United States Patent

[11] **3,623,118**

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[21] Appl. No. **838,143**
[22] Filed **July 1, 1969**
[45] Patented **Nov. 23, 1971**

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[54] **WAVEGUIDE-FED HELICAL ANTENNA**
11 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **343/863,** 333/34, 343/895
[51] **Int. Cl.** **H01q 1/36,** H01q 1/50, H03h 7/38
[50] **Field of Search** 343/863, 824, 872, 840, 895, 908, 700, 705, 707, 709; 219/10.49, 10.55; 333/34

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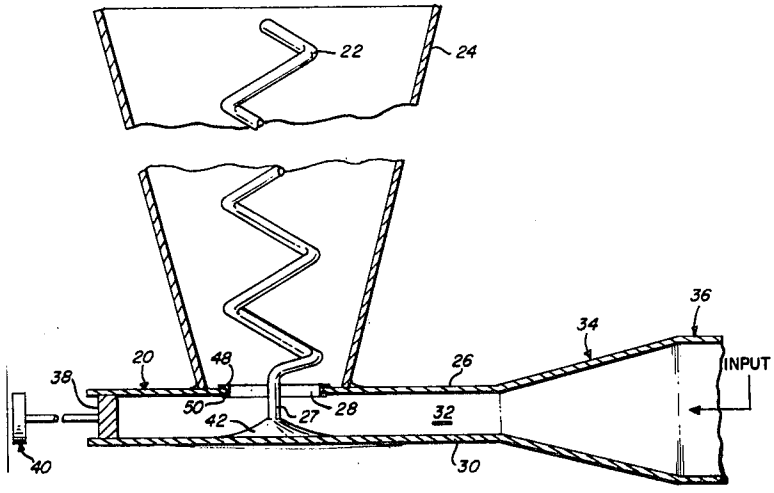
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Assistant Examiner—Marvin Nussbaum
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ABSTRACT: A helical antenna excited from a waveguide having sidewalls of reduced height to provide an improved impedance match between the waveguide and the helix, one end of the helix being attached to the waveguide whereby heat may be conducted therefrom during operation.



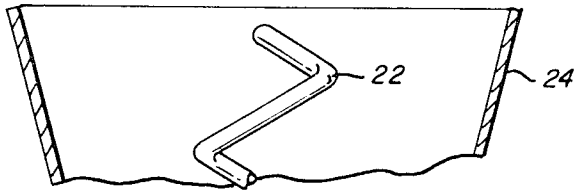


FIG. 1

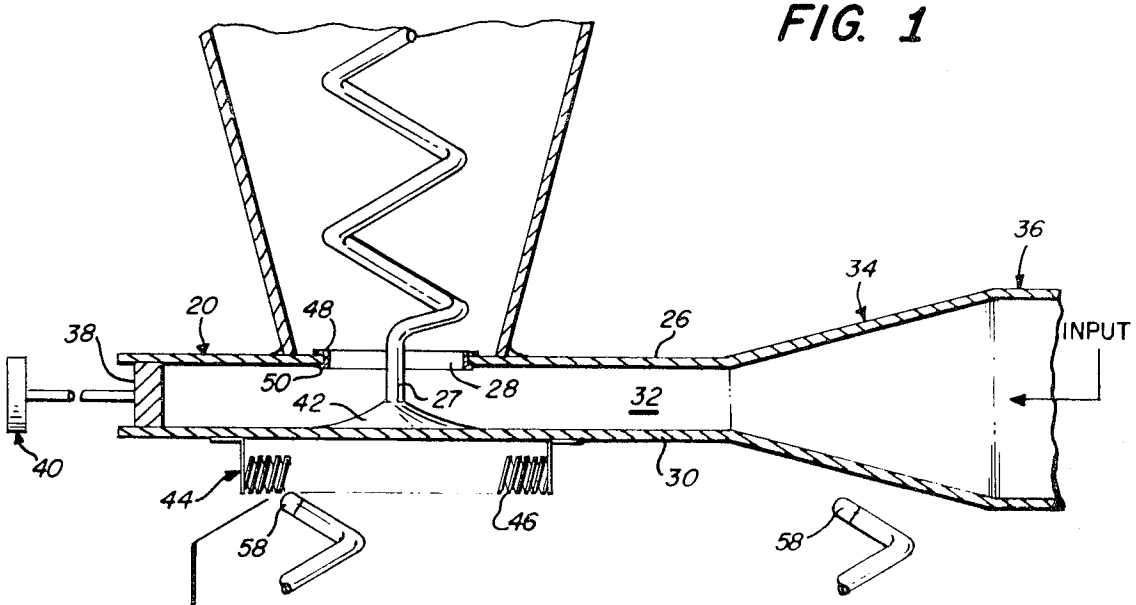
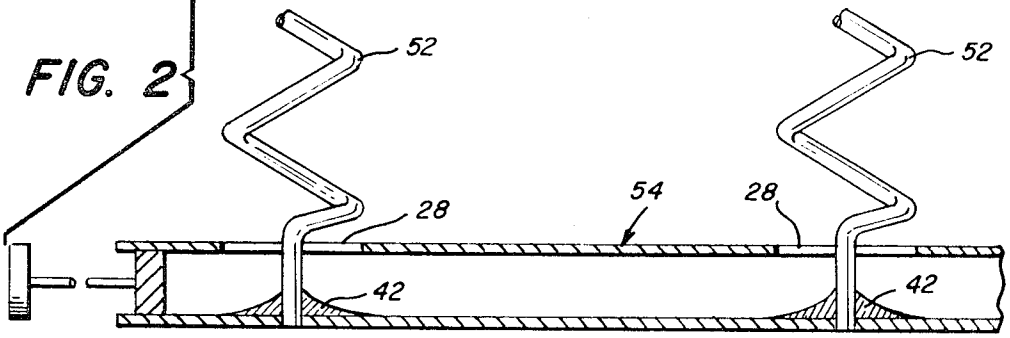


