

June 20, 1961

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2,989,749

UNIDIRECTIONAL FREQUENCY-INDEPENDENT COPLANAR ANTENNA

Filed April 6, 1959

3 Sheets-Sheet 1

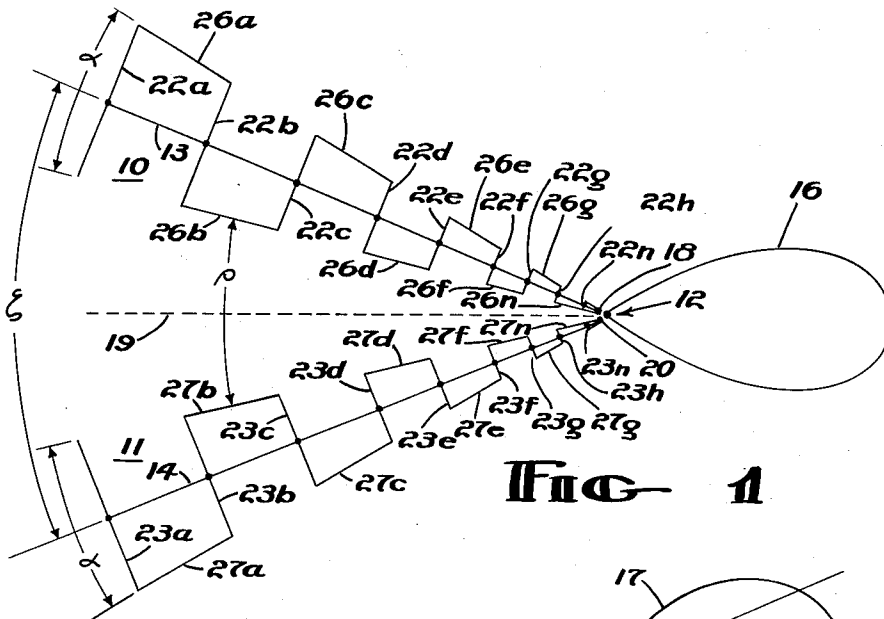


FIG. 1



FIG. 2

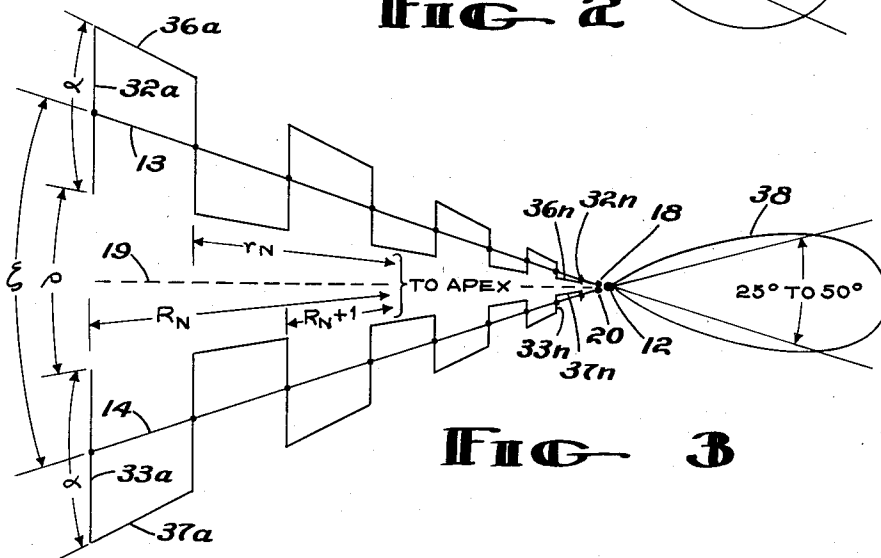


FIG. 3

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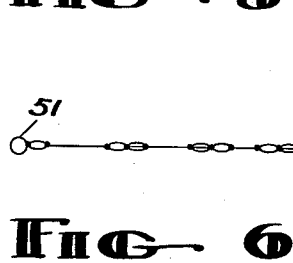
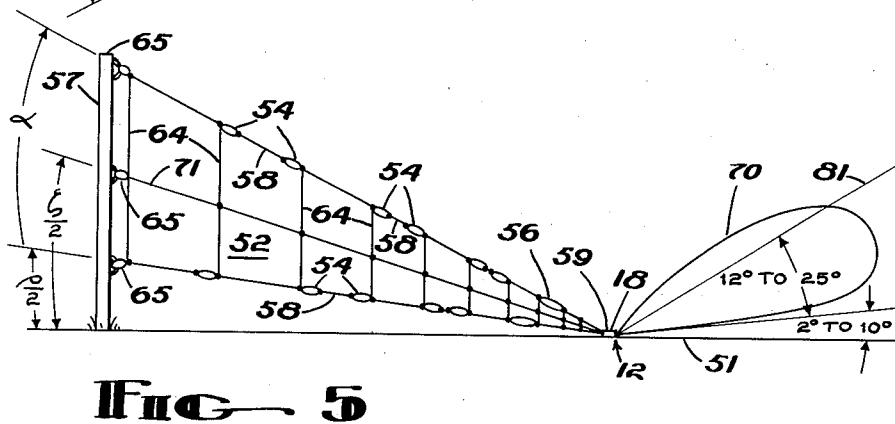
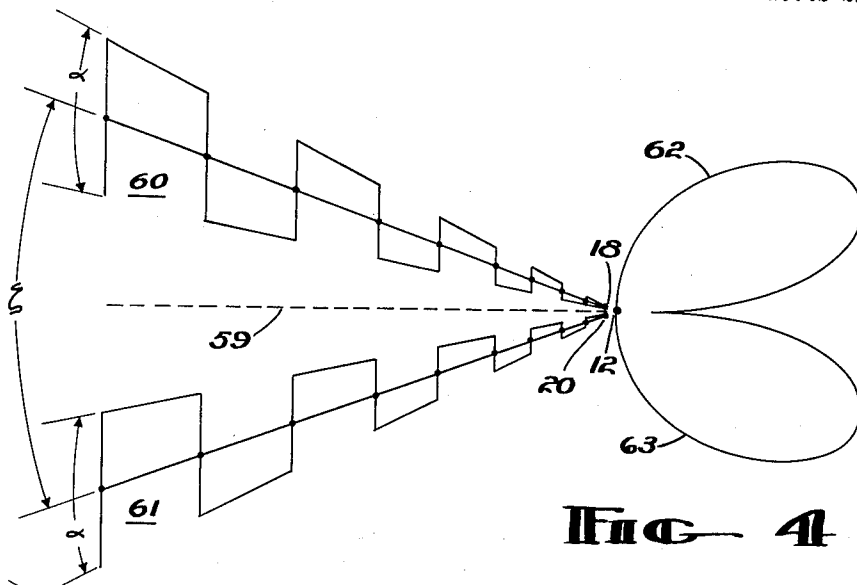
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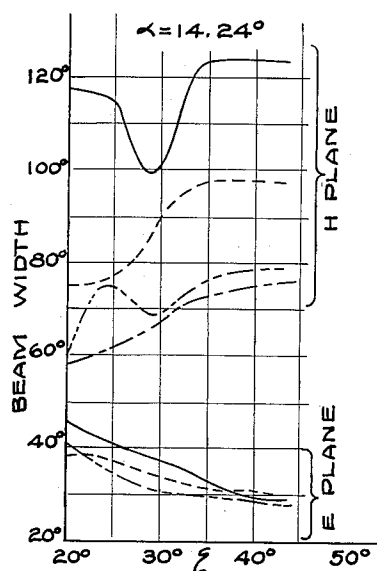
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3 Sheets-Sheet 3



$\tau = 0.75$  ———  
 $\tau = 0.83$  - - - - -  
 $\tau = 0.915$  - - - - -  
 $\tau = 0.95$  - - - - -

