Sept. 28, 1965 S. D. SPIEGELMAN 3,209,362

LOG-PERIODIC BOW-TIE ANTENNA

Filed Jan. 8, 1964

FIG. 1

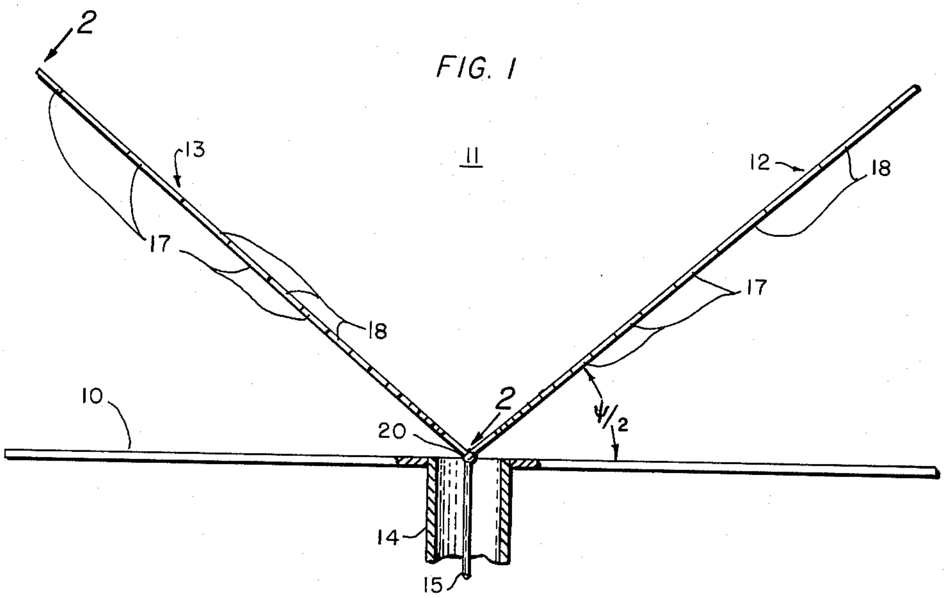
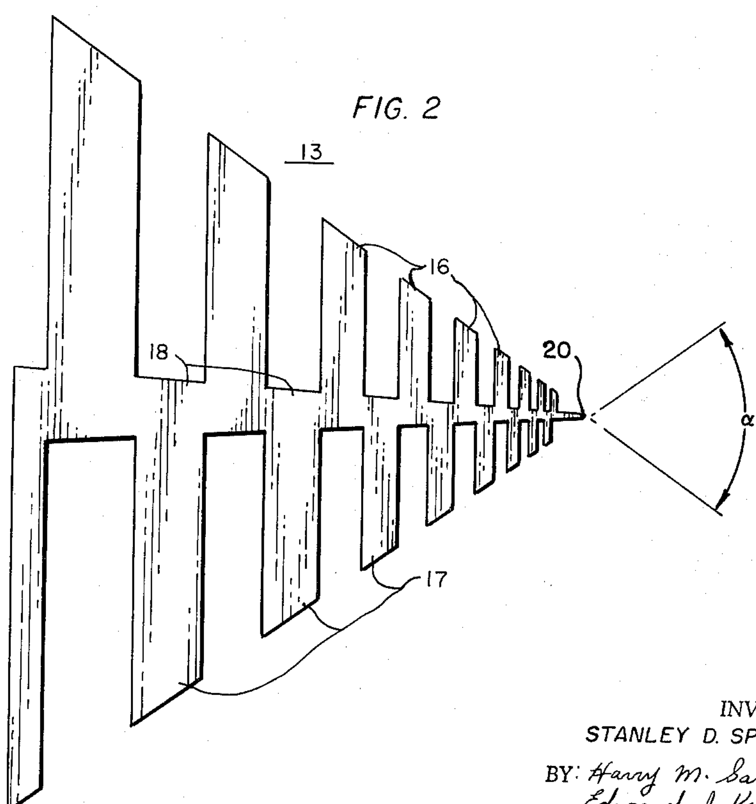