FIG. 2



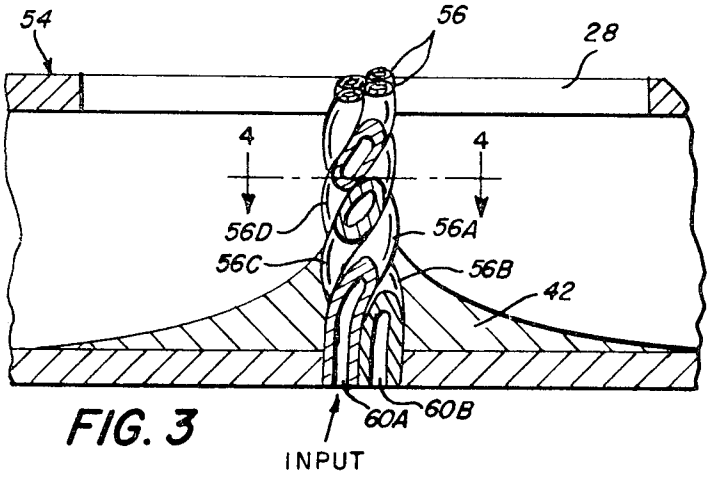


FIG. 3

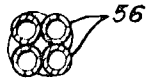


FIG. 4

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WAVEGUIDE-FED HELICAL ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to helical antennas, and more particularly, to a helical antenna coupled to a waveguide in a manner providing for increased continuous-wave power transmission from the helix with optimum matching between antenna components.

A helical antenna is frequently used as a source for electromagnetic radiation having circular polarization. Helical antennas are used both singly and in groups as in a helical antenna array. A helical antenna can provide a more directive beam pattern than a radiating element, such as a radiating slot aperture in a waveguide wall, and consequently, there is typically less mutual coupling between neighboring helical antenna elements in a helical antenna array than is present between neighboring slot radiators in an array of slot radiators. Accordingly, helical antenna arrays have more uniform radiation directivity patterns with reduced side (or grating) lobes.

In situations requiring high continuous-wave (hereinafter sometimes referred to as CW) power transmission in a broad region of space, antenna arrays are normally utilized with the number of radiating elements kept small, since large arrays tend to narrow the beam of radiation. However, in a high-powered array containing relatively few elements, each element itself must be capable of radiating large quantities of electromagnetic power. And furthermore, if circular polarization is desired, then only such elements as are capable of radiating circularly polarized radiation may be utilized.

A typical radiator for operation at high power levels is the horn radiator fed directly from a waveguide. Horn radiators have been utilized both singly and in an array to radiate energy at high power levels, but such radiation is inherently linearly polarized. To provide circular polarization from such a horn radiator, a dielectric or metallic vane is inserted into the horn. However, high-powered CW radiation may overheat and damage the dielectric vane, thereby restricting the use of such an antenna to lower power levels; and a metallic vane greatly reduces the bandwidth of such an antenna thereby restricting the use of such an antenna to relatively narrow bandwidth applications. Furthermore, horns occupy a substantially larger volume of space than do helical antennas, so that in certain applications such as with airborne equipment where relatively little space is available for antennas, the helical antenna is preferred.

