

[54] **SHIELDED END-FIRE ANTENNA**

[75] Inventor: **Keith R. Carver**, Lexington, Ky.

[73] Assignee: **The Ohio State University**,
Columbus, Ohio

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Related U.S. Application Data

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abandoned.

[52] U.S. Cl. **343/786, 343/895**

[51] Int. Cl. **H01q 1/36, H01q 13/02**

[58] Field of Search **343/895, 772, 785-786**

[56] **References Cited**

UNITED STATES PATENTS

2,863,148 12/1958 Gammon et al. **343/895**

Primary Examiner—Rudolph V. Rolinec

Assistant Examiner—Marvin Nussbaum

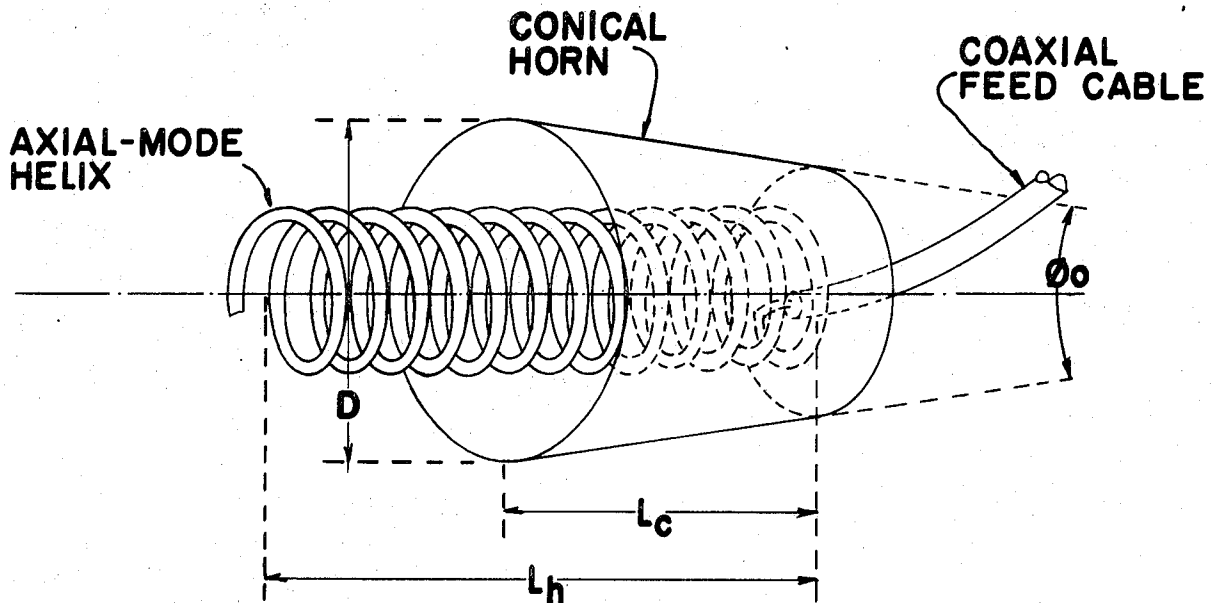
Attorney—Anthony D. Cennamo

[57]

ABSTRACT

The invention is for an antenna comprising an end-fire radiator in a shielded structure. A specific case is an axial-mode helical antenna in a conical horn which produces a circularly polarized pencil beam with low side-lobe level over a 2-to-1 bandwidth with a gain in the order of four times that of a simple helix.