FIG. 7

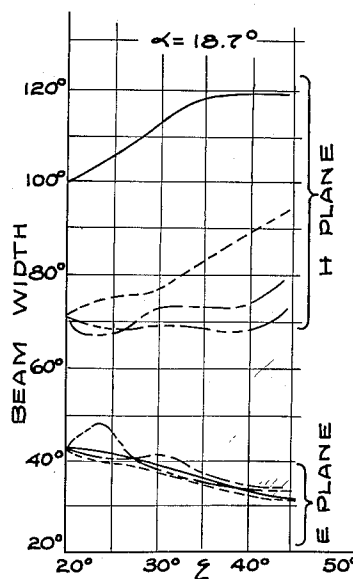


FIG. 8

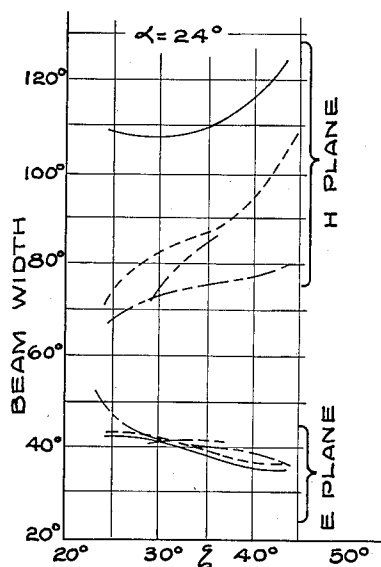


FIG. 9

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## UNIDIRECTIONAL FREQUENCY-INDEPENDENT COPLANAR ANTENNA

Raymond H. Du Hamel and David G. Berry, Cedar Rapids, Iowa, assignors to Collins Radio Company, Cedar Rapids, Iowa, a corporation of Iowa  
Filed Apr. 6, 1959, Ser. No. 804,357  
10 Claims. (Cl. 343-793)

This invention relates to unidirectional antennas of the logarithmically periodic type having all radiating members aligned in a single plane. Prior unidirectional logarithmically periodic antennas were all nonplanar. However, like such prior antennas, it is capable of providing a substantially constant radiation-pattern and input-impedance over an indefinitely-wide frequency range. The present invention, however, can provide purer linear polarization, a better back-to-front ratio, and other characteristics which are given below.

A prior coplanar logarithmically periodic antenna, which is not unidirectional but provides a figure-eight pattern is described and claimed in patent application Serial Number 721,408, filed March 14, 1958 by Raymond H. Du Hamel and Fred R. Ore, assigned to the same assignee as the present application. A bidirectional pattern, however, is a distinct disadvantage in most situations. The present invention teaches how this prior coplanar antenna can be modified to obtain outstanding unidirectional characteristics, while maintaining the coplanar aspect of structure.

Prior nonplanar logarithmically periodic antennas (with radiating elements in two different planes intersecting at an angle  $\psi$ ) were also described and claimed in patent application Serial Number 721,408 cited above.

Both the unidirectional coplanar and nonplanar types of logarithmically periodic antennas have been found better in over-all consideration than prior antennas.

In many ways the unidirectional coplanar and nonplanar logarithmically periodic antennas have opposite characteristics as is shown by the following:

| Nonplanar Antenna                                                                 | Coplanar Antenna                                                                              |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| 1. Single unidirectional lobe when opposite sides are non-image.                  | 1. Two symmetrical but unidirectional lobes in the E-plane when opposite sides are non-image. |
| 2. Two symmetrical unidirectional lobes in H-plane when opposite sides are image. | 2. Single unidirectional lobe when sides are image.                                           |

Further, where parameters are made as nearly alike as possible, the coplanar antenna had a narrow E-plane beam-width but a broader H-plane beam-width than the nonplanar antenna. Also, the coplanar periodic antenna can be built to have better a back-to-front ratio than the nonplanar periodic antenna.

It is, therefore, the principal object of this invention to provide a coplanar logarithmically periodic antenna having unidirectional characteristics.

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

FIGURE 1 illustrates a top view of an embodiment of the invention having image half-portions and its E-plane radiation pattern;

FIGURE 2 shows a side view of the antennas in FIGURES 1, 3 and 4 and their H-plane radiation pattern;

FIGURE 3 shows another embodiment of the invention having image half-portions and its E-plane pattern;

FIGURE 4 shows another form of the invention hav-

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ing opposite half-portions that are non-image, and a resulting split-beam E-plane pattern;

FIGURE 5 illustrates a modified version of the image embodiment of the invention provided over a ground plane, and its corresponding E-plane pattern;

FIGURE 6 shows a top view of the antenna in FIGURE 5 and its pattern;

FIGURES 7, 8 and 9 provide diagrams showing the relationship between beam-widths and various parameters of the invention.

The embodiment of FIGURE 1 is first considered. It includes two half-portions 10 and 11 which lie in a single plane. Each half-portion is triangular in configuration and tapers to a common apex point 12 for the coplanar antenna system. The entire structure is angularly referenced to apex point 12.

Each antenna half-portion 10 and 11 includes a longitudinal conducting member 13 or 14 which bisects an angle  $\alpha$  bounding each half-portion. Each half-portion has a vertex very near to apex 12 but the two vertices are separated to prevent voltage breakdown, since an input transmission line has opposite sides connected to the vertices.

