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H-GUIDE MICROWAVE ANTENNA

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2 Sheets-Sheet 1

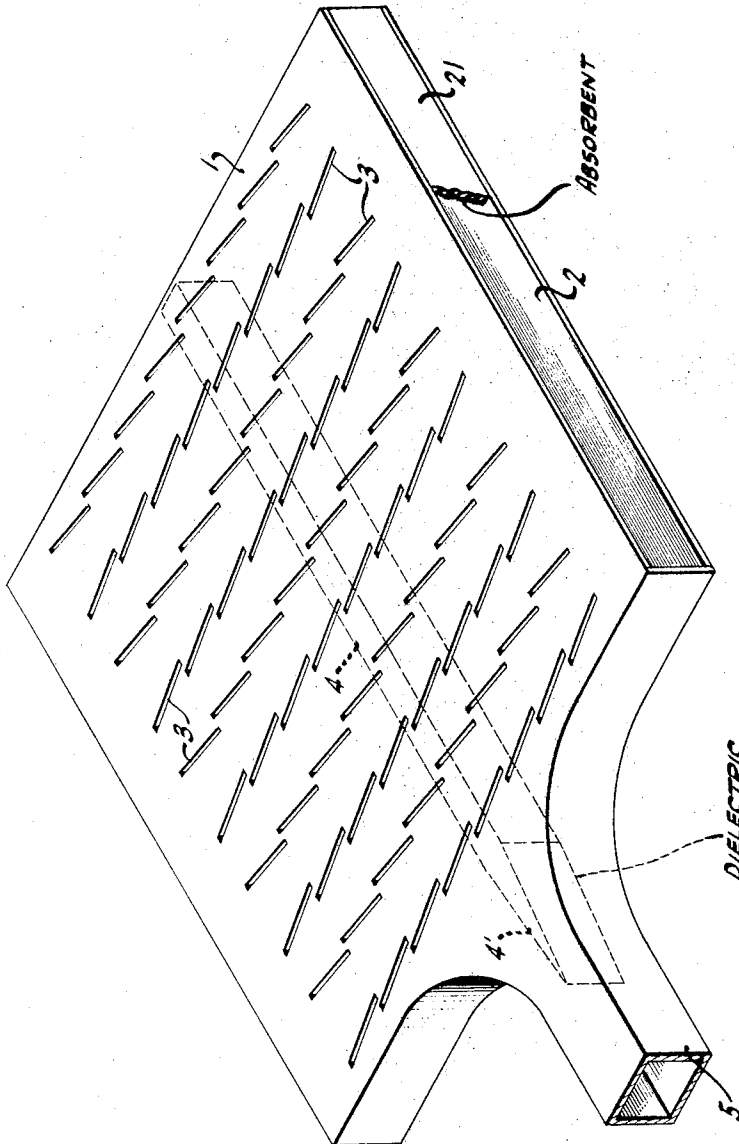


FIG-1

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FIG-2

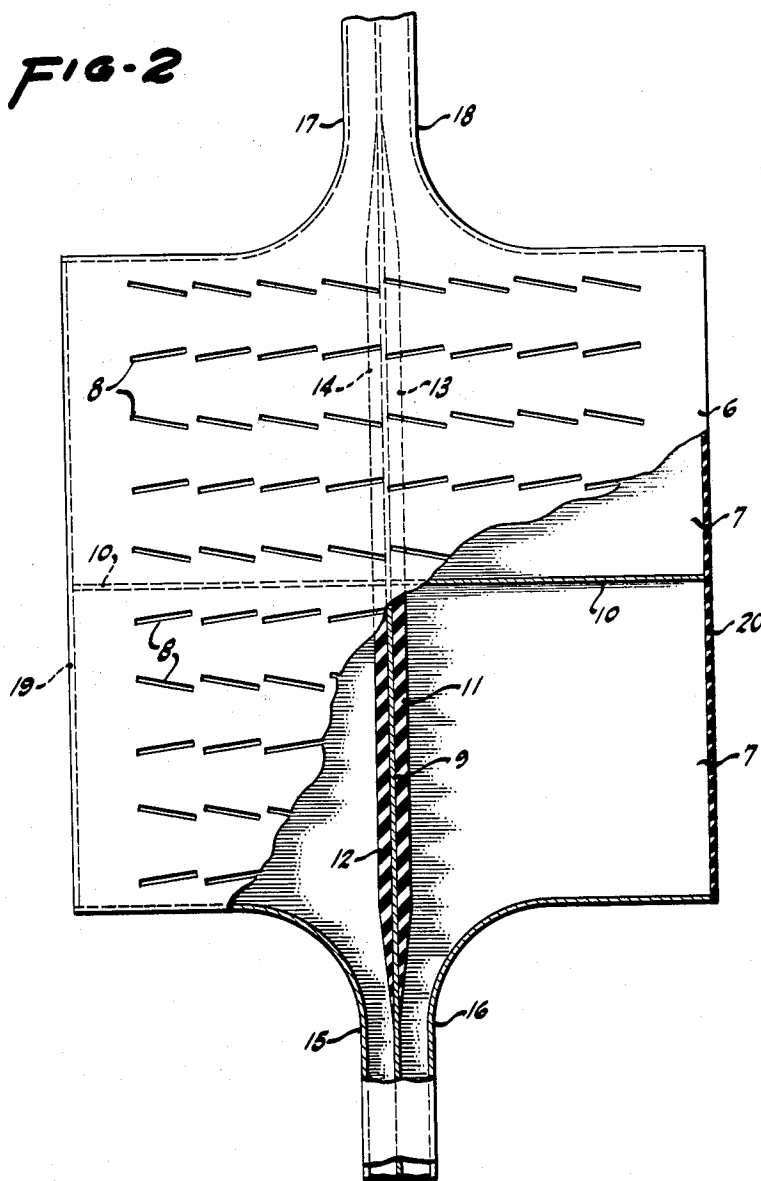
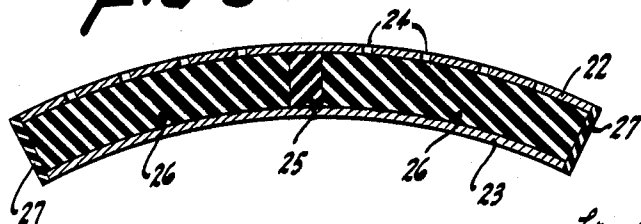


FIG-3



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H-GUIDE MICROWAVE ANTENNA

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6 Claims. (Cl. 343—771)

This invention relates to an improved microwave antenna of exceptional versatility and simplicity of structural design. The improved antenna is especially adapted for airborne applications, being of light weight and suitable for flush mounting. The antenna can be designed for a highly directional radiation pattern, as a broadside pencil-beam antenna, as a squinted pencil-beam antenna, as a conical-scan antenna, or as a monopulse antenna, as desired.

A known type of waveguide has two conductive plates that define the two larger, opposite sides of a space through which microwaves are transmitted, and a strip of solid dielectric between the two plates. This strip of dielectric is narrower than the two plates, and preferably bisects the space between the two plates lengthwise, so that a cross-section of the two conductive plates and aforesaid strip of dielectric somewhat resembles the letter H—hence, this type of waveguide is commonly referred to as an H-guide. The remaining space between the two conductive plates is filled with any dielectric—fluid, solid, or vacuum—of lower dielectric constant than the aforesaid strip. Although it is commonly of a generally flat shape, the H-guide can be curved in cross-section—for example, the two plates can be segments of two coaxial cylinders.

