Oct. 18, 1960 W. ROTMAN 2,957,173

VARIABLE CONDUCTANCE TROUGH WAVEGUIDE ANTENNAS

Filed March 20, 1957 2 Sheets-Sheet 1

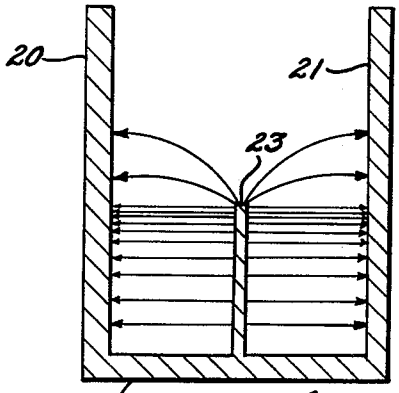


Fig. 1

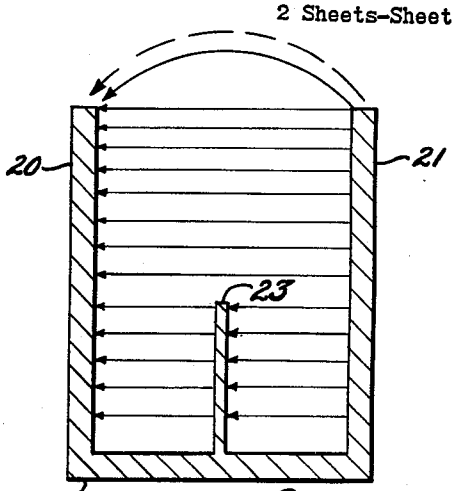


Fig. 2

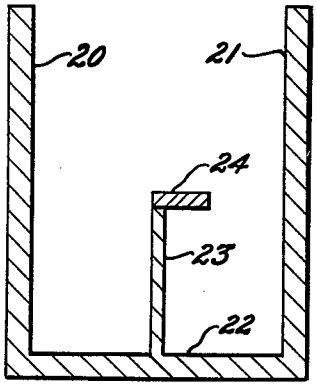


Fig. 3

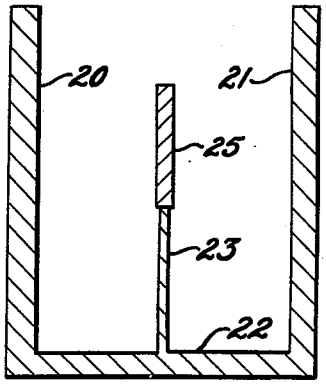


Fig. 4

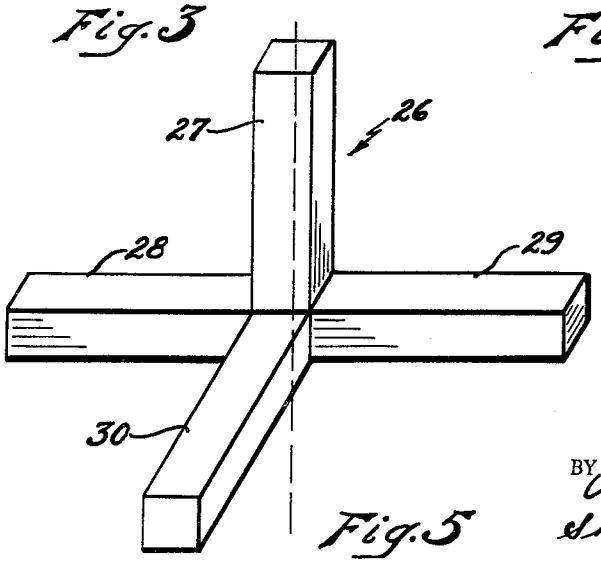


Fig. 5

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Oct. 18, 1960 W. ROTMAN 2,957,173

