

1

3,005,984

SLOTTED WAVEGUIDE ANTENNAS

Charles F. Winter, Wrentham, and John E. Walsh,
Wellesley, Mass., assignors to Raytheon Company, a
corporation of Delaware

Filed Dec. 29, 1958, Ser. No. 783,416

4 Claims. (Cl. 343-771)

This invention relates to antennas and particularly pertains to an ultra-high-frequency antenna array utilizing slotted waveguides to effect the interchange of radio frequency energy with free space.

This invention is especially useful in the ultra-high-frequency range whereby, for example, it is desired to determine target angle by diplexing two separate signals into and/or out of each end of the waveguide forming the antenna. Heretofore, slotted waveguides have been used wherein two different signals are diplexed into the antenna. However, these signals were all radiated in the same pattern and the means utilized to separate the signals were generally complex, bulky and costly to manufacture. Further, the provision of two different patterns required two separate antennas whose phase center separation was at least as great as the length of one antenna. It is, therefore, a principal object of the present invention to provide a single antenna having two beams whose phase centers are separated a distance less than one antenna length.

It is another object of the present invention to provide a single waveguide antenna array with two patterns and separate feeds.

Another object of the present invention is to provide a slotted waveguide antenna having two divergent antenna patterns allowing separate transmission or reception with each pattern simultaneously.

It is a further object of the present invention to provide a slotted waveguide antenna array having two directive and divergent antenna patterns wherein the direction from which a signal is received determines the end of the waveguide to which the signal will be coupled.

A still further object of the present invention is the provision of a dual beam antenna that is exceptionally small and light in weight and that requires no additional equipment or structure to separately provide signals received by each beam.

These and other objects and features of the invention, together with their incident advantages, will be more readily understood and appreciated from the following detailed description of the preferred embodiment thereof selected for purposes of illustration and shown in the accompanying drawing which shows a perspective view of the slotted waveguide and the dual beam or antenna pattern orientation in accordance with the invention.

In accordance with the present invention, a rectangular waveguide is provided with a plurality of coupling elements for interchanging energy between free space and the waveguide. The spacing and excitation of the coupling elements are designed to add constructively at one end of the waveguide for one antenna pattern and simultaneously to constructively add at the other end of the waveguide for the other pattern. This allows separate transmission or reception with each beam or antenna pattern separately or simultaneously. For the case of transmission the coupling elements attenuate energy supplied at one end of the waveguide sufficient to prevent destructive interference from energy reaching the other end of the waveguide, and for the case of reception, energy received from free space within each antenna pattern is coupled to a different one of the waveguide ends.

2

With reference now to the drawing, there is shown a hollow rectangular waveguide 1 having two broad walls 2 and two narrow walls 3. A plurality of slots 11-17 which act as coupling or radiating elements are cut in one of the broad walls 2. If desired, the broad wall 2 of the waveguide may be made in the form of a cover plate into which the slots are cut so that the frequency of operation may be changed to any frequency of operation occurring over a broad frequency band by simply changing the outer cover plate to another containing differently dimensioned and differently positioned slots. The slots are excited by being positioned off the center line of the wall since a slot is excited when there are components of current whose direction of flow is transverse to the longitudinal axis of the slot.

In an actual embodiment built in accordance with the present invention and successfully tried out in practice, a one-dimensional, vertically polarized antenna having dual beams making substantially equal and opposite angles with an imaginary line normal to the total array was developed for operation at about 10,000 m.c.p.s. The divergent beams were each disposed at an angle α of about 12° and had a phase separation center of 1.5". The waveguide 1 and slots 11-17 had the following dimensions. The waveguide 1 was of rectangular configuration with internal dimensions of .750" x .200". As shown in the drawing, spaced apart about .700" center to center. The length of slots 11 and 17 were .576" with centers each offset .030" above the longitudinal center line of the broad wall. The length of slots 12 and 16 were .582" with centers each offset .067" below the longitudinal center line of the broad wall. The length of slots 13 and 15 were .613" with centers each offset .210" above the longitudinal center line of the broad wall. The length of slot 14 was .626" and its center was offset .270" below the longitudinal center line of the broad wall. The total array was symmetrical about a transverse line passing through the center of slot 14.

The slot spacings were for two beams or antenna patterns each divergent 12° , and were determined by the equi-phase condition $s = \lambda/2[\lambda/\lambda_g + \sin \alpha]$. Assuming that

db coupled = $10 \log \left(\frac{\text{power incident at a slot}}{\text{power transmitted past a slot}} \right)$

and that the beams or antenna patterns are similar, the coupling of the slots by pairs from each end of the waveguide are identical.

The following data shows db coupled and voltage for the identified slots. The total db coupled is 15.5 db.

Slot Number.....	11	12	13	14	15	16	17
Db Coupled, referred from End 18.....	.25	1.0	4.0	5.0	4.0	1.0	.25
Voltage Amplitude:							
End 18.....	1.40	2.65	4.00	2.65	1.40	-----	-----
End 19.....	-----	-----	1.40	2.65	4.00	2.65	1.40

An array constructed and arranged as described hereinabove provides a 20° half-power beam width and a 1.5" phase center separation, the phase center of beam number 1 being located at about the center of slot 13 and the phase center of beam number 2 being located at about the center of slot 15. The dual beam antenna array for the embodiment shown consists of a total of 7 slots disposed and arranged as described hereinabove. A first portion of 5 slots, slots 11-12-13-14-15, add constructively at end 18 of the waveguide to form beam or pattern number 1, and a second portion of 5 slots, slots 13-14-15-16-17, add constructively at end 19 of the waveguide to form beam or pattern number 2,

and a portion comprised of 3 slots, slots 13—14—15, intermediate to the ends of the total array are common to both the aforementioned first and second portions of the slots. As pointed out hereinbefore, a reflected signal received from a target or the like within beam number 2, is coupled, for example, to end 19 of the antenna but not to end 18. The reverse is likewise true for a signal received from a target within beam number 1.

It may now be readily apparent that the antenna described hereinabove may be used to satisfy a radar application requiring two separate and divergent beams from a single antenna having a zero or small phase center separation. Although it is noted that the prior art teaches slotted waveguides per se and slotted waveguides into which two signals may be diplexed, the present invention provides substantial advantages in that no additional equipment is necessary to provide the divergent beams or to separate signals received by each beam since input power for dual beam transmission is supplied at opposite ends of the waveguide and signals received from free space within each of the antenna patterns is substantially coupled to a different one of the waveguide ends.

The entire dual beam antenna, which effectively comprises two separate antennas in the physical space of one antenna, may be comprised of a conventional piece of waveguide less than 4.5" long formed in accordance with the invention.

While the present invention has been described in its preferred embodiment, it is realized that modifications may be made, and it is desired that it be understood that no limitations on the invention are intended other than may be imposed by the scope of the appended claims.

What is claimed is:

1. A dual pattern antenna comprising: a waveguide having two broad walls and two narrow walls; a plurality of regularly spaced coupling elements provided in one of said broad walls for coupling energy between said waveguide and free space, said coupling elements being arranged and adapted to provide divergent antenna patterns having a predetermined phase center separation, the coupling element intermediate the ends of said waveguide being longer and spaced farther distant from the longitudinal axis of said one broad wall than the other coupling elements, each of said other coupling elements progressing toward each end of said waveguide being successively shorter and closer to said longitudinal axis, said coupling elements providing an increasing and then decreasing amount of coupled energy with respect to the ends of said waveguide whereby input power at each end of said waveguide is substantially attenuated before it reaches the opposite end and power received from free space within each of said antenna patterns is substantially coupled to one of said waveguide ends and power received from free space within another of said antenna patterns is substantially coupled to said other waveguide end.

2. A dual pattern slotted waveguide antenna comprising: a waveguide having two broad walls and two narrow walls, one of said broad walls having a plurality of slots therein for coupling energy between said waveguide and free space, said slots being arranged and adapted to provide divergent antenna patterns each having a phase center, said phase centers being separated a distance less than the length of said antenna, the slot intermediate the ends of said waveguide being longer and spaced farther distant from the longitudinal axis of said one broad wall than the other slots, each of said other slots progressing toward each end of said waveguide being successively

shorter and closer to said longitudinal axis, said slots providing an increasing and then decreasing amount of coupled energy with respect to both ends of said waveguide whereby input power at each end of said waveguide is substantially attenuated before it reaches the opposite end and power received from free space within each of said antenna patterns is substantially coupled to one of said waveguide ends and power received from free space within another of said antenna patterns is substantially coupled to said other waveguide end.

3. A dual pattern slotted waveguide antenna comprising: a waveguide having two broad walls and two narrow walls, one of said broad walls having a plurality of slots therein for coupling energy between said waveguide and free space, said slots being arranged and adapted to provide divergent antenna patterns having a small phase center separation, the slot intermediate the ends of said waveguide being longer and spaced farther distant from the longitudinal axis of said one broad wall than the other slots, each of said other slots progressing toward each end of said waveguide being successively shorter and closer to said longitudinal axis, said slots providing an increasing and then decreasing amount of coupled energy with respect to each end of said waveguide extending over a length less than the effective length of said antenna whereby input power at each end of said waveguide is substantially attenuated before it reaches the opposite end and power received from free space within each of said antenna patterns is substantially coupled to one of said waveguide ends and power received from free space within another of said antenna patterns is substantially coupled to said other waveguide end.

4. A dual pattern antenna comprising: a waveguide having two broad walls and two narrow walls, one of said broad walls having a plurality of slots forming an array for interchanging energy between said waveguide and free space, said array being arranged and adapted to provide two divergent antenna patterns having a small phase center separation, said patterns being divergent from an imaginary line normal to said broad wall, a first portion of said slots producing one pattern and having a phase center disposed to one side of said imaginary line, a second portion of said slots producing the other pattern and having a phase center disposed on the other side of said imaginary line, the center portion of said array simultaneously forming a part of said first and second portions, the slots providing longitudinally increasing and then decreasing amounts of coupled energy beginning at each end of said array and extending over a distance less than the length of said array, said slots being regularly spaced apart and decreasing in length and in spacing from the longitudinal axis of said one broad wall in the direction of each end of said waveguide from said imaginary line whereby energy received from free space within each of said antenna patterns is substantially coupled to a different one of the ends of said waveguide.

References Cited in the file of this patent

UNITED STATES PATENTS

2,596,480	Guptill et al. -----	May 13, 1952
2,659,005	Gruenberg -----	Nov. 10, 1953
2,881,436	Stavis -----	Apr. 7, 1959
2,932,823	Beck et al. -----	Apr. 12, 1960
2,937,373	Carter -----	May 17, 1960

FOREIGN PATENTS

53,376	France -----	Feb. 26, 1945
--------	--------------	---------------

UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 3,005,984

October 24, 1961

Charles F. Winter et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 27, for "spaced apart about .700" center" read -- each longitudinal slot was --.

Signed and sealed this 10th day of April 1962.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents