Dec. 12, 1961 R. H. DU HAMEL ET AL 3,013,268

ELLIPTICAL-POLARIZED LOGARITHMICALLY PERIODIC ANTENNA

Filed April 23, 1959 3 Sheets-Sheet 1

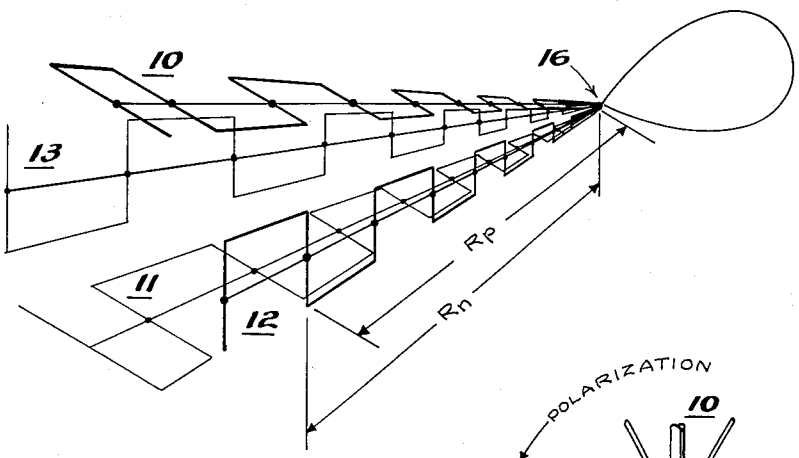


FIG. 1

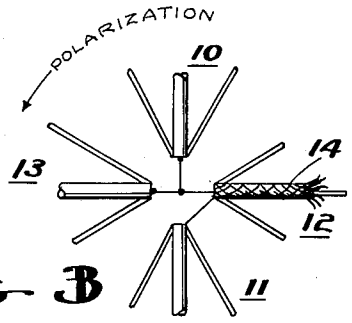


FIG. 3

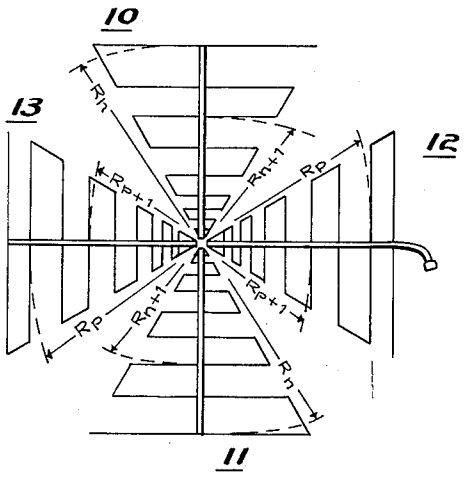


FIG. 2

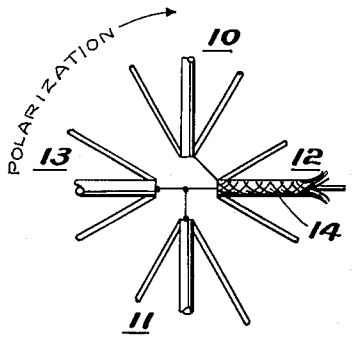


FIG. 4

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FIG. 5

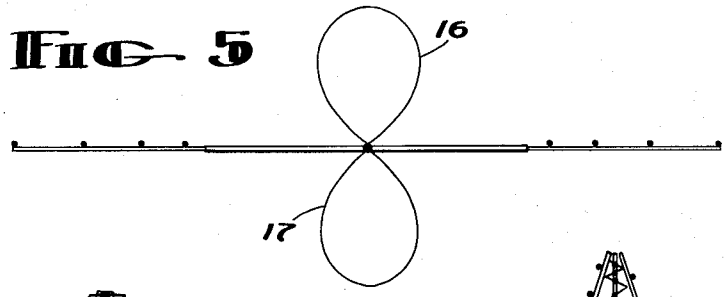


