements forming each zone at substantially the inner end thereof, each two opposite V-elements and each two opposite parallel dipoles forming a pair constituting dipole halves, the connection from each adjacent conducting element of the dipole sections being to a different feeder, all of said elements being selectively spaced from each other, each element of each pair of conducting V-elements having arms of substantially equal length substantially defining an apex with the apexes of the plurality of V-elements all lying in substantially a straight line and terminating at the feeder, each of the parallel dipoles all lying in a common plane and also terminating at the feeder, the said V-elements and parallel dipoles of each pair being of different electrical lengths with successive V-elements and dipoles differing in electrical length with respect to each other by substantially the same scale factor, each V-element and each dipole and the feeder between successive V-elements and dipoles constituting a cell, and the selective spacings between adjacent dipoles decreasing from one end to the other with the greater spacing being between the longest dipoles and being such that the combination of V-elements and dipole lengths and spacings provides a substantially uniform wide-band response over a plurality of selected frequency bands, the connection between the V-elements and the dipoles and the feeder being made in such a manner that the directive gain of the antenna increases as operation shifts from one band to an adjacent band of higher frequencies, and means to connect the feeder to an external circuit at a location substantially removed from the longest of the V-elements and dipole elements and in the direction of the smallest of the elements.

10. An aerial system for wide-band use covering intermittent frequency ranges comprising an array of a plurality of substantially coplanar conducting elements arranged in a plurality of zones, the conducting elements of each zone being similar, at least one zone comprising a plurality of herringbonelike conducting V-elements planarly arranged, at least one other zone comprising a plurality of substantially straight and oppositely positioned conductor elements, a two-conductor balanced feeder connected to each of said conducting elements at substantially the inner end thereof, each two opposite V-elements forming a pair constituting dipole halves, each two oppositely positioned elements also forming a pair constituting dipole halves, the connection from each adjacent dipole section being to a different feeder, said V-elements of the zone being selectively spaced from each other, the elements of each pair of V-elements and each pair of oppositely positioned elements having arms of substantially equal length, the V-elements of one zone substantially defining an apex with the apexes of the plurality of V-elements all lying in substantially a straight line and terminating at the feeder and the oppositely positioned elements of a second zone also terminating at the feeder, the said dipoles of each pair being of different electrical lengths with successive dipoles in each zone differing in electrical length with respect to each other by substantially the same scale factor, each dipole and the feeder between successive dipoles constituting a cell, and the selective spacings between adjacent dipoles decreasing from one end to the other with the greater spacing being between the longest dipoles and being such that the combination of dipole lengths and spacings provides a substantially uniform wide-band response over a plurality of frequency bands bearing substantially harmonic frequency relationships to each other, the connection between the dipoles and the feeder being made in such a manner that the directive gain of the antenna increases as operation shifts from one band to an adjacent band of higher frequencies, and means to connect the feeder to an external circuit at a location substantially removed from the longest of the V-elements and in the direction of the smallest of the V-elements.

11. An aerial system for wide-band use covering intermittent frequency ranges comprising a plurality of pairs of substantially coplanar conducting elements, the elements being arranged in a plurality of zones, a two-conductor balanced feeder connected to each of said elements at substantially the inner end thereof, the elements within each zone being arranged in substantially parallel side-by-side relationship and progressively differing length and spacing, the connection from each adjacent element being to a different feeder, each pair of elements having arms of substantially equal length, the ratio of the lengths, of any two adjacent elements within any one of said zones being determined and substantially proportioned by a length scale factor established by the ratio of the length of one of the conducting elements to the length of the next adjacent longer conducting element so that the elements of each pair have different electrical lengths and successive elements with each zone differ in electrical length with respect to each adjacent element by substantially the same scale factor, each conductor and the feeder between successive conductors constituting a cell, the ratio of the spacing of one conducting element in each zone to the next smaller element and the spacing of the same conducting element in the said zone to the next longer conducting element also establishing a spacing scale factor, each of the scale factors having a value of less than unity so that the selective spacings between adjacent conductors differ from one end to the other with the greater spacing being between the longest conductors

and being such that the combination of conductor lengths and spacings provides a substantially uniform wide-band response over the zone, the connection between the conductors and the feeder being made in such a manner that the directive gain of the antenna increases as operation shifts from one band to an adjacent band of higher frequencies, and means to connect the feeder to an external circuit at a location substantially removed from the longest of the conducting elements and in the direction of the smallest of the said elements.