FIG. 2



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United States Patent Office

3,209,362

Patented Sept. 28, 1965

3,209,362

LOG-PERIODIC BOW-TIE ANTENNA

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Filed Jan. 8, 1964, Ser. No. 336,609

4 Claims. (Cl. 343—792.5)

The present invention relates to a "bow-tie" log-periodic antenna and more particularly to a broadband, linearly-polarized, unidirectional antenna which has the property that the location of its phase canter (effective center of radiation) is essentially independent of frequency.

This antenna was developed to fill the requirement for a broadband primary feed for a paraboloidal reflector. Proper operation of such primary feeds require that the phase center be located at the focus of the paraboloid. If the phase center is displaced from the focus along the focal axis, the result is a loss in gain. If the displacement is transverse to the focal axis, the secondary beam from the reflector will be tilted away from the focal axis.

The general purpose of this invention is to provide a unidirectional, broadband antenna the phase center of which remains substantially fixed. To obtain this, the present invention contemplates a unique arrangement of two log-periodic antenna elements, in the shape of a "bow-tie," and fed in parallel against a ground plane. It will also be seen that this arrangement does not require a balanced feed and may therefore be fed directly by a coaxial line.

It is, therefore, the object of this invention to provide a broadband, linearly-polarized, unidirectional antenna having a fixed phase center.

It is also an object of this invention to provide a broadband, linearly-polarized, unidirectional antenna having a fixed phase center which can be fed directly by an unbalanced feed.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof, and wherein:

FIG. 1 shows a side elevation view, partly in section, of a preferred embodiment of the invention; and

FIG. 2 shows a view of one of the antenna elements looking in the direction of the arrows 2—2 of FIG. 1.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 an antenna **11** having a highly conductive ground plane **10** and two antenna elements **12** and **13**. The outer conductor **14** of a coaxial line is connected to the ground plane **10** while the inner conductor **15** is connected to the antenna elements **12** and **13** at their apex or common feed point **20**. The ground plane **10** should extend a substantial distance beyond all sides of the elements **12** and **13**.

The antenna elements **12** and **13**, which are identical, are conventional log-periodic antenna elements being generally triangular in shape and having staggered conducting teeth **16** and **17** extending laterally from a center conductor **18**. As mentioned in FIG. 1, element **12** is a mirror image of element **13**. Elements **12** and **13** and ground plane **10** are all mounted perpendicular to the plane of the paper as viewed in FIG. 1. The radiation characteristics of such antenna elements are well-known and are assumed to be common knowledge in the antenna art. Briefly, at a given frequency, the radiation from a log-periodic antenna element originates from a comparatively narrow radiating region centered around the tooth whose length is equal to one-quarter wavelength.

In the present device the radiating tooth will be fed against the ground plane **10**. It is now readily seen that the effective phase center of element **13** together with its image, formed by the ground plane **10**, will be located at the ground plane or at the axis of symmetry of element **13** and its image. The location of the phase center can be calculated approximately from the following formula:

$$d=\frac{\lambda}{4}\cot\frac{\alpha}{2}\cos\frac{\psi}{2}$$

where d is the distance from apex **20** to the phase center along plane **10** as viewed in FIG. 1, λ is the wavelength at the operating frequency, α is the angle formed between the outer edges of teeth **16** and **17**, and ψ is the angle formed between the element **13** and its image or in other words, ψ is twice the angle formed between element **13** and the ground plane **10**. From this equation it is seen that the location of the phase center is dependent upon the wavelength at the operating frequency.

Since antenna element **12** is identical to element **13**, the phase center for element **12** and its image will be located on the ground plane **10** and spaced from point **20** the same distance as the phase center for element **13** but in the opposite direction from apex **20**. The resulting phase center for both elements **12** and **13** when combined will be located at the mid-point or at the apex or feed point **20**.