FIG. 6

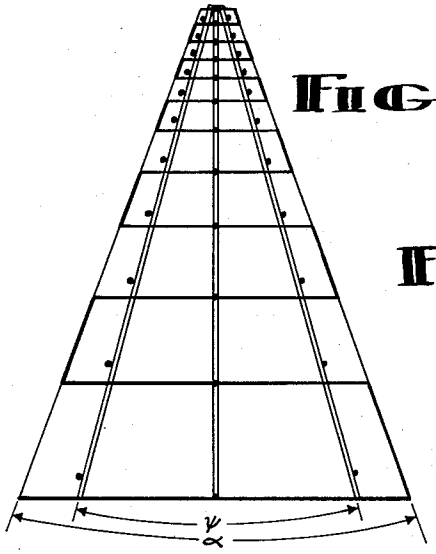
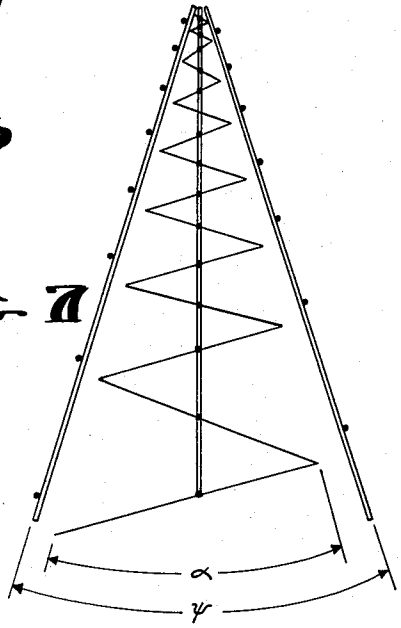


FIG. 7



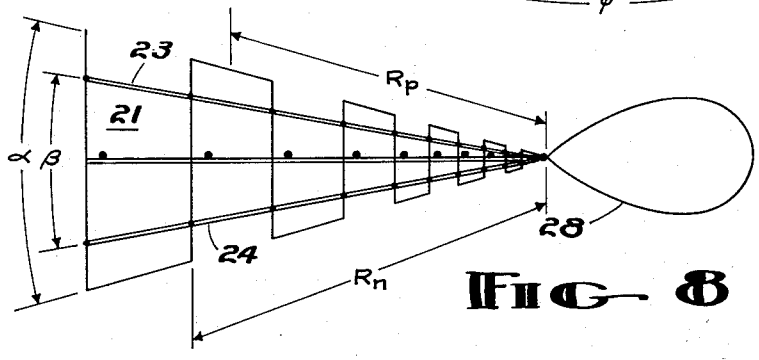


FIG. 8

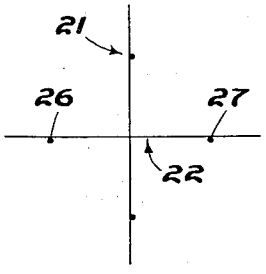


FIG. 9

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ELLIPTICAL-POLARIZED LOGARITHMICALLY PERIODIC ANTENNA

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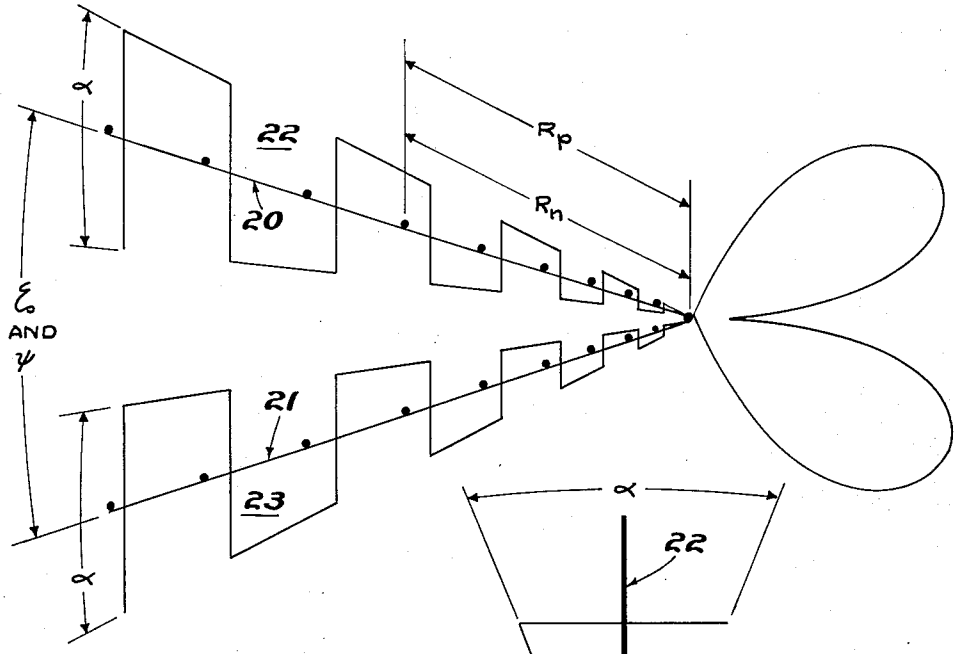