An angle  $\zeta$  is included between longitudinal members 13 and 14 of the two half-portions and defines the positions of the half-portions relative to each other. Each half-portion in FIGURE 1 has a plurality of teeth that are defined in the same manner as a straight-toothed half-portion found in the above-cited application, where in parameters  $\alpha$ ,  $\sigma$ ,  $\tau$  and  $R_N$  apply. The structural novelty of the present invention is in the relationship between the half-portions, they being in the same plane separated by an angle  $\zeta$ . To reiterate briefly,  $R_N$  is the distance from the apex of the antenna to the longest transverse rod 22a; and

$$\tau = \frac{R_{n+1}}{R_n} \quad (1)$$

where  $R_N$  and  $R_{n+1}$  are the distances from the apex of two corresponding transverse rods in adjacent periods of structure such as to transverse rods 22a and 22c. Each period of structure comprises any three adjacent transverse rods such as 22a, b and c or 22c, d and e. Adjacent structural periods have a transverse rod in common such as 22c. Within any single structural period, adjacent transverse rods have distances  $R_N$  and  $r_N$  from the apex with distance having a ratio  $\sigma$ . For logarithmic symmetry within each period of structure  $\sigma = \sqrt{\tau}$ . This is a preferred condition in most cases. As  $\tau$  is increased, the spacing between transverse rods becomes smaller, and their number becomes greater for a given antenna length  $R_N$ . Thus, as  $\tau$  approaches one, the number of transverse rods approaches infinity for a given finite length antenna. The transverse rods need not be perpendicular to the longitudinal conducting member of their half-portion. In fact, in a preferred form of the invention shown in FIGURE 3, transverse rods of equal length in the two half-portions are aligned with each other.

The opposite half-portions 10 and 11 in FIGURE 1 are constructed identically. The two half-portions are placed symmetrically about a line 19 which bisects angle  $\zeta$ . Thus, they are images of each other about line 19.

The frequency range over which substantial constant pattern and input impedance is obtained is determined by the lengths of the longest and shortest transverse members. The lowest frequency of the range is that at which the longest rod 22a is approximately a half wavelength and the highest frequency is that at which the shortest rod 22n is approximately a tenth of a wavelength. Hence, the length of the smallest element 22n should be made as small as possible to extend the high

frequency limit as high as possible. Practical difficulties in making very small teeth will cause a high-frequency limit; although theoretically as the teeth become infinitesimally small as they approach the apex, the upper frequency limit of the antenna approaches infinity. On the other hand, the low-frequency limit can theoretically approach zero by adding larger and larger teeth at the end of each half-portion away from the apex, thus having the longest transverse rod approach infinity.

The free-space pattern of the antenna is illustrated by curves 16 and 17 in FIGURES 1 and 2. There is only a single radiation lobe that is not observed to have any significant side lobes on equipment capable of measuring 30 decibels below the maximum beam intensity. E-plane pattern 16 is shown in FIGURE 1, and H-plane pattern 17 is shown in FIGURE 2. However, as the structure is placed near objects which are less than a few wavelengths away, there will of course be found some deterioration of the pattern as a function of frequency. For example, if the antenna of FIGURE 1 is placed at a specified distance above and parallel to the ground, with no other near reflecting objects, the vertical pattern of the antenna will vary as a function of frequency; however, the horizontal pattern will remain independent of frequency. It is later taught herein how a unique property of this antenna can be utilized to maintain its vertical pattern frequency independent when placing it over ground.

FIGURE 3 illustrates another form of the invention which has parameters  $\alpha$ ,  $\tau$ , and  $\zeta$  defined in the same manner as given for FIGURE 1 except that correspondingly sized transverse rods 32a-n and 33a-n are respectively aligned. FIGURE 2 also provides a side view of the antenna in FIGURE 3. The pattern response of the antenna in FIGURE 3 is very similar to that found with the antenna of FIGURE 1, except that a somewhat higher front-to-back ratio was found with the antenna of FIGURE 3. A further slight difference in structure between FIGURES 1 and 3 is in the nonperiodic parts of the half-portions near apex 12. In FIGURE 3 there is no triangular shape to the apex parts as there is in FIGURE 1, but only the center rods 13 and 14 are brought to transmission line connection terminals 18 and 20. Terminals 18 and 20 are brought as close to apex 12 as possible while maintaining voltage separation between them.