With antenna element **12** oriented as a mirror image of element **13** a single radiation lobe is excited up and along the plane of symmetry of the antenna as viewed in FIG. 1. This condition is referred to as the sum mode. If one of the elements **12** or **13** were rotated 180° such that teeth **16** were coming out of the paper in FIG. 1 to produce two-fold symmetry a split beam radiation lobe would be produced. This condition is referred to as a difference mode and is undesirable for a paraboloid feed.

It has been determined experimentally that the single lobe is approximately circular in cross-section over a fairly wide range of values for ψ centered about the value $\psi=\alpha$. It has also been determined experimentally that the optimum impedance performance is obtained when ψ is equal to α.

A minimum value for α which will permit successful operation has been determined. As stated above, the effective phase center of each antenna element (together with its image) is located at the ground plane at a distance d from the feed point **20** as given by the equation:

$$d=\frac{\lambda}{4}\cot\frac{\alpha}{2}\cos\frac{\psi}{2}$$

The spacing between the phase centers of the two elements **12** and **13** is then twice this distance or $2d$. The effective currents at the two radiating regions on each element are in phase. Therefore, the radiation pattern of the antenna **11** will be a single-lobed, unidirectional pattern directed up and along the plane of symmetry, provided the distance $2d$ is less than approximately one wavelength. Introduction of this assumption into the equation for d yields:

$$\cot\frac{\alpha}{2}\cos\frac{\psi}{2}<2$$

It is assumed that α is equal to ψ to insure a lobe of circular cross-section and optimum impedance. With this assumption, the above equation yields:

$$\sin^2\frac{\alpha}{2}+2\sin\frac{\alpha}{2}-1>0$$

This restriction is satisfied for values of α greater than approximately 45°. The validity of this restriction has been satisfied experimentally. A log-periodic antenna model with α equal to 30° gave unsatisfactory multi-lobed performance. On the other hand, models constructed with α equal to 45°, 53°, and 60° gave satisfactory performance.

When this antenna is used as a primary feed for a paraboloid many desirable features exist. The phase center remains fixed at the feed point of the antenna; the bandwidth of the antenna is restricted at the low frequency end only by the length of the longest tooth, and at the high frequency end only by the care exercised in maintaining fine details in the vicinity of the feed point; with α greater than 45° and α equal to ψ the resulting single-lobed, unidirectional pattern with a circular cross-section provides optimum illumination of the paraboloidal reflector; the antenna may be fed directly from a coaxial transmission line supplying a desirable broad band feed.

Of course, the above advantages are only some of the more important while many modifications and variations of the present invention are possible in the light of the aobve teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An antenna comprising a pair of log-periodic antenna elements, a ground plane, and a coaxial transmission line; each said antenna elements being generally triangular in shape and having a central conductor extending from the apex to the base; a plurality of conducting teeth extending laterally from said central conductor and being alternately arranged on opposite sides thereof; the

outer edges of said teeth being tapered to form the sides of the triangular shape; the plane of each said antenna element and said ground plane all being perpendicular to a common plane; said common plane bisecting said triangular shape and passing through each said central conductor, each said apex, and said ground plane; each said antenna being mounted at equal angles with respect to said ground plane with each said apex being closest to said ground plane; and the inner conductor of said coaxial line connected to each said central conductor at said apex while the outer conductor of said coaxial line is connected to said ground plane.

2. An antenna according to claim **1** and wherein said apex angle is approximately equal to twice the angle between each said antenna element and said ground plane.

3. An antenna according to claim **2** and wherein said apex angle is greater than 45°.

4. An antenna according to claim **1** and wherein the distance between the corresponding teeth of each said antenna element is less than approximately one wavelength at the operating frequency of said corresponding teeth.

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ELI LIEBERMAN, *Primary Examiner.*