2 Claims, 7 Drawing Figures



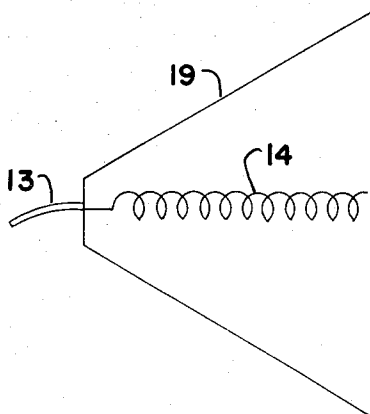


FIG. 2

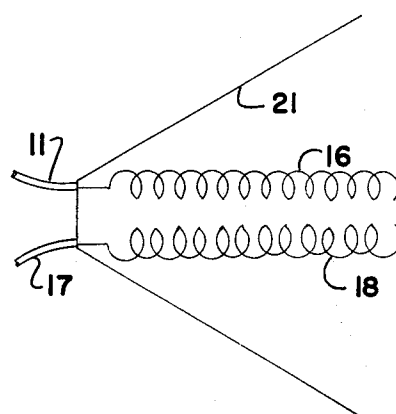


FIG. 3

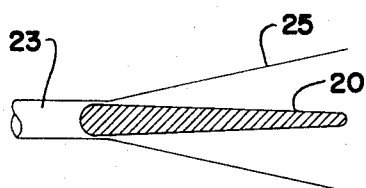


FIG. 4

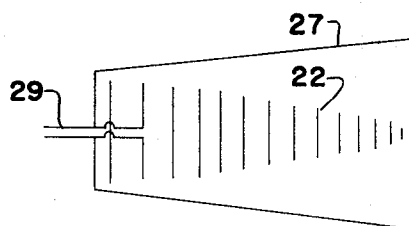


FIG. 5

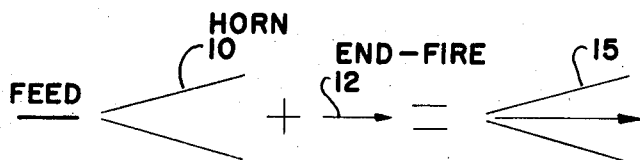
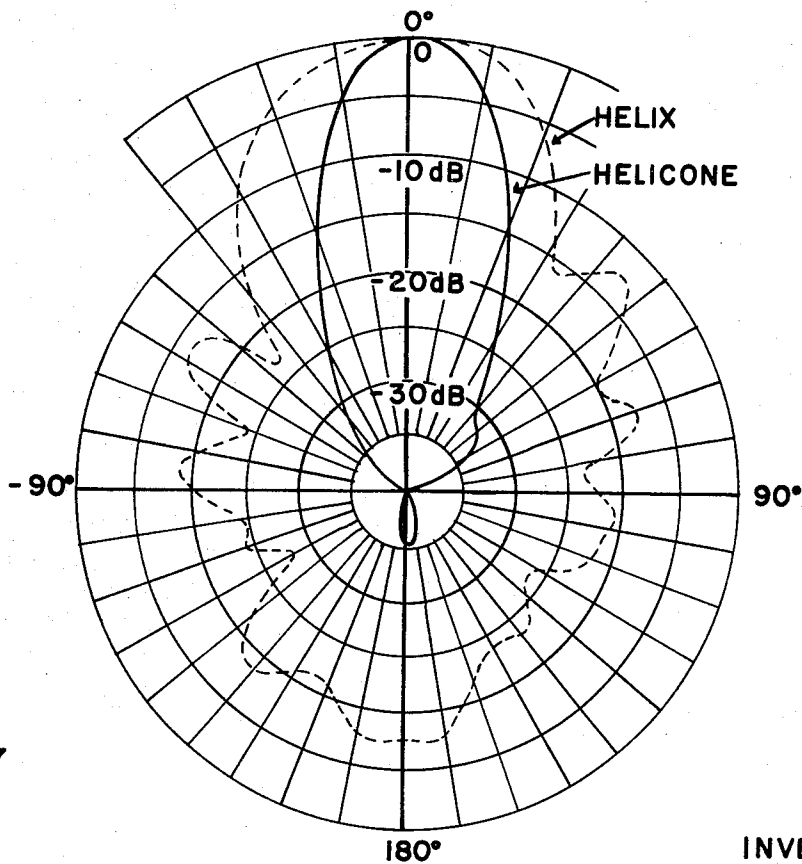
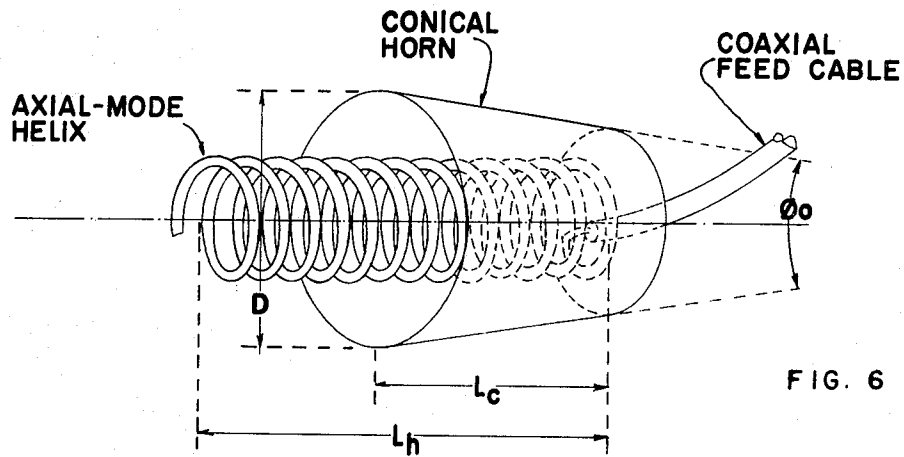


FIG. 1

INVENTOR
KEITH R. CARVER

BY
Anthony D. Cumano
ATTORNEY



INVENTOR
KEITH R. CARVER

BY
Anthony D. Carver
ATTORNEY

SHIELDED END-FIRE ANTENNA

This application is a continuation of Ser. No. 694,139, filed Dec. 28, 1967, now abandoned.