Among the parameters which can be varied are  $\alpha$ ,  $\tau$  and  $\zeta$ . The effect upon structure as  $\alpha$ ,  $\zeta$  or  $\tau$  is varied is evident from inspection of FIGURES 1 or 3 and Expression 1; the effect of the variation upon the antenna radiation pattern is not evident from the parameters themselves, and was discovered by experiment.

FIGURES 7, 8 and 9 show the experimentally-found effect upon beam-width of the respective parameters. It has been found desirable for the coplanar antenna of this invention to have angle  $\alpha$  less than about 30°, to have  $\tau$  greater than about .7, and to have an angle  $\delta$  between the inner edges of the two half-portions that is greater than

$$\frac{3\alpha}{2}$$

in order to have a standing wave ratio of less than two-to-one at the antenna terminals with frequency variation. Thus it is noted by examining FIGURES 7-9 and from other experiences involved with this invention that the E-plane beam-width between half-power points can be controllably varied from about 25° to 50°, and that the H-plane beam-width can be controllably varied from about 50° to 140°.

The planar embodiment of FIGURE 4 differs in structure and pattern from the embodiments of FIGURES 1 and 3. In FIGURE 4, the opposite half-portions 60 and 61 are positioned oppositely with respect to a line 59 which bisects angle  $\zeta$ . That is they are nonsymmetrical about line 50 and are not images of each other in a mir-

ror plane through line 59, as they were in FIGURES 1 and 3. This change from image to non-image planar relationship causes a peculiar change in the radiation pattern. The single beam of the image relationship changes to a split-beam for the non-image relationship having two lobes 62 and 63 in the E-plane having a null along center line 59 where a maximum was previously. The split-beam is unidirectional in the sense that both lobes are in the forward direction of the antenna and there is no significant back-lobing in free space. The two lobes have an angle of the order of 70° between their directions of maximum intensity but it is controllable by varying  $\zeta$ ; as  $\zeta$  decreases, the angle between the beams increases. FIGURE 2 also represents a side view of the antenna in FIGURE 4 and its pattern. There is no significant H-plane pattern since it would pass through the null of FIGURE 4.

The split-beam E-plane pattern is particularly useful for direction-finding purposes.

FIGURES 5 and 6 illustrate elevational and top views of another embodiment of the invention. This embodiment utilizes the image characteristic of the embodiments of FIGURE 3. Accordingly, if a reflecting surface is passed through line 19 perpendicularly to the plane of the antenna, one of the half-portions can be dispensed with, since the image in the reflecting plane of the remaining half-portion will substitute for it. In FIGURE 5, the ground surface 51 provides a reflecting plane so that only a single half-portion 52 is needed. In FIGURE 5, the structure is designed for high-frequency use and is made with wire suitably supported by insulators in a wire-suspension arrangement between a pair of posts 57 and 59. The wire suspensions between the posts is electrically broken by insulators between the teeth of the periodic structure. Thus, single insulators 56 are placed between adjacent teeth where the electrical gap is small, and a pair of insulators 54 joined by a wire 58 is placed between teeth where a large gap would exist. The longest vertical wire is connected by insulators 65 to post 57.

A wire 71 bisects angle  $\alpha$  and is electrically connected to each of the vertical antenna wires 64. One end of wire 71 connects to another insulator 65 attached to post 57 and the other end terminates at point 18 on insulated post 59 very near the angular apex 12 of the antenna structure, where it is connected to the center conductor 74 of a coaxial transmission line 73 which may lie on or may be buried beneath the surface of the ground.

The terminal impedance of the antenna in FIGURES 1, 3 and 5 is approximately 150 ohms with a standing wave ratio of less than two-to-one across the antenna bandwidths previously defined. When the antenna is arranged as shown in FIGURE 5 over a ground plane, the input impedance is reduced to about 75 ohms unbalanced.