The H-guide propagates microwaves in the lengthwise direction of its strip of highest dielectric constant, and the electric and magnetic field intensities decrease rapidly with increasing distance away from the strip. Thus, the electromagnetic energy is concentrated in and near the central strip of dielectric, and losses at the edges of the guide are small—these losses can be made as small as may be desired by extending the width of the conductive plates. Various modes can be propagated, as is described, for example, in my article "Hybrid H-Guide Feeds Flush-Mounted Antennas," in *Electronics*, March 31, 1961, pages 54 through 57, and the references listed therein at page 57. All modes that can be propagated in an H-guide are referred to generically as H-guide modes. It is postulated that any H-guide mode may be employed in the operation of antennas according to the present invention; however, the HEM_{11a} mode (antisymmetric hybrid electromagnetic mode of the first order and the first rank) described by Moore and Beam in "A Duo-Dielectric Parallel Plane Waveguide," *Proceedings NEC*, volume 12, April 1957, page 689, has been found to be particularly advantageous.

The width of the central strip of higher dielectric constant in relation to the overall width of the H-guide can vary considerably, depending upon the mode desired, the field strength and consequent amount of loss that can be tolerated at the edges of the H-guide, and the like. This invention is limited to structures in which the central strip of dielectric occupies no more than half the width of the whole space between the two conductive plates.

In brief, the antenna of the present invention is an H-guide modified by providing an array of radiating slots in one of the two conductive plates of the waveguide. The antenna consists essentially of two electrically conductive plates disposed in spaced relation to each other, defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, and a narrower slab of solid dielectric extending between the two

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plates, preferably bisecting the space between the plates lengthwise. One of the two metal plates is provided with two-dimensional array of radiating slots, dimensioned and spaced to transmit a microwave beam in the desired radiation pattern. The radiation pattern obtained depends upon the arrangement of the array of slots and the field pattern of the H-guide mode employed. In practice, the array of slots is designed to achieve a desired radiation pattern, applying known principles of slot array design to the field pattern of the selected mode. By means of longitudinal and transverse metal septa dividing the space between the two metal plates into four quarters, and with proper choice of design parameters (mainly the conductances of the radiating slots), the two-dimensional array of slots can be divided into four independent apertures that can be fed with microwave energy in various phase relations through four separate waveguide inputs to the four quarters of the antenna. Thus, the radiation pattern can be varied electrically by varying the phase relations among the input microwaves. Patterns can also be changed by switching from one H-guide mode to another, e.g., by changing frequency.

The invention may be understood better from the following illustrative description and the accompanying drawings.

FIG. 1 of the drawings is a somewhat schematic, perspective view, broken away in part, showing one embodiment of the invention.

FIG. 2 is a somewhat schematic, partially broken away, plan view of a second embodiment.

FIG. 3 is a somewhat schematic cross-section of a third embodiment.

Referring to FIG. 1, two flat metal plates 1 and 2 are parallel to each other and are separated by a flat space. A flat slab 4 of solid dielectric extends laterally between and normal to the plates 1 and 2, and extends lengthwise from one end to the other of the space between plates 1 and 2, preferably bisecting this space, as shown. The remaining space between plates 1 and 2 is filled with another dielectric of lower dielectric constant, e.g., air. Thus, plates 1 and 2 and slab 4 form an H-guide capable of transmitting microwaves in an H-guide mode. The mode desired at a particular frequency is selected when the antenna is designed, and is achieved by appropriate choice of the dielectrics employed, the spacing between plates 1 and 2, the width of slab 4, the taper of the input horn hereinafter described, and, if necessary, other expedients known to those skilled in the art, e.g., mode filtering. A choice of parameters that will produce one mode at a selected frequency may produce another mode at another frequency, and this may be taken advantage of to provide different radiation patterns for the antenna at different frequencies.

Plate 1 contains a plurality of slots 3, which extend through plate 1, so that each slot can be supplied with electromagnetic wave energy from the space between the two plates and can radiate this energy into space. The slots 3 are arranged in a two-dimensional array for forming a radiation pattern or beam of the desired directional properties. The design of slot sizes and arrangement of configurations to obtain various radiation patterns is well known to those skilled in the art, and requires no further description, except to point out that the field pattern of the selected H-guide mode must be taken into consideration. Design equations for the polarity useful HEM_{11a} mode, a description of antennas designed from these equations, and a comparison of calculated and measured radiation patterns will be found in my article "Hybrid H-Guide Feeds Flush-Mounted Antennas," referred to hereinbefore.