VARIABLE CONDUCTANCE TROUGH WAVEGUIDE ANTENNAS

Filed March 20, 1957 2 Sheets-Sheet 2

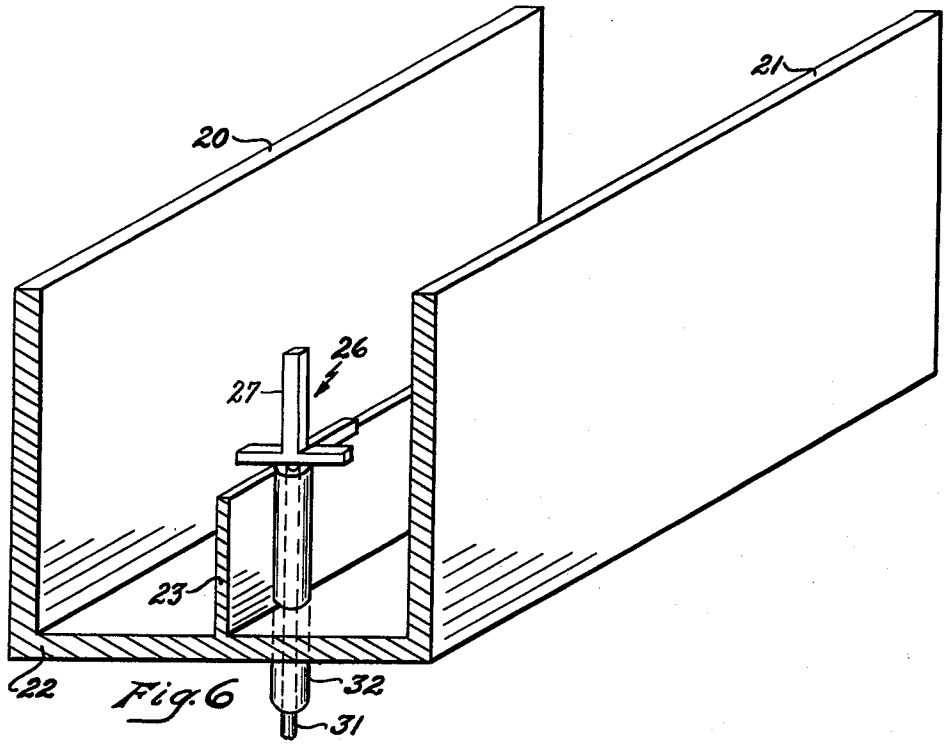


Fig. 6

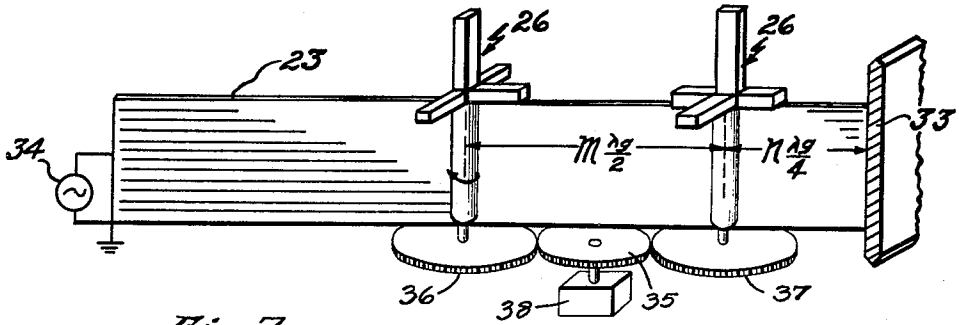


Fig. 7

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VARIABLE CONDUCTANCE TROUGH WAVEGUIDE ANTENNAS

Walter Rotman, Brighton, Mass.

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4 Claims. (Cl. 343—772)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates generally to antennas and more particularly to apparatus for the transmission of high-frequency electrical energy. The invention is characterized by the utilization of a special waveguide structure as a means for radiating energy to the surrounding space and involves the use of elements within the waveguide structure for controlling the conductance and radiation intensity or attenuation rate in the waveguide. Control of these parameters enables the obtaining of various desired controlled radiation characteristics which include a lobing pattern.