Helical antennas provide circular polarization, are of relatively wide bandwidth, and have been excited directly from a waveguide as has been shown in the patent to Gammon, U.S. Pat. No. 2,863,148 which issued Dec. 2, 1958. Helical antenna elements are advantageously used in antenna arrays since the interelement spacing is not restricted by spacing restrictions such as are found, for example, with an array of slot radiators in a waveguide where a spacing of an integral number of one-half wavelengths is utilized. However, helical antennas of the prior art have been coupled to a source of electromagnetic wave therein, in a manner which provides only limited means for withdrawal of heat from the helix. As a result, CW radiation having a high power density may overheat such antenna causing it to malfunction.

Accordingly, it is a primary object of this invention to provide a means for coupling a helical radiating element to a waveguide-type structure in a fashion which provides for withdrawal of the heat produced within the helix due to the interaction of electromagnetic radiation with the helix.

Furthermore, it is an object of the invention to provide a means for coupling a helical radiating element to a waveguide-type structure such that the impedance of the waveguide-type structure matches the intrinsic impedance of the helix over a broad bandwidth so that a maximum portion of the power in the waveguide type structure can be coupled to the helical radiating element.

SUMMARY OF THE INVENTION

A waveguide-type structure coupling electromagnetic power to a helical antenna, the helical antenna having a helix with an end portion for insertion into the waveguide-type structure, the waveguide-type structure having a top wall and a bottom wall joined by sidewalls and having cross-sectional dimensions wherein the height of the sidewalls is substantially less than one-half the width of the top wall whereby the impedance of the waveguide-type structure is matched to the intrinsic impedance of the helix to couple into the helix a maximum portion of the electromagnetic power supplied by the waveguide-type structure at a predetermined carrier frequency, and a coupling means providing optimum conduction of heat from the helix, the coupling means comprising an aperture in the top wall, the end portion of the helix passing through the aperture, and a flared termination on the end portion in thermal and electrical contact with the bottom wall whereby a broadband impedance match is provided between the helix and the waveguide-type structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned objects and other features of the invention are explained in the following description taken in connection with the accompanying drawings wherein:

FIG. 1 is a side elevation view of the waveguide and helical antenna of the invention cut away to show the connection of the helical antenna to the waveguide;

FIG. 2 is a side elevation view of two fluid-cooled helical antennas forming an array, the waveguide supporting the helical antennas being cut away to show the connection of the helical antenna with the waveguide for admission of cooling fluid;

FIG. 3 is an enlarged view of the bottom section of a helical antenna of FIG. 2 partially cut away to show a construction of helix by means of tubes through which fluid can pass along the helical structure for withdrawal of heat; and

FIG. 4 is a sectional view of a fluid-cooled helical antenna taken along the lines 4—4 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown an embodiment of the invention in which a waveguide **20** feeds electromagnetic radiation to a helical antenna **22** positioned within a horn **24** which is rigidly affixed, as by brazing, to a top wall **26** of the waveguide **20**. An end portion **27** of the helical antenna **22** enters the waveguide **20** through an aperture **28**, preferably of circular shape, in the top wall **26** and is rigidly supported by a bottom wall **30** of the waveguide **20**. In order to couple, regardless of frequency within a broadband, substantially all of the electromagnetic power within the waveguide **20** to the helical antenna **22**, the impedance of the waveguide **20** is matched to the intrinsic impedance of the helical antenna **22** by constructing the waveguide **20** with sidewalls having reduced height, one such sidewall **32** being shown in FIG. 1, and supplying electromagnetic power to the waveguide **20** through a transition **34** connecting with a waveguide **36** of standard cross-sectional dimensions. A tuning plunger **38**, preferably of copper, may be slidably supported within an end of waveguide **20** thereby partially forming a tuned cavity, the tuning plunger **38** being positioned with the aid of handle **40** to tune the waveguide **20** to the helical antenna **22** at a predetermined carrier frequency of the electromagnetic energy. To further improve the coupling of electromagnetic power, the end portion **27** of the helical antenna **22** is terminated with a flare **42** of an electrically and thermally conductive material, such as an alloy of silver, the flare **42** having an exponential shape, as shown in FIG. 1, and being affixed to the bottom wall **30**, preferably by brazing. Electromagnetic power coupled to the helical antenna **22** interacts therewith resulting in a conversion of a portion of this power into heat which raises the temperature of the helical antenna **22**, the temperature increasing with increasing electromagnetic