Electromagnetic wave energy is fed into the space between plates 1 and 2 at one end of the dielectric slab 4, whereby the electromagnetic wave energy is transmitted

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lengthwise of the dielectric slab 4 and extends laterally outward therefrom, the electric and magnetic fields diminishing exponentially with increasing distance from slab 4. A preferred feed-in for the electromagnetic wave energy comprises a waveguide 5, which flares outward into a semi-flared horn opening into the space between the plates 1 and 2, as shown. The wider dimension of waveguide 5 may be either horizontal or vertical; the choice will determine the polarization of the input microwaves, and this in turn will have an influence upon which mode is established in the H-guide. The dielectric slab 4 is provided with a tapered portion 4' extending into the horn for better impedance matching.

A strip of microwave absorbing material 21 is placed over each of the otherwise open, small sides of the space between plates 1 and 2. This material absorbs any microwaves that reach the edges of the H-guide. Generally, the fields are quite weak at this distance from strip 4, and hence losses to the absorbing material are small. Losses can be reduced at the expense of increased antenna size, by extending the width of plates 1 and 2. The chief function of the absorbing strips is to prevent the leakage of microwaves out of the edges of the H-guide, which might otherwise be sufficient to distort the radiation pattern of the antenna. The far end of the H-guide, opposite the feed horn, can be shorted by closing it with a conductive metal strip, or terminated with an absorbing element. In the first case, the antenna will be resonant, and in the second case, nonresonant.

The embodiment illustrated in FIG. 2 comprises two parallel metal plates 6 and 7, which correspond to and are generally similar to the plates 1 and 2 of the first embodiment herein described. Plate 6 is provided with a two-dimensional radiating array of slots 8 corresponding to the slots 3 of FIG. 1. The space between plates 6 and 7 is divided lengthwise into two halves by a metal septum 9, which extends between and electrically connects together the plates 6 and 7. A second metal septum 10 further divides the space between plates 6 and 7 into four electrically separated quarters, which can be fed separately with waves in various phase relations, as hereinafter explained. The dielectric slab that extends lengthwise of the plates 6 and 7 is divided into four parts 11, 12, 13, and 14 by the two metal septa. The metal septum 10 bisects the antenna transversely and acts as a short termination for one half of the embodiment. The metal septum 9 further subdivides the embodiment into four quarters without introducing a disturbance or a modification in the preselected H-guide mode. The metal septa and proper design of the slot conductances in the array of slots 8, according to the principles hereinbefore discussed, permit the four quarters of the antenna shown in FIG. 2 to be separately fed; and the radiation pattern and beam direction can be varied electrically by varying the phase relations of the input waves.

In order to feed the four quarters of the antenna separately, four input waveguides 15, 16, 17, and 18 are provided, as shown. Each input waveguide preferably terminates in a semi-flared horn opening into a different quarter of the antenna from the other horns. It will be noted that each horn supplies electromagnetic energy adjacent to an end of a solid dielectric slab that extends lengthwise through the space between the plates 6 and 7, and is approximately in longitudinal alignment with the slab.

Absorbing strips 19 and 20 are placed over the otherwise open sides of the H-guide, to prevent the leakage of microwaves therefrom.

FIG. 3 shows an embodiment having a curved cross-section. In this example, the two conductive plates 22 and 23 are segments of two coaxial cylinders. The outer plate 22 is provided with an array of radiating slots 24. Dielectric slab 25 extends lengthwise through and bisects the space between plates 22 and 23. The remaining space between the two plates is filled with another dielectric

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26 of lower dielectric constant than slab 25. Absorbing strips 27 cover the two sides of the H-guide.

The invention is not limited to the specific examples herein illustrated and described, and various changes may be made within the scope of the inventive principles disclosed.

What is claimed is:

1. A microwave antenna comprising two electrically conductive plates disposed in spaced relation to each other and defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, one of said plates having a two-dimensional array of radiating slots therein, a slab of solid dielectric extending laterally between and normal to said plates and extending lengthwise from one end to the other of the space between the plates, said slab having a width parallel to the plates that is less than one-half of the plate widths, and means for supplying electromagnetic wave energy into the space between the plates at one end of said slab.

2. A microwave antenna consisting essentially of two metal plates disposed in spaced relation to each other and defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, one of said plates having a two-dimensional array of radiating slots therein, a slab of solid dielectric extending laterally between and normal to said plates and extending lengthwise from one end to the other of and approximately bisecting the space between the plates, said slab taking up a minor portion of said space for propagation, and an input horn opening into the space between said plates for supplying electromagnetic wave energy thereto, the longitudinal axis of said horn being aligned with the longitudinal axis of said slab.

3. A microwave antenna comprising two electrically conductive plates disposed in spaced relation to each other and defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, one of said plates having a two-dimensional array of radiating slots therein, an electrically conductive septum extending laterally between and normal to said plates and extending lengthwise from one end to the other of the space between the plates, two slabs of solid dielectric extending parallel and adjacent to said septum on opposite sides thereof, said slabs taking up a minor portion of said space for propagation, a first input horn opening into the space between said plates on one side of said septum for supplying electromagnetic wave energy thereto, a second input horn opening into the space between said plates on the other side of said septum for supplying electromagnetic wave energy thereto, each of said horns being substantially in longitudinal alignment with a different one of said slabs.

4. A microwave antenna comprising two electrically conductive plates disposed in spaced relation to each other and defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, one of said plates having a two-dimensional array of radiating slots therein, an electrically conductive septum extending laterally between and normal to said plates and extending lengthwise from one end to the other of and approximately bisecting the space between the plates, two slabs of solid dielectric extending laterally between and normal to said plates and extending lengthwise perpendicular to opposite sides of said septum, said slabs taking up a minor portion of said space for propagation, a first input horn opening into the space between said plates on one side of said septum for supplying electromagnetic wave energy thereto, a second input horn opening into the space between said plates on the other side of said septum for supplying electromagnetic wave energy thereto, each of said horns being substantially in longitudinal alignment with a different one of said slabs.

5. A microwave antenna consisting essentially of two metal plates disposed in spaced relation to each other and defining therebetween a space for the propagation of electromagnetic waves in an H-guide mode, one of said plates

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having a two-dimensional array of radiating slots therein, a metal first septum extending laterally between and normal to said plates and extending lengthwise from one end to the other of the space between the plates, a metal second septum crossing said first septum perpendicular thereto, said second septum extending laterally between and normal to said plates and extending lengthwise from one side to the other of the space between the plates, the two septa dividing the space between the two plates into four approximately equal quarters, four slabs of solid dielectric extending parallel and adjacent to said first septum, two of said slabs being on one side and two on the other side of said first septum, two of said slabs extending perpendicular to one side and two extending perpendicular to the other side of said second septum, said slabs taking up a minor portion of said space for propagation, and four input horns, each of said horns opening into a different one of the four quarters into which the space between said two plates is divided by the two septa, each of said horns being substantially in longitudinal alignment with a different one of said slabs.

6. A microwave antenna comprising two curved, electrically conductive plates disposed in spaced relation to each other and defining therebetween a curved space for the propagation of electromagnetic waves in an H-guide mode, one of said plates having a two-dimensional array of radiating slots therein, a slab of solid dielectric ex-

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tending laterally between and normal to said plates and extending lengthwise from one end to the other of the space between the plates, said slab occupying no more than half of the whole width of said space, a solid electric of lower dielectric constant than said slab filling the remainder of said space, and means for supplying electromagnetic wave energy into the space between the plates at one end of said slab.

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