CROSS REFERENCES AND BACKGROUND

End-fire antennas are usually structurally characterized by an axis of symmetry of near-symmetry. Examples are the axial-mode helical beam antenna (Kraus, 1947), the polyrod antenna (Mueller and Tyrrell, 1947), the Yagi-Uda antenna (Yagi, 1928), the log conical spiral (Deschamps and DuHamel, 1961), and the end-fire array antenna (Riblet and Birchard, 1944). All end-fire radiators possess the common characteristic that their direction of maximum radiation lies on or very near the axis of the antenna; usually this beam maximum is in the direction away from the feed end. The sidelobe level of ordinary end-fire antennas is usually not small in terms of the main beam response. For example, the first sidelobes of the axial-mode helix may be only 8 dB below the main beam maximum. The rectangular electromagnetic horn is well known (Barrow and Lewis, 1939; Barrow and Chu, 1939) as is the conical horn (Southworth and King, 1939). Rectangular and conical horns have radiation patterns which vary with the physical dimensions and exhibit these patterns over moderate bandwidths. Ordinary horns fed by waveguides carrying a low order mode exhibit strong fields at one or more of the mouth edges, resulting in relatively high sidelobe levels. The main beam is usually directed along the axis of the horn away from the feed end.

SUMMARY OF INVENTION

The present invention combines a shielding structure with an end-fire antenna. The shield may extend partially along the end-fire antenna, completely along the end-fire antenna, or beyond the end-fire antenna, dependent upon the design requirements. The antenna continuously excites the shield along its axis so that the wave is primarily bound toward the axis of the shield. This results in a highly tapered aperture distribution and consequently has a far-field pattern with a very low sidelobe level.

OBJECTS

It is accordingly a principal object of the invention to provide a new and improved antenna that combines the advantages of a shielding structure with that of an end-fire antenna.

Another object of the invention is to provide a new and improved circularly polarized antenna that yields a pattern having very low sidelobe levels, over a 2-to-1 bandwidth and with a gain considerably greater than that of a simple helix.

Further objects and features will become apparent from the following detailed description when taken in conjunction with the drawings in which:

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a simple schematic illustration of the fundamental principles of the present invention;

FIG. 2 is a first embodiment of the present invention;

FIG. 3 is a second embodiment of the present invention;

FIG. 4 is a third embodiment of the present invention;

FIG. 5 is a fourth embodiment of the present invention;

FIG. 6 is a complete and practical working embodiment of the present invention; and,

FIG. 7 is a graphical representation of the comparisons of the measured far-zone power patterns for an helix and for a combined shielding structure with a helix.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to FIG. 1 there is illustrated schematically the basic shielded end-fire antenna 15 of the present invention. The antenna comprises a shielding structure 10 and an end-fire antenna 12.

In FIGS. 2, 3, 4, and 5 there is illustrated schematically alternative arrangements of the combined shield and antenna. Specifically, in FIG. 2 of the end-fire antenna 12 is an axial-mode helix 14 and the shielding structure 19 is a conical horn. In FIG. 3 a conical horn 21 is again utilized but in this instance with a multifilar helix 16-18, together with a pair of coaxial feed lines 11, 17. In FIG. 4 the conical horn 25 is the shielding structure but in this instance an end-fire antenna other than a helix is utilized. In this embodiment the antenna 20 is a polyrod 20 fed by a waveguide 23. In FIG. 5 still another type of end-fire antenna 22 is shown — in this instance — a Yagi-Uda. Also in FIG. 5 another type of shielded structure 27 is utilized — particularly, a rectangular horn 27 fed by a two-wire balanced feed 29.

In each of the antennas of FIGS. 2, 3, 4, 5, the shield extends either partially along the end-fire antenna, completely along the end-fire antenna, or beyond the end-fire antenna, depending upon the design requirements and the characteristics sought.

The shielded end-fire antennas of FIGS. 2 - 4 are electrically characterized by: a main beam in a direction along the axis of symmetry and away from the feed end; by a much lower sidelobe level than is normally obtainable with either a shield (or horn) alone or end-fire antenna alone; and by bandwidth and polarization properties comparable to those of the end-fire antenna alone. In addition, shielded end-fire antennas exhibit smaller half-power beamwidths and higher gain than the end-fire antenna alone.

The end-fire antenna functions as an element continuously exciting the shield along its axis, so that the wave is primarily bound toward the axis of the shield. This results in a highly tapered aperture distribution and consequently in a far-field pattern with a very low sidelobe level. The sidelobes outside the included angle of the cone are normally very low, when the physical dimensions of the antenna are properly chosen.