power until a state of equilibrium is reached between the rate at which heat is produced within the helical antenna 22 and the rate at which heat is withdrawn therefrom. While some measure of heat withdrawal is effected by means of radiation and of cooling by air circulating about the horn 24, these means are inadequate to maintain a sufficiently low temperature to insure proper operation of the helical antenna 22 and reduce the chance of arcing in the presence of high electromagnetic power. In accordance with the invention, the temperature is maintained sufficiently low by means of the end portion 27 and flare 42, at the base of the helical antenna 22, through which heat is conducted to a heat sink 44 mounted externally to the bottom wall 30 and in thermal contact therewith, the heat sink 44 having fins 46 for cooling by air or other fluid. In order to provide a smooth edge to the aperture 28 and reduce the chance of arcing between the edge of the aperture 28 and the helical antenna 22 when an intense electric field is present, a bushing 48 of dielectric material such as Teflon or boron nitride is inserted into the aperture 28, the resilient lip 50 of bushing 48 permitting a press fit.

As an example in the construction of an embodiment of the invention designed to operate with electromagnetic radiation having a carrier frequency in the range of 2.5 GHz–3.5 GHz, the waveguide 36 has inside dimensions of width 2.84 inches by height 1.34 inches, while for the reduced-height waveguide 20, the top wall 26 has width 2.84 inches and the height of the sidewalls 32 is reduced to one-third that of the standard dimension of waveguide 36 so that sidewall 32 has a height of 0.45 inches. The helical antenna 22 has a height of approximately six inches above the bottom wall 30 and is formed of five turns of wire having a diameter of one-eighth inch, there being one inch between turns. The circular aperture 28 is one inch in diameter, and the bushing 48 has a thickness of 0.040 inches. The side of horn 24 extends outwardly making an angle of approximately 25° with the axis of the horn. The flare 42 has an outer diameter of 1.125 inches and a height of approximately 0.2 inches. The impedance of both the waveguide 20 and the helical antenna 22 is approximately 135 ohms. The dialectric between the horn 24 and the helical antenna 22 is simply atmospheric air which provides a relatively small amount of cooling by convection, the major portion of the cooling being done with the heat sink 44. Thus, even at altitudes of 50,000 feet where cooling by atmospheric air is substantially reduced from that at sea level, the helical antenna 22 can transmit 2500 watts of continuous-wave, or average, power.

Referring now to FIG. 2, there is an array of radiating elements, each radiating element being a helical antenna 52 which is adapted for fluid cooling, two such antennas being shown in the figure. The helical antennas 52 are supported by and coupled to a waveguide 54 having reduced sidewall height whereby the impedance of the waveguide 54 is matched to each helical antenna 52.

The fluid cooling is explained in detail with the aid of FIGS. 3 and 4 showing enlarged views of the base of the helical antenna 52. The helical antenna 52 is composed of four tubes 56 which are designated 56A–D, being preferably of copper, and having an outside diameter of approximately 0.05 inch. The four tubes 56 are twisted about each other to form a flexible cable which is bent into the shape of a helix. The top of each helical antenna 52 is terminated with a metallic cap 58, as shown in FIG. 2, which has an interior void through which fluid flows, so that for example, fluid which enters tube 56A at opening 60A passes upwards along tube 56A, through cap 58 and into tube 56B, thence downwards through tube 56B to exit at opening 60B. Accordingly, cooling of the helical antenna 52 is effected by forcing a fluid such as cold water or oil into tubes 56A and 56C and withdrawing the heated fluid from tubes 56B and 56D.

It is understood that the above-described embodiments of the invention are illustrative only and that modifications thereof will occur to those skilled in the art. Accordingly, it is desired that this invention is not to be limited to the embodiments disclosed herein but is to be limited only as defined by the appended claims.

What is claimed is:

1. In combination:
   a. antenna means comprising an elongated electrically conductive element;
   b. waveguide means coupling electromagnetic radiation into the antenna means; and
   c. cooling means connecting with the antenna means and passing through the waveguide, the cooling means comprising fluid circulation means within the antenna means whereby heat generated within the antenna means by interaction with electromagnetic power is withdrawn from the antenna means, the antenna means being a helical antenna and the waveguide means having sidewalls which have dimensions providing an impedance to the waveguide means which matches the intrinsic impedance of the helical antenna.