A vertically-polarized radiation pattern is obtained from the embodiment of FIGURE 5 which has characteristics that make it superior to any known broad-band type of antenna that radiates vertically-polarized radiation. Of most importance is the fact that its vertical pattern as well as its horizontal pattern does not vary with frequency within its bandwidth, which is without theoretical restriction. FIGURE 5 shows its E-plane radiation pattern and FIGURE 6 shows a top view of the pattern. This occurs because half-portion 52 is oriented with respect to ground so that it and its image form an antenna similar to FIGURE 3, which is basically frequency independent. The top-view of the pattern in FIGURE 6 is very nearly the same as the H-plane pattern 39 shown in FIGURE 2 which may have a beam-width of between 50° and 140° and is controlled by varying  $\zeta$ ,  $\alpha$  and  $\tau$  as is given in FIGURES 7-9. On the other hand, the E-plane pattern in FIGURE 5 will have a beam-width slightly less than half that found in the embodiments of FIGURES 1 and 3 as given in FIGURES 7-9. That is, the angle between ground 51 and a line 81 pass-

ing through the upper half-power point of the beam is the same as one-half of the E-plane beam-width 38 found in FIGURE 3. Because of ground losses, the lobe is prevented from going down to the ground. Consequently, the bottom of the lobe will vary from about 2° to 10° over a frequency range of from about 3-30 mc. due to ground effects. However, the top of the beam is defined by line 81 will not change as a function of frequency; and the angle of maximum radiation will be substantially invariant with frequency.

The use of ground as a reflection device depends upon its conductivity. In many situations the conductivity of the ground is insufficient to provide a desired amount of reflection. In such cases wires may be stretched along the ground beneath in the immediate vicinity of the antenna in order to provide the necessary high conductivity required for reflection.

The half-portions described herein may have solid teeth, straight or curved as given in the prior cited application.

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. A coplanar unidirectional logarithmically-periodic antenna, comprising two antenna half-portions, both half-portions lying in the same plane, each being generally triangular in shape and having apexes adjacent to each other, each half-portion having outer lateral boundaries within an apex angle  $\alpha$ , a central-conducting member included along each half-portion, from its apex, a plurality of conducting teeth formed in each half-portion, said teeth extending alternately on opposite sides of their central-conducting member, the radial distances from the apex of the inner sides of adjacent teeth on the same side of said central-conducting member having a ratio  $\tau$ , the ratio of the radial distance from the apex of the inner to outer sides of a given tooth being given by a ratio  $\sigma$ , transmission line means having opposite sides connected to the respective apexes of the antenna half-portions, an angle  $\xi$  located between the central-conducting members of the half-portion and adjacent edges of said half-portions being separated from each other.

2. A logarithmically periodic antenna as defined in claim 1 in which both of said half-portions are mirror-images of each other in an imaginary plane midway between the two half-portions.

3. A periodic antenna as defined in claim 1 in which said half-portions are positioned symmetrically about a line bisecting angle  $\xi$ .

4. A periodic antenna as defined in claim 1 in which said half-portions are positioned with a nonimage relationship with respect to a plane transverse to the plane on the antenna and bisecting angle  $\xi$ , whereby a split beam is provided in the E-plane of the antenna.

5. A periodic antenna as defined in claim 1 in which the central-conducting members have the same relative positions in both half-portions.

6. A periodic antenna as defined in claim 1 in which said teeth are formed of rod-like conductors positioned about the contours of the respective teeth.

7. A periodic antenna as defined in claim 6 in which a rod-like conductor provides each of said central conducting members and is electrically connected to each of said teeth.

8. A vertically-polarized logarithmically-periodic antenna, comprising an antenna portion formed generally triangular in shape, a ground-plane positioned below said antenna portion and transverse to said portion, said portion having outer lateral boundaries included within an apex angle  $\alpha$ , a plurality of conducting teeth formed along said antenna portion, a conducting member included along said portion from its apex and electrically connected to said teeth, said apex being positioned close to said ground-plane but electrically separated therefrom, the edge of said antenna adjacent to said ground-plane being angularly separated therefrom, the radial distances from the apex of the inner sides of adjacent teeth on one side of said conducting member having a ratio  $\tau$ , the ratio of the radial distance from the apex of the inner to outer sides of a given tooth being ratio  $\sigma$ , an angle

$$\frac{\xi}{2}$$

being formed between the ground-plane and said conducting member, transmission line means having opposite sides connected to said apex and to said ground-plane.

9. A periodic antenna as defined in claim 8 wherein said teeth are formed of rod-like conductors positioned about the contours of said teeth, and said conducting member being formed of a rod-like member bisecting angle  $\alpha$ .

10. A periodic antenna as defined in claim 9 in which said antenna is supported in a suspension manner, comprising insulators connected to and supporting three outer corners of said antenna portion, means for supporting said insulators with respect to said ground-plane, insulated members being connected between the outer edges of said teeth under tension to provide suspension support along the edges of said antenna portion, and a catenary distortion resulting to said angles  $\alpha$  and

$$\frac{\xi}{2}$$

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