A trough waveguide of either rectangular channel shape, U-shape, V-shape or variations thereof having a symmetrically disposed fin therein comprises the transmission line which is modified to produce the controlled radiation. The basic concept on which this invention relies is that anti-symmetrical obstacles in a trough waveguide couple energy from the "bound" symmetrical trough guide mode, a transverse electric (TE) mode, into energy in a transverse electromagnetic (TEM) field which radiates into free space from the open side of the waveguide. Symmetrical obstacles, on the other hand, react as tuning elements. In accordance with above principles, a variety of radiating devices may be constructed.

The trough waveguides, together with their radiating elements, have utility alone or as primary line source arrays for use with secondary reflectors, horns, or lenses in radar and communication antenna systems. In this respect, they are superior to slots or dipole equivalent arrays on rectangular or circular waveguides.

Because of the superior electrical and mechanical properties of the antennas of this invention, many new advantages are realized.

It is contemplated that the subject invention will open new vistas in the fields of radio astronomy, radar, and communications.

It is an object of this invention to produce an antenna comprising a trough waveguide with means for controlling radiation therefrom.

It is another object of the invention to produce an antenna composed of discreet resonant radiating elements.

Still another object of the invention involves the production of novel radiating, non-susceptive elements whose conductances are variable.

It is a further object of the invention to produce an antenna which is easily and economically produced by conventional, commercial manufacturing techniques.

It is a still further object of this invention to produce a novel antenna for broadband radiation.

Another object of the invention is to produce a novel resonant radiating element for use in a trough waveguide.

Still another object of the invention involves the production of a novel traveling wave antenna array of resonant radiating elements.

A further object of the invention involves the production of a novel antenna suitable for producing a sequential lobing radiation pattern.

A still further object of the invention involves the production of an antenna array where a phase reversal is achieved between successive radiating elements.

These and other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the illustrative embodiments in the accompanying drawings, wherein:

Figure 1 is a cross-sectional view of a trough waveguide with a representation of the electric field of the transverse electric (TE) mode therein;

Figure 2 is a cross-section of a trough waveguide with a representation of the electric components of the transverse electromagnetic (TEM) field;

Figure 3 is a cross-section of a trough waveguide with a TE mode to TEM field coupler;

Figure 4 is a cross-sectional view of a trough waveguide with a tuning element for the TE mode;

Figure 5 is a pictorial view of the tri-rod coupling element;

Figure 6 is a pictorial view of a rotatable tri-rod coupler in a trough waveguide; and

Figure 7 is a schematic representation of a part of a trough waveguide with variable coupling elements for lobe switching.

The invention utilizes a symmetrical non-radiating trough waveguide which acts as a transmission line. This type of waveguide in its mechanical construction is left open on one side; however, it still acts as a transmission line. Its characteristics, frequency-wise follow those of a waveguide while it retains simplicity of a strip transmission line. The general configuration of the waveguide has two side walls and a bottom, thus forming a trough, and a substantially centrally disposed fin member of less height than the side walls. The embodiment of Figure 1 is a channel or rectangular form of trough waveguide but various alternative forms can be achieved by deformation of the side walls, for example, the trough may be of U or V shape as long as symmetry about the central fin is maintained in order to avoid spurious modes.

Like numerals will designate like parts of the waveguide throughout the specification.

Figure 1, for illustration purposes, shows a rectangular trough waveguide having side walls **20** and **21**, a bottom wall **22** and a substantially centrally disposed fin member **23**. When the side walls **20** and **21** are less than one-half wavelength apart, a TE (transverse electric) mode may be propagated along the axis of the guide. This mode is "bound" to the center fin and has an electric field with a general configuration as shown in Figure 1. The intensity of the field lines of the electric vector increases from the bottom **22** of the waveguide to the top of the central vane or fin **23**. The transverse currents on the sides of fin **23** vary from a minimum at the free edge to a maximum at its base.