2. A coupling electromagnetic power from a waveguide-type structure to a helical antenna, the device comprising:
   a. waveguide means having a wall and an aperture spaced from the wall, the aperture adapted to receive an end portion of the helical antenna so that the wall makes contact with the end portion, the waveguide means being positioned to couple electromagnetic power to the helical antenna;
   b. flared coupling means situated on the wall and contacting the end portion; and
   c. heat sink means in thermal contact with the wall for withdrawing heat from the helical antenna through the end portion and the flared coupling means.

3. The device of claim 2 in which the waveguide means includes a transition means terminating in a section of waveguide having dimensions such that the spacing between the aperture and the wall is substantially less than one-half the width of the wall whereby the impedance at the terminus of the transition is substantially equal to the intrinsic impedance of the helical antenna.

4. An antenna array including:
   a. a plurality of radiating elements, each radiating element being a helical antenna element;
   b. a waveguide coupling electromagnetic power to each radiating element; and
   c. cooling means connecting with each radiating element and passing through the waveguide, the cooling means including fluid circulation means within each radiating element whereby heat generated within the radiating elements by interaction with the electromagnetic power is withdrawn from the radiating elements.

5. An antenna feed system comprising:
   a. a waveguide having a top wall, and a bottom wall which are joined by sidewalls, there being an aperture in the top wall; and
   b. a radiating element connecting with the bottom wall interior to the waveguide and extending upwards through the aperture to a region exterior of the waveguide whereby electromagnetic radiation is coupled from the waveguide to the radiating element, the radiating element having enclosed passages for circulation of cooling fluid, the passages extending through the bottom wall whereby cooling fluid is introduced and withdrawn from the radiating element.

6. The apparatus of claim 5 in which the radiating element is a helical antenna, and the sidewalls are of reduced height whereby the impedance of the waveguide is substantially matched to the impedance of the helical antenna.

7. An antenna array including:
   a. a plurality of radiating elements;
   b. a waveguide coupling electromagnetic power to each radiating element, the waveguide having apertures through which each of the radiating elements extends and connects with an interior surface of a wall of the waveguide; and

c. cooling means connecting with each radiating element and passing through the waveguide whereby heat generated within the radiating elements by interaction with the electromagnetic power is withdrawn from the radiating elements.

8. In combination:

a. antenna means comprising a helical radiating element;

b. waveguide means coupling electromagnetic radiation into the antenna means, the helical radiating element extending through an aperture in the waveguide means and connecting with an interior surface of a wall of the waveguide means; and

c. coupling means situated on the wall and being in thermal contact with an end portion of the helical radiating element for withdrawing heat generated within the antenna means by interaction with electromagnetic power, the coupling means having a flared outer surface for coupling electromagnetic radiation between the waveguide means and the helical radiating element.

9. An antenna array including:

a. a plurality of helical radiating elements;

b. a waveguide coupling electromagnetic power to each helical radiating element, the waveguide having apertures through which each of the radiating elements extends and connects with an interior surface of a wall of the waveguide; and

c. coupling means situated on the wall and being in thermal contact with end portions of the helical radiating elements for withdrawing heat generated within the helical radiating elements by interaction with the electromagnetic power, the coupling means having flared outer surfaces for coupling electromagnetic radiation between the waveguide means and the helical radiating elements.

10. In combination:

a. waveguide means having a top wall and a bottom wall which are joined by sidewalls, there being an aperture in the top wall;

b. a helical radiating element having an end portion thereof, the helical radiating element being positioned external to the waveguide means such that the end portion of the helical radiating element passes through the aperture toward the bottom wall;

c. coupling means situated on the bottom wall and being in thermal contact with the end portion of the helical radiating element for withdrawing heat generated within the helical radiating element by interaction with electromagnetic power, the coupling means having a flared outer surface for coupling electromagnetic radiation between the waveguide means and the helical radiating element;

d. transition means coupling electromagnetic energy from a source of input energy to the waveguide means, said transition means including waveguide walls which are tapered to form a waveguide of reduced height from a waveguide of standard cross-sectional dimensions, said tapered walls cooperating with said flared outer surface of said coupling means to provide an impedance match between a waveguide of standard cross-sectional dimensions and said helical radiating element; and

e. a horn affixed to the top wall and enclosing the helical radiating element for directing electromagnetic energy for radiation therefrom.

11. The device of claim 10 further comprising tuning means for tuning the waveguide means to the helical radiating element at a predetermined carrier frequency of the electromagnetic energy.

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