FIG. 10

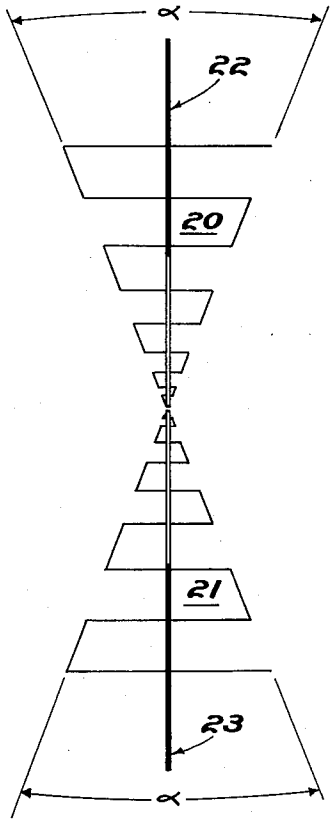


FIG. 11

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3,013,268

ELLIPTICAL-POLARIZED LOGARITHMICALLY PERIODIC ANTENNA

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Filed Apr. 23, 1959, Ser. No. 808,373
16 Claims. (Cl. 343—797)

This invention relates to logarithmically periodic antennas capable of operating with elliptically-polarized radiation including the special cases of circular-polarization and linear-polarization at any angle.

Linearly-polarized logarithmically periodic antennas having straight-edged teeth are described by patent application Serial Number 721,408 filed March 14, 1958, by the same inventors as the present application. All matter in that application relating to the construction of logarithmically periodic antennas is incorporated herein by reference.

The present invention comprises a logarithmically periodic antenna having at least two elements which lie in planes at right angles. The two elements are constructed with the same parameter τ which is defined in the prior-cited application. However, one of the elements is stretched with respect to the other so that their comparable teeth have different distances from a common apex.

Thereore, it is an object of this invention to provide an antenna having an elliptically-polarized radiation pattern which can be made to operate over a wide a frequency range as desired without theoretical limitations. In practice, maximum size for an antenna structure controls its low-frequency limit and construction tolerance controls its high-frequency limit. However, a 20-to-1 frequency range is easily obtainable.

It is another object of this invention to provide a frequency independent antenna which can be constructed to provide a circularly-polarized radiation pattern.

It is still another object of this invention to enable control of the axial ratio of elliptical polarization.

Further objects, features and advantages of this invention will become apparent to one skilled in the art upon further study of the following specification and accompanying drawings in which:

FIGURE 1 is a perspective view of an antenna made according to this invention.

FIGURE 2 shows another view of FIGURES 1 and 5.

FIGURES 3 and 4 illustrate transmission-line feed connections to the apex of the antenna in any of FIGURES 1, 5, 6, 7 and 10 for opposite rotations of polarization.

FIGURE 5 shows a plane configuration of the invention and its bi-directional patterns.

FIGURE 6 illustrates another form of the invention.

FIGURE 7 is a form of the antenna having triangular teeth.

FIGURES 8 and 9 illustrate side and back views of an elliptically-polarized antenna having two quadrature positioned elements.

FIGURES 10 and 11 show another form of elliptically-polarized logarithmically periodic antenna.

Certain parameters found in the prior-cited application dealing with logarithmically periodic antennas are also applicable to the present invention. These parameters are α, β, and τ, which are used to define a single element of the antenna, designated as a half-portion in the prior application, and a parameter ψ defining the angle between two elements. To summarize briefly, α is the angle bounding the sides of an element. Angle β is between a pair of rods symmetrically-placed internally along the entire length of an element, and β may be zero by using

a single centrally-positioned rod. Angle ψ separates the planes of opposite elements in an antenna. Parameter τ controls the number of rods in a finite sized element and is defined by the following expression

$$\tau=\frac{R_{n+1}}{R_n} \tag{1}$$

where R_n and R_{n+1} are the distances from the apex for comparable transverse edges of teeth in adjacent structural periods of an element, where R_n is the larger distance. The longitudinal width of any tooth is defined by:

$$\sigma=\frac{r_n}{R_n} \tag{2}$$

where r_n and R_n are distances from the apex of transverse edges on opposite sides of a tooth. For structural symmetry of an element:

$$\sigma=\sqrt{\tau} \tag{3}$$

In FIGURES 1 and 2, there are two pairs of antenna elements in which elements 10 and 11 provide one pair and 12 and 13 provide a second pair. Each pair comprises a logarithmically-periodic antenna as defined in the above-cited patent application. However, special positioning and relative proportioning is necessary between the two antennas in order to obtain a single elliptically-polarized antenna. The four elements have the same values of τ and α, and each pair has the same angle ψ. Both pairs have a common apex 16, but the planes of one pair are perpendicular to the planes of the other pair.

However, the pair 12 and 13 is sized differently from the pair 10 and 11, in that one pair is stretched by a factor K. To prevent confusion between the two pairs, the apex distances for any transverse tooth edge in pair 10 and 11 will be designated R_n and the apex distance for a comparable transverse tooth edge in pair 12 and 13 will be designated R_p. Comparable tooth edges are those having most nearly equal distances to the apex.

For clarity, τ is restated in the nomenclature distinguishing the pairs of elements, as follows:

$$\tau=\frac{R_{n+1}}{R_n}=\frac{R_{p+1}}{R_p} \tag{4}$$

Therefore,

$$R_n=KR_p \tag{5}$$

Experiments have shown the following relationship:

$$K=\tau\frac{S}{2\pi}=\frac{R_p}{R_n}=\frac{R_{p+1}}{R_{n+1}} \tag{6}$$

where S is the time-phase in radians between the electric-field vectors of the respective antenna pairs. Where circular polarization is desired, S is $\pi/2$, and K is $\tau^{1/4}$. Linear polarization requires S to be zero. Other values of S obtain different degrees of elliptical polarization.

The direction of rotation of the resultant vector of the component quadrature electric fields is determined by the manner of connecting a transmission line to the antenna. FIGURE 3 illustrates how a transmission line 14 may be connected to the apex portion of the antenna to obtain one rotational direction of polarization. Coaxial cable 14 shown in FIGURE 3 is brought centrally along antenna element 12 where its outer conductor is electrically connected to the vertexes of elements 12 and 10. The inner conductor is electrically connected to the vertexes of elements 13 and 11. A balanced line may be used by connecting its opposite sides in the same manner as was done for the opposite sides of the coaxial line.

By switching the order of connections to elements 10 and 11 as shown in FIGURE 4, the opposite direction of elliptical polarization is obtained. Here, the inner con-

ductor is connected to elements **11** and **13**, and the outer conductor is connected to elements **12** and **10**.

The angle ψ of each pair of elements may have any value between 0 and 180°, but ψ is preferably the same for both pairs. In the special case, where ψ is 180°, the antenna will lie along a single plane and has an edge view as shown in FIGURE 5. FIGURE 2 is also representative of an elevational view of FIGURE 5, as well, being an end view of FIGURE 1. In the case of the planar arrangement of FIGURE 5, a bi-directional pattern results having radiation lobes **16** and **17**.

Where ψ is less than 180°, the radiation pattern becomes uni-directional as shown in FIGURE 1, and its predominent radiation beam is off the apex end of the antenna.

Any of the forms of teeth for logarithmically-periodic antennas may be used in the elliptically-polarized type taught by this application. Thus, in FIGURES 1 and 6, trapezoidal teeth are shown. However, in FIGURE 7, triangular teeth are provided.

The angles ψ and α may have any value relative to each other. However, it is preferable with trapezoidal teeth that they not be close to equality, because then the outer edges of the teeth may touch each other to cause mutual-coupling effects which adversely affect operation of the antenna. In FIG. 1, angle ψ is greater than angle α. In FIGURE 6, angle ψ is less than angle α. Either case is satisfactory as long as the edges of the elements do not become too close to each other. In the case of triangular teeth, the mutual coupling is not prohibitive when the angles are equal.

It has been found that the axial ratio between the magnitudes of component quadrature electric-field vectors can be maintained less than 2-to-1 where circular polarization is intended over a large frequency range. It was also found that the ratio tended to improve as angle α was made smaller.

FIGURE 8 shows a side view and FIGURE 9 shows a back view of a form of circularly-polarized antenna having two elements **21** and **22** which are positioned with common axes. The elements each have a pair of conducting rods **23** and **24** or **26** and **27** throughout their length and spaced by angle β. They are electrically connected to their respective teeth. Half-portion **22** is constructed with the same value of τ as element **21**; however, element **22** is stretched by factor K defined by expression 4 above. The pattern **28** of the antenna in FIGURE 8 is unidirectional as shown. This antenna is fed by connecting opposite sides of a transmission line to the vertexes of the two elements.

The frequency range of an elliptically-polarized antenna in this application is determined in the same manner as was previously explained in the above cited application. However, the tolerances for the elements in the circularly-polarized case are generally more critical than with the prior linear periodic antennas because of the structural phasing relationship between the teeth of the quadrature-positioned elements, which are relatively close to each other along their sides. Furthermore, the axial ratio for the antenna tends to become more constant as angle α is decreased.

FIGURE 10 shows a side view and FIGURE 11 illustrates an end view of another form of the invention, which provides a unidirectional split beam that is elliptically polarized. It also has two pair of elements. Pair **20** and **21** comprise a split-beam nonplaner logarithmically periodic antenna as taught in a patent application titled "Frequency Independent Split-Beam Antenna," No. 804,356, filed about April 6, 1959, by the same inventors as the present application. The second pair of elements **22** and **23** comprise a planer logarithmically-periodic antenna as taught in a patent application Ser. No. 804,357 filed about April 6, 1959, titled "Frequency-Independent Unidirectional Coplaner Antenna" by Haymond H. Du Hamel and David G. Berry, and assigned to the same assignee as the present invention. To obtain circular polarization, the component antennas are constructed with equal values for α and τ. The angle ζ for the component coplaner antenna is made equal to the angle ψ for the component non-planer antenna. Hence, elements **20** and **22** have a common axis, and likewise elements **21** and **23** have a common axis. One of the component antennas is stretched with respect to the other component antenna by a factor K as defined by expression 5 above, wherein S is

$$\frac{\pi}{2}$$

for circular polarization.

The split-beam characteristic of the antenna in FIGURES 10 and 11 is not obtainable with the antennas in FIGURES 1–7.

However, an antenna like the one in FIGURE 10 may be constructed to have a single forward beam by having the non-planer elements reversed to a non-image relationship, as defined in patent application Ser. No. 721,408 cited above, and having the coplaner elements in an image relationship as defined in patent application Serial No. 804,357, filed about April 6, 1959 by the same inventors as the present application.

One-half of the structure in FIGURES 10 and 11 is similar to the embodiment of FIGURES 8 and 9. If the one-half structure is placed over a ground plane, positioned to bisect angles ζ and ψ in FIGURE 10, an image of the structure will be caused in the ground plane. The one-half structure and its image combine to provide a structure different than that in FIGURES 10 and 11; because the resulting coplaner antenna has a single beam, and the resulting nonplaner antenna has a split beam. However, the ground-plane prevents a split-beam pattern from being obtained, and a single unidirectional beam off the apex end of the antenna results. However, their component beam patterns are different with equal values of α and $\psi=\zeta$. This results in the axial ratio varying at different points in the beam. Accordingly, different α, ψ and ζ angles may be used to obtain approximate component equal patterns that approximately coincide; and the axial ratio is thereby made substantially the same over the entire beam.

Although this invention has been described with respect to particular embodiments thereof, it is not to be so limited as changes and modifications may be made therein which are within the full intended scope of the invention as defined by the appended claims.

We claim:

1. An elliptically polarized logarithmically periodic antenna having at least two antenna elements, each being triangular in shape and having apexes positioned adjacent to each other, said elements lying in planes that are positioned perpendicular to each other, each element having outer lateral boundaries included within an apex angle α, logitudinally conducting means included along each element from its apex to its opposite end, a plurality of conducting teeth formed along the edges of each element, with, said teeth having inner and outer edges with respect to said apexes, said teeth alternating on opposite sides of each of said elements, the radial distances from the apex to the inner sides of adjacent teeth on either element having a geometric-sequence ratio of τ, the ratio of the radial distance from the apex of the inner to the outer sides of a tooth being given by a geometric-sequence ratio σ, one of said elements being longer axially with respect to the other element by a factor K, which is equal to

$$\frac{S}{\tau 2\pi}$$

where S represents a required time-phase between quadrature electric field components.

2. An antenna as defined in claim 1 for providing circular polarization in which

$$\tau\frac{S}{2\pi} \text{ is made } \tau^{1/4}$$

3. An antenna as defined in claim 2 in which linear polarization is provided at 45° in which

$$\tau\frac{S}{2\pi} \text{ is made } 1$$

4. An elliptically polarized antenna as defined in claim 1 in which the angular shapes of the two elements intersect each other symmetrically.

5. An elliptical-polarized logarithmically-periodic antenna comprising two pairs of elements, each pair having two elements spaced opposite each other by an angular separation ψ, and having adjacent apexes, one pair being positioned perpendicularly with respect to the other pair, the elements of each pair being, generally triangular in shape and having their ends opposite their apices positioned adjacent to each other, each element having outer lateral bounderies included within an apex angle α, conducting means connected axially along each of said elements from its apex to its opposite end, a plurality of conducting teeth formed alternately on opposite sides of each element, said teeth having inner and outer sides with respect to said apexes, the radial distances from the apex of the inner sides of adjacent teeth having a geometric-sequence ratio τ, the ratio of the radial distance from the apex of the inner to outer sides of a given tooth being given by a geometric-sequence ratio σ, transmission line means having opposite sides, one of said opposite sides being connected to the apexes of one element of each pair, and the other of said opposite sides being connected by the other element in each pair, and one of said pair of elements having the radial distances of its teeth from the apex greater than the radial distances of the teeth from the apex of the other pair of elements by an amount

$$\tau\frac{S}{2\pi}$$

6. An elliptically polarized antenna as defined in claim 5 in which circular polarization is provided, and one of said pairs of elements is greater in axial proportions than the other pair by an amount $\tau^{1/4}$.

7. An elliptically polarized antenna as defined in claim 6 in which the teeth are trapezoidal in shape.

8. An antenna as defined in claim 5 in which said teeth are made of rod-like conducting members positioned along the periphery of said teeth.

9. An antenna as defined in claim 5 in which said teeth are triangular in shape.

10. An antenna as defined in claim 9 in which said triangular teeth are formed of rod-like conducting members positioned along the edges of said teeth.

11. An antenna as defined in claim 5 in which the angle α is less than angle ψ.

12. An antenna as defined in claim 5 in which said ψ angle is less than angle α, said elements being interlaced with each other but not electrically contacting each other.

13. an elliptically polarized antenna including as components a first and a second logarithmically periodic antenna, in which said antennas are positioned with a common apex, said antennas extending in the same direction from said apex, said antennas being positioned in intersecting normal planes and being positioned over a substantially level grounded surface with the apex thereof being near said grounded surface but not touching said grounded surface, one of said antennas lying in a plane which intersects the grounded surface at an angle less than 90° and which produces an intersecting line with said grounded surface which is normal to the intersecting line of the normal planes in which said first and second antennas lie.

14. An elliptically polarized antenna having as components a pair of non-planer logarithmic periodic antenna elements and a pair of co-planer logarithmic periodic antenna elements, the two antenna elements of one pair of antenna elements each having a common center conductive boom with separate ones of the two antenna elements of the other pair of antenna elements, the apex of the individual antenna elements of each of the two pairs of antenna elements being positioned close together but not making electrical coupling.

15. An elliptically polarized antenna in accordance with claim 14 in which said pair of non-planer antenna elements have an image relationship, and said pair of co-planer antenna elements have a non-image relationship, said antenna providing a radiation pattern having a split beam with elliptical polarization.

16. An elliptically polarized antenna in accordance with claim 14, in which said pair of co-planer antenna elements have an image relationship, and said pair of non-planer antenna elements have a non-image relationship, whereby a single predominent beam is provided in a forward direction.

References Cited in the file of this patent

UNITED STATES PATENTS

2,278,560	Peters	Apr. 7, 1942
2,480,154	Masters	Aug. 30, 1949

OTHER REFERENCES

"Broadband Logarithmically Periodic Antenna Structures," by Du Hamel and Isbell, IRE Transactions, March 1957, part I, pages 119 to 125.

"Logarithmically Periodic Antenna Designs," by Du Hamel and Ore, IRE National Convention Record, March 1958, part 1, pages 139–151.

"Logarithmically Periodic Antenna Arrays," by Du-Hamel and Berry, 1958 Wescon Convention Record, August 1958, part I, pp. 161–174.