The electric components of the TEM (transverse electromagnetic) field is depicted in Figure 2 and can be propagated wherever side walls exist as is shown by the dashed lines at the open end of the trough, radiation into space is achieved whenever the field strikes the open top or "aperture" of the guide. The creation of an asymmetry causes energy from the TE field to be converted into a TEM field which is not bound to the center fin. The TEM field is capable of being propagated in all directions at right angles to the TE vectors which allows a release of energy from the open side of the waveguide.

Although the trough waveguide is shown as a unitary structure of highly conductive material, each of portions designated as **20, 21, 22** and **23** could be made of separate

ieces of stock of any material secured together by conentional means as long as the interior of the trough is ılated or otherwise lined with a highly conductive maerial.

The characteristics of a trough waveguide are such hat the cut-off wavelength depends upon the electrical ieight of the center fin 23, e.g., the cut-off wavelength s approximately that at which the center fin is a quaer wavelength. The side wall (20, 21) height above he center fin 23 and the spacing between side walls act o prevent unwanted, uncontrolled radiation. Less than ıalf wavelength spacing between the side walls allows or operation of the line over a range of frequencies. The spacing of the side walls, at any rate, should not :xceed a half wavelength of the highest frequency in he range. The TE mode is critically dependent upon he dimensions of the center fin while the TEM or radiatng mode is independent of the fin 23.

Figure 3 represents a basic principle or concept upon vhich this invention is based. An anti-symmetrical obstacle, such as a horizontal rod 24, has the ability in a rough waveguide to convert some of the energy from he "bound" TE mode into the TEM field which is then radiated into free space. Utilization of this principle ıllows for the production of controlled radiation along he length of the waveguide. The rod 24, perpendicular o center fin 23, creates an asymmetry such that when rod 24 is excited, it reradiates the incident energy in both the TEM field and the TE mode thereby causing a portion of the incident energy from the TE mode to be converted into the TEM field while another portion is reflected back in the TE mode towards the source. The shunt admittance of the rod as measured in the trough guide appears to have two components: a reactive susceptance determined by the amount of reflected energy and a conductance governed by the amount of energy coupled between the TE mode and the TEM field and subsequently radiated. The rod 24 will appear as a resonant element if the capacitive susceptance is cancelled by an additional reflection, equal in magnitude but opposite in phase. Changing the length of the rod increases both the susceptive and conductive component.

Symmetrical obstacles do not couple the TE mode and TEM field; therefore, they may be used as tuning elements. The vertical post 25 placed above fin 23 (Figure 4) is greater than a quarter wavelength and by virtue of its symmetry does not couple energy, but causes a reflection which appears as an inductive shunt susceptance.

The tri-rod coupler 26 (Figure 5) may be applied to a waveguide as illustrated in Figure 6. The coupling of tri-rod 26 may be varied continuously from zero to some maximum value while its susceptance remains substantially zero. Rotation of the coupler allows for the production of various desired radiation amplitudes and for modification of the radiation pattern.

Coupler 26 comprises an inductive tuning post 27, symmetrical capacitive tuning rods 28 and 29, and an asymmetrical coupling rod 30. By combining elements 24 and 25 of Figures 3 and 4 the structure of Figure 5 results without elements 28 and 29. Rotation of the two element structures comprising elements 27 and 30 mounted on the fin 23 of a waveguide will be considered. Capacitive asymmetric rod 30, when at a position at right angles to the fin 23, may be resonated by adjusting the length of vertical post 27. When element 30 lies on top of and in line with the fin 23, a lack of asymmetry occurs and the conductance drops to zero with only a residual susceptance, due to the vertical post 27 remaining.

Identical elements 28 and 29, at right angles to the inductive post 27 and on either side thereof, compensate for the residual susceptance, effectively reducing it to substantially zero.

As shown in Figure 6, the tri-rod coupler 26 is mounted

on a shaft 31 housed by a tubular portion 32 forming a part of the center fin 23 in the trough waveguide. By passing the shaft 31 through center fin 23, the rotation of the shaft does not disturb the field within the guide. Rotation of shaft 31 produces a rotation of coupler 26, which, because of its symmetry, remains approximately in resonance in all of its orientations and the conductance varies smoothly and cyclically from zero to a maximum value.

By placing a number of tri-rod couplers 26, properly oriented, along the fin, the variations in phase and conductance produced by the different orientations of the coupler may be utilized to produce various radiation characteristics. For example, a broadside radiating antenna may be constructed by utilizing the 180° phase reversal obtained by having rod 30 project on opposite sides of fin 23 at half wavelength intervals.

A holding means may be provided for the shaft 32 (e.g., a set screw in the projecting portion of tubular portion 32 below wall 22) where movement of the coupler will not be affected at too frequent intervals. For relatively long periods of fixed positions of the coupler, post 27 of the tri-rod coupler could house a screw means therein which would engage fin 23 thus securing the coupler to the fin without the need of a shaft or housing.

By utilizing the rotating means displayed in Figure 6, the tri-rod coupler may be used for several different types of sequential lobing antenna systems.

Referring to the schematic representation of Figure 7 which shows only the center fin of a trough waveguide, couplers 26 are placed an integral number m of half wavelengths apart with a shorting termination 33 placed an odd number n of quarter wavelengths on the fin 23 beyond the second coupler. A signal source 34 feeds the waveguide. The shafts of the two couplers are geared together as shown by gears 35, 36 and 37 and oriented so that one coupler is mechanically 90° out of phase with the other. Thus, when attached to a driving means 38 and the first coupler is at its maximum conductance, the second element is completely decoupled, and vice versa. Since the elements are spaced a half wavelength apart, the input admittance to the trough waveguide is the sum of the admittances of the two couplers. It can be seen that as the couplers are rotated in synchronism, the input conductance remains approximately constant while the susceptance is always significant. Thus, this antenna system always presents a good match to the transmitter. However, the apparent point of radiation moves from the first coupler to the second and back again as the elements are rotated, completing two cycles for one rotation of the couplers. If this device is used as the primary feed for a microwave lens or reflector, sequential lobing of the radiation pattern may be obtained.

Although the invention has been described with reference to particular embodiments, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments within the spirit and scope of the appended claims.

I claim:

1. A waveguide adapted for the controlled interchange of energy between itself and surrounding space comprising a transmission line of generally trough-shaped cross section which is substantially constant throughout its length, a center fin symmetrically disposed within said generally trough-shaped structure and a tri-rod coupling element mounted on said center fin, said tri-rod coupler comprising a horizontal radiating or coupling element, a tuning element at right angles to said radiating element and a pair of capacitive tuning elements each of which is mutually perpendicular to both said radiating element and said tuning element.

2. A waveguide as defined in claim 1 wherein a number of said tri-rod couplers are oriented on said center fin.

3. A waveguide as defined in claim 2 including means for adjusting the orientation of said tri-rod couplers.

4. A sequential lobing antenna comprising a generally trough-shaped waveguide having a centrally disposed fin member extending longitudinally thereof, at least one pair of tri-rod couplers mounted on said fin an integral number of half wavelengths apart, and means for rotating said tri-rod couplers simultaneously in a 90° mechanically out of phase relation, said tri-rod coupler comprising a horizontal radiating or coupling element, a vertical tuning element attached to one end of said radiating element and a pair of capacitive tuning elements each of which is perpendicular to said radiating element and said vertical tuning element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,281,552	Barrow	May 5, 1942
2,799,831	Fubini	July 16, 1957
2,806,210	Edwards	Sept. 10, 1957
2,829,348	Kostriza et al.	Apr. 1, 1958
2,849,711	MacKimmie	Aug. 26, 1958
2,903,656	Weisbaum	Sept. 9, 1959

OTHER REFERENCES

Pub. I. "Some New Microwave Antenna Designs Based on the Trough Wave Guide," Rotman and Karas, 1956 IRE Convention Record, vol. 4, Part I, copyright 1956, pp. 230–235.

Pub. II. "The Bell System Technical Journal," vol. 34, No. 1, January 1955, pp. 71, 72.