Referring to FIG. 6 there is illustrated a complete operable and preferred embodiment of the present invention. The symbols used in FIG. 6 are identified as follows:

λ = free-space wavelength at design frequency

ϕ_0 = included cone angle

D = mouth diameter

L_c = truncated cone altitude

L_h = total axial length of helix

N = number of helix turns

α = helix pitch angle

C = circumference of imaginary cylinder on which helix is wound

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In a specific feed arrangement — wherein the antenna was center-fed the following dimensions were found to yield the optimum results:

$$\begin{aligned}\phi_o &= 45^\circ \\ D &= 3\lambda \\ L_c &= L_h = 3\lambda \\ N &= 10 \\ \alpha &= 14^\circ \\ C &= \lambda\end{aligned}$$

In another modification of the arrangement shown in FIG. 6 that is either a center-fed or modified to be peripherally fed, the following range of parameters were found to yield optimum results:

$$\begin{aligned}30^\circ &\leq \phi_o \leq 70^\circ \\ 0.75\lambda &\leq D \leq 5.00 \\ 0 &\leq L_c \leq 4.00 \\ 0.25 &\leq L_h \leq 4.00 \\ 1 &\leq N \leq 16 \\ 10^\circ &\leq \alpha \leq 16^\circ \\ C &= \lambda\end{aligned}$$

The far field of the antenna of FIG. 5 is characterized by extremely low sidelobe levels and by an almost axially symmetric pencil beam. The measured far-zone patterns of a simple 10-turn helix are compared in FIG. 7 having the dimensions described relating to FIG. 6. The patterns were measured with a linearly polarized test antenna in a plane normal to the aperture and are typical of patterns measured in any plane normal to the aperture and in any axial rotation of the test antenna. The half power beamwidth (HPBW) of the antenna of FIG. 6 is about 17° as compared to 33° for the simple 10-turn helical antenna; the first sidelobe level is down almost 20 dB from — 14 dB for the helix to — 33 dB for the antenna of the present invention. This low sidelobe and backlobe level is valuable for radio astronomy and other applications.

The antenna of FIG. 6 has a radiation pattern bandwidth of 2-to-1, where patterns of the type in FIG. 7 (solid line) are obtained over the entire frequency range. The aperture distribution is highly tapered and is of the form $1 - r^2$, where $r = 0$ at the center of the mouth and unity at the edge. The impedance bandwidth is also 2-to-1, with a resistance of about 100 ohms and a reactance varying from —20 to —55 ohms, depending on the exact input configuration and frequency.

The axial ratio of the antenna of the present invention on axis is substantially the same as that on the axis of the helix alone, i.e., $(2N + 1)/2N^2$. The low axial ratio on axis is maintained over the 2-to-1 bandwidth. However, the axial ratio increases for angles off axis, so that the axis of the antenna is not an aspect of polarization stationarity. The axial ratio may reach 2-to-1 at 20° off axis.

Further, the antenna of the present invention has superior bandwidth properties as compared to the conical horn excited from a circularly polarized waveguide with the TE_{11} mode. It also has lower on-axis axial ratio and lower sidelobe level than a conical horn excited by

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a short helix of two-to-four turns.

An approximate expression for the directivity D of the combined shield/antenna has been found empirically, for mouth diameters between 2λ and 4λ to be

$$D = 7.8d_\lambda^2$$

where d_λ is the mouth diameter in wavelengths. For example, an antenna of mouth diameter 3.2λ has $D \cong 80$ or about 19 dB. Since the HPBW of the antenna is about half that of a helix of the same axial length, it has the same HPBW as a simple helix four times as long. The mutual coupling between antennas used in an array is very small, due to the extremely low side radiation.

What is claimed is:

1. An antenna comprising an end-fire radiating antenna and a shielding structure surrounding said element, said shielding structure comprises a conical electromagnetic horn, said radiating antenna is an axial mode helical conductor, and wherein the parameters of said antenna are within the following range:

$$\begin{aligned}30^\circ &\leq \phi_o \leq 70^\circ \\ 0.75\lambda &\leq D \leq 5.00\lambda \\ 0.75\lambda &\leq L_c \leq 4.00\lambda \\ 0.25\lambda &\leq L_h \leq 4.00\lambda \\ 1 &\leq N \leq 16 \\ 10^\circ &\leq \alpha \leq 16^\circ \\ 0.90\lambda &\leq C \leq 1.10\lambda\end{aligned}$$

wherein

λ = free-space wavelength at design frequency

ϕ_o = included cone angle

D = mouth diameter

L_c = truncated cone altitude

L_h = total axial length of helix

N = number of helix turns

α = helix pitch angle

C = circumference of imaginary cylinder on which helix is wound.

2. An antenna as set forth in claim 1 wherein said antenna has the following parameters:

$$\begin{aligned}\phi &\sim 45^\circ \\ D &\sim 3\lambda \\ L_c &= L_h = 3\lambda \\ N &= 10 \\ \alpha &= 14^\circ \\ C &= \lambda\end{aligned}$$

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