12. The antenna claimed in claim 11 in which the conducting elements of the zones are arranged in V-formation with the open end of the V faced toward the feeder connection.

13. The antenna claimed in claim 11 in which the conducting elements of the separate zones are parallel dipoles.

14. The antenna claimed in claim 11 in which the conducting elements of each zone are of similar form and the conducting elements of at least one zone are arranged in V-formation with the open end of the V faced toward the feeder connection and in which the conducting elements of at least one other zone are parallel dipoles.

15. A broad band unidirectional antenna covering intermediate ranges of a wide frequency spectrum comprising a multiplicity of substantially coplanar conductor elements, each conductor element forming half of a dipole, the two elements of each dipole being of substantially the same length, the several dipole elements being selectively spaced along an axis and arranged in a plurality of separate zones, the electrical length of the dipoles decreasing with distance along the axis, the electrical length of adjacent dipole elements of the separate zones differing by a selected zone scale factor which is substantially constant in each zone, the electrical length of each dipole of all zones being approximately an odd multiple of a half-wave length at a frequency within the operating spectrum over which the antenna is to provide maximum response in each zone, a pair of feeder conductors for feeding all of the dipole elements, one element of each dipole being connected to one feeder conductor and the other element of each dipole being connected to the opposite feeder conductor, adjacent elements of different dipoles being connected to opposite feeder conductors so that the directional gain of the antenna is maximum in the direction along the feeder from the end with longer dipoles toward the end with shorter dipoles and increases as the operation shifts from one frequency within the spectrum whereat the element lengths are approximately an odd integral number of half-wave lengths to the next higher frequency range where the element lengths are once more approximately an odd integral number of half-wave lengths, the ratio of the lengths of any two adjacent dipole elements within any one of the zones being determined by the zonal scale factor of substantially constant value within the zone, and means to connect the feeder conductors to an external circuit at a location which is substantially removed from the longest dipole element in the direction of the shortest dipole element.

16. The antenna claimed in claim 15 wherein the dipole elements of at least one of the zones extend in a direction substantially perpendicular to the axis of the feeder conductors.

17. The antenna claimed in claim 15 in which the dipole elements of at least one of the zones comprise V-shaped elements whose apexes lie on substantially a straight line and between which elements in the region of the open portion of the V-formation there is an angular spacing in the range from about 50° and 150°.

18. The antenna claimed in claim 15 wherein the corresponding dipole elements of each zone extend parallel to each other and wherein certain of the dipoles extend substantially perpendicular to the feeder and wherein other dipoles are V-shaped elements whose apexes lie on substantially a straight line with the angular spacing between the elements of the open portion of the V-formation being within the angular limits of 50° and 150°.

No references cited.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,150,376 September 22, 1964

Robert L. Carrel et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 33, after "may" insert -- be --; column 3, lines 44 to 46, the equation should appear as shown below instead of as in the patent:

$$\tau X = \frac{L^X_{(n+1)}}{L^X_n} = \frac{\Delta S^X_{(n+1)}}{\Delta S^X_n}$$

line 47, for "$L_n{}^X$" read -- L^X_n --; line 49, for "$L_{(n+1)}{}^X$" read -- $L^X_{(n+1)}$ --; line 51, for "$\Delta S_n{}^X$" read -- ΔS^X_n --; line 53, for "$\Delta S_{(n+1)}{}^X$" read -- $\Delta S^X_{(n+1)}$ --; column 6, line 7, for "large" read -- larger --; line 14, for "that" read -- than --; column 8, line 58, strike out the comma.

Signed and sealed this 5th day of January 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents