June 15, 1965 J. H. PROVENCHER 3,189,908

RIDGED WAVEGUIDE SLOT ANTENNA

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FIG. 1

(PRIOR ART)

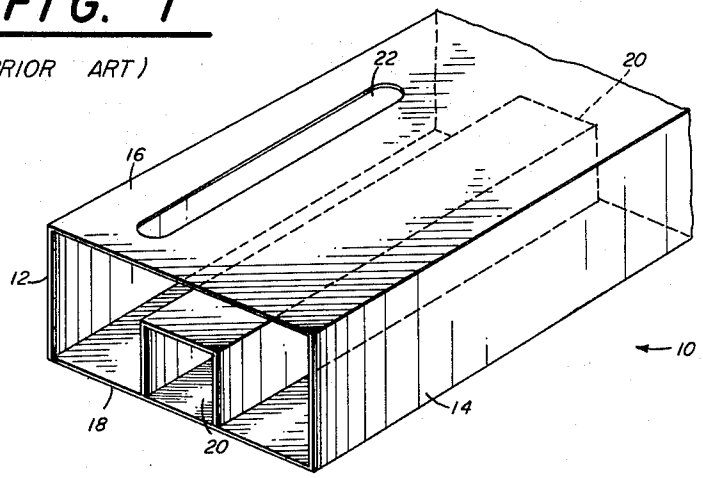
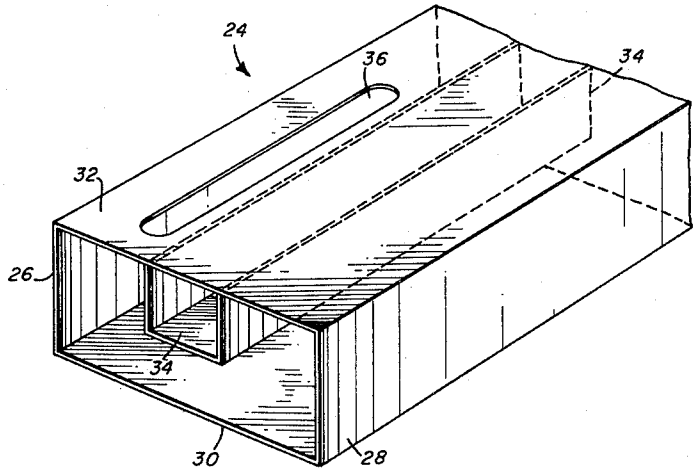


FIG. 2



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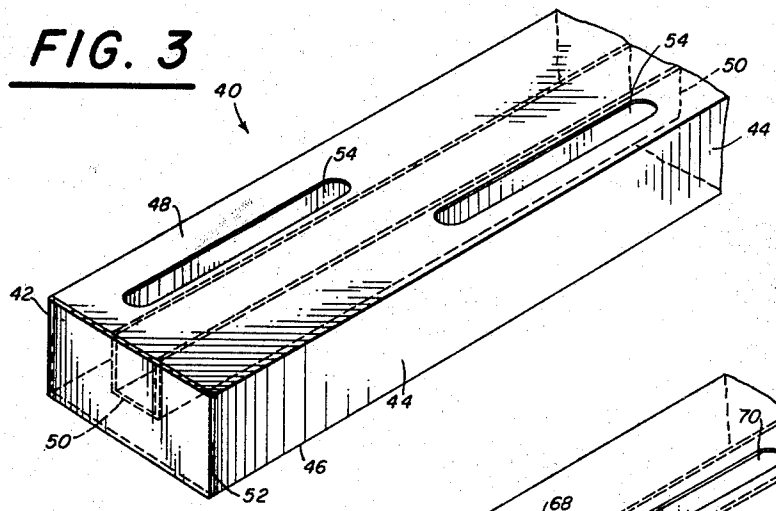
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RIDGED WAVEGUIDE SLOT ANTENNA

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FIG. 3



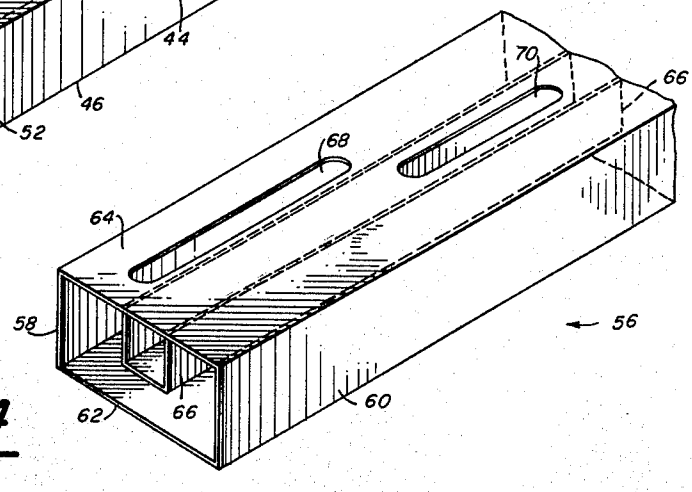


FIG. 4

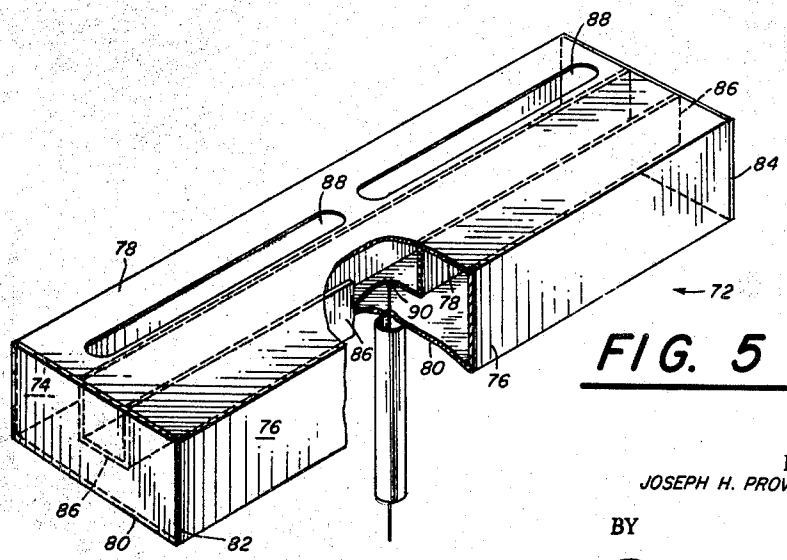


FIG. 5

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RIDGED WAVEGUIDE SLOT ANTENNA

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Filed Jan. 22, 1962, Ser. No. 167,983
19 Claims. (Cl. 343—771)
(Granted under Title 35, U.S. Code (1952), sec. 266)

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

The present invention relates to antennas and more particularly, to a slot antenna and specifically, to a slotted ridged waveguide.

One method of radiating or receiving electromagnetic energy is through the use of a series of discrete slots in a waveguide. These slots are usually resonant for a given frequency and are normally spaced approximately one-half guide wavelength apart and additionally, are alternated on either side of the waveguide center line. The radiation pattern of such an array of slots is then controlled by a given amplitude distribution along the length of the array. The contribution from each slot is controlled by the displacement of the slot off the waveguide center line.

The staggering of the slots about the center line causes undesirable radiation outside of the principal planes and this radiation becomes more pronounced as the off-center displacement is increased. In that the slots are approximately one-half wavelength long, their length is frequency dependent and this limits the operation of such an antenna over a relatively narrow frequency band. Such frequency dependency results in pattern deterioration and large impedance changes as the frequency is moved away from a resonant frequency. In addition, precise machining of slot length and slot spacing is required thereby causing the entire antenna to be highly resonant.

In addition, the width of a slotted waveguide imposes somewhat of a restriction on its use as an element in a parallel array, especially when spacings on the order of a half wavelength are required. This width restriction, however, can be reduced by loading the waveguide, either with a dielectric or through the use of a ridge. In either case, attenuation will result but may be minimized by proper choice of the loading material or ridge dimensions.

An object of the present invention is to provide a slotted waveguide antenna wherein the length of the slot is not directly related to the operating frequency and will not be required to be resonant at that frequency.

A further object of the invention is to provide a slotted waveguide antenna wherein precise machining of slot length and slot spacing is not required.

An additional object of the invention is to provide an antenna which is capable of scanning both in azimuth and elevation.

An additional object of the invention is to provide a slotted waveguide antenna capable of radiating large amounts of power from a small physical space, i.e., couple out the most power with the smallest number of slots.

An additional object of the invention is to provide a slotted waveguide antenna which has a stable radiation pattern and an acceptable impedance level over a relatively broad frequency band.

Another object of the invention is to provide a slotted waveguide antenna capable of radiating a large amount of power from a slot relatively close to the center line of the waveguide.

A further object of the invention is to provide a slotted waveguide antenna which has a stable pattern and stable impedance as the frequency is moved away from the resonant frequency.

An additional object of the invention is to provide a slotted waveguide antenna wherein undesirable radiation outside the principal planes is reduced.

A further object of the invention is to provide a slotted waveguide antenna wherein power extracted from the slot is relatively independent of the center line displacement of the slots, hence, requiring less stringent tolerances in manufacture.

In order to better understand the embodiments of the invention reference is made to the following drawings wherein:

FIG. 1 illustrates the prior art slotted waveguide;

FIG. 2 illustrates one embodiment of the present invention;

FIG. 3 illustrates another embodiment of the present invention showing slots staggered on either side of the center line;

FIG. 4 illustrates an embodiment of the present invention incorporating the height finding feature; and

FIG. 5 illustrates another embodiment of the invention having the radiating slots on the same side of the center line waveguide.

As shown in FIG. 1 the prior art slotted waveguide antennas comprised a rectangular waveguide **10** having short sides **12** and **14** and long sides **16** and **18**. Mounted internally on one long side as on side **18** is a loading ridge **20** which extends internally of the waveguide. The loading ridge increases the cut-off wavelength, and widens the frequency range over which only the dominant mode will propagate. In the wall **16** opposite to wall **18** upon which the loading ridge **20** is mounted, a radiating slot **22** is provided.

As is well-known, a hole or joint or slot in a waveguide wall introduces the possibility that energy will leak from the guide to outer space. When this happens, fields inside the guide are affected, thereby introducing an irregularity with resulting reflection. Thus, when magnetic flux breaks through radiating slot **22** the associated interference with the flow of currents in the wall produces voltage across the slot **22** that gives rise to an electric field that will extend outside the guide.

In the embodiment of the invention illustrated in FIG. 2, a rectangular waveguide **24** is provided having short sides **26, 28** and long sides **30, 32**. Mounted on one long wall of the waveguide **24** as on wall **32** is a loading ridge **34** which extends internally into the hollow waveguide **24**. Also, cut into long wall **32** is a longitudinally extending radiating slot **36**. As shown, the slot is off the center line of the waveguide and lies outside the area on wall **32** bounded by the loading ridge **34**. This is done so that the area inside loading ridge **34** is essentially a dead area.

In the embodiment of FIG. 2, the length of the slot is not directly related to the operating frequency and will not be resonant at that frequency. Generally, for the shunt slot cut in a ridged waveguide such as shown in FIG. 1 maximum power is coupled out when the slot is of resonant length, which is in the vicinity of 0.5 free space wavelength. However, in the present invention a slot length which gives the maximum coupled power is in the vicinity of 0.6 free space wavelength. In addition, the power level of the embodiment shown in FIG. 2 is relatively higher than that of the resonant slot cut in the wall of a waveguide opposite the ridge, such as shown in the prior art of FIG. 1. For short arrays, where large amounts of power need to be removed by a few slots, there would be a decided advantage in this type of configuration. Under other conditions, i.e., for long arrays, it would be possible to remove the power with fewer slots or a greater percentage of the power in the same length, by utilizing an array incorporating the features of the invention set forth in FIG. 2 in conjunction with a number of conventional longitudinal shunt slots. Further, it is noted that similar

results are obtained at 100 megacycles on either side of the center frequency of 3,000 megacycles and this would indicate that the slot of FIG. 2 behaves in a similar manner for given bandwidths whereas the slot of FIG. 1, in that it is resonant at a single frequency, does not give the relatively broad bandwidth.

FIG. 3 illustrates an embodiment of the invention utilizing radiating slots positioned on alternate sides of the waveguide center line with a shorting plate properly positioned on each end. An array of this type exhibits a stable radiation pattern over a relatively broad frequency band. The array comprises a waveguide **40** having short sides **42**, **44**; long sides **46**, **48** and a loading ridge **50** positioned on one of the long sides such as side **48**. Positioned on each end of the waveguide **40** is a shorting plate **52**. Spaced on alternate sides of the center line and outside of the area bounded by the ridge **50** are radiating slots **54** which are spaced apart in the long direction of the waveguide in integral multiples of one-half guide wavelength. The length of the slots is approximately 0.6 free space wavelength of the middle operating frequency.

FIG. 4 illustrates another embodiment of the invention wherein a dual frequency feature is added to the antenna. In FIG. 4, rectangular waveguide **56** is provided having short sides **58**, **60** and long sides **62**, **64**. Positioned on one long side of the waveguide **56**, say on side **64**, is a loading ridge **66**. A radiating slot **68** is provided adjacent the area bounded by the loading ridge **66** in wall **64** for the lower operating frequency band. Another slot **70** is provided in the wall **64** within the area bounded by the loading ridge **66** and provides a means of obtaining an independent beam for a higher operating frequency band. Essentially then, there is a waveguide positioned within a waveguide, i.e., ridge **66** acts as one waveguide while the main waveguide **56** also performs its function. This technique can be extended to three or more waveguides, each with its independent slot array for the appropriate frequency band.

The embodiment of FIG. 5 exhibits a stable radiation pattern with good impedance characteristics over a relatively broad frequency range. This embodiment comprises a section of rectangular waveguide **72** again having short sides **74**, **76** and long sides **78**, **80**. Both ends are closed by shorting plates **82** and **84**. Mounted on one of the long sides as on side **78** is a loading ridge **86**. Cut into the same wall that the loading ridge is mounted on are two radiating slots **88** which are approximately 0.6 free spaced wavelengths long and positioned approximately one-half guide wavelength apart in the axial direction of the waveguide **72**. The feed to this 2-slot element will enter the waveguide at the midpoint between them, as does probe **90**.

In the operation of the embodiments of the invention the antennas may be center fed or end fed, short circuited or loaded at the ends. Through the use of the slot longer than one-half wavelength at the operating frequency, the band-width restrictions of the resonant slot are avoided.

Experimental slot radiating data, taken by well-known methods, of the conventional slot ridged waveguides, contrasted with the adjacent slot ridged waveguides has been plotted and is available. These curves show a different behavior for both types of slot. For any given displacement off the center line of the waveguide, the conventional slot radiates at a lower power level than the adjacent slot, and has a shorter length than the adjacent slot. The experimental frequency chosen was one in which the length of the conventional slot was near resonance. For this frequency and with a given waveguide configuration, the maximum radiation for the conventional slot was about 50%, while that of the adjacent slot was about 73% of input power. Further, the displacement of the conventional slot was 0.650 inch off the center line, while the displacement of the adjacent slot was 0.360 inch off the center line of the waveguide. Thus, the use of the adjacent slot would allow a more compact array than the use

of the conventional slot. In general, the relative power level of the adjacent slot, for any given displacement off center line is higher than that of the conventional slot.

In addition, through the use of the adjacent slot a stable radiation pattern and an acceptable impedance level over a relatively broad frequency band is possible. If shaping of the radiated beam is desired or if it is desired to reduce back radiation, chokes or wings may be placed on the sides of the slot and the entire configuration may be placed in a conducting sheet.

In a summary, when a waveguide is excited in a suitable manner, electromagnetic waves travel down the waveguide in uniform pattern. In the conventional waveguide, if a longitudinal slot is cut in the wall of the long side, transverse currents will be intercepted and an electric field will appear across the slot. Thus, the slot is adapted for the interchange of energy between the waveguide and the surrounding space. The magnitude of the radiation is proportional to the displacement of the slot off the waveguide center line. By placing additional slots staggered about the center line, spaced one-half guide wavelength apart along the waveguide and having a length about one-half guide wavelength, the fields from the individual slots can be made to radiate approximately in phase so that the energy is directed in a concentrated beam in a direction roughly perpendicular to the face of the waveguide.

In the adjacent slot case the off center line displacement can be held constant and the amplitude distribution can be controlled by the length of the slot i.e., for the slot cut in the wall containing the loading ridge. The two-slot configuration such that shown in FIG. 5 can be used as an individual element in a planar array, thereby eliminating the need to stagger the slots to maintain an in-phase array. Additionally, an array such as that shown in FIG. 3 can be made which exhibits a stable radiation pattern for a relatively broad frequency band. In this array the metal plate **52** is placed about a quarter guide wavelength beyond the last slot **54** at the end of waveguide **40**.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An antenna comprising; a rectangular waveguide; a loading ridge mounted on and projecting internally from a wall of said rectangular waveguide; at least one radiating slot located adjacent to the ridge in the same wall that the loading ridge is mounted on.

2. An antenna as set forth in claim **1** wherein said at least one radiating slot is parallel to the axis of propagation of energy in said rectangular waveguide.

3. An antenna as set forth in claim **1** wherein at least one slot has a physical length greater than one-half free space wavelength at the operating frequency.

4. An antenna as set forth in claim **1** wherein the physical length of said radiating slot is greater than one-half free space wavelength and is substantially equal to one-half guide wavelength at the operating frequency.

5. An antenna comprising; a rectangular waveguide; a loading ridge located internally of said rectangular width waveguide and on one wall of said rectangular waveguide; a slot located in the wall that the rectangular loading ridge is mounted on; said slot being parallel to the axis of propagation of energy in the waveguide.

6. An antenna as set forth in claim **5** wherein said loading ridge is located on a wall of said rectangular waveguide having a long dimension as compared to the two walls of said rectangular waveguide having a short dimension.

7. A broadband frequency antenna comprising; a rectangular waveguide having two walls with a long dimension and two walls with a short dimension; a loading ridge mounted internally in said waveguide and on one of said walls of said waveguide; loading slots located in said wall

of said rectangular waveguide having said loading ridge mounted thereon; and said rectangular waveguide adapted to be center fed.

8. A broadband frequency antenna as set forth in claim 7 wherein said radiating slots have a physical length of substantially one-half guide wavelength of the center operating frequency.

9. A broadband frequency antenna as set forth in claim 8 wherein said radiating slots are spaced one-half guide wavelength apart at the operating frequency.

10. A broadband frequency antenna as set forth in claim 7 wherein said radiating slots are positioned on the same side of the waveguide center line.

11. A broadband frequency antenna as set forth in claim 7 wherein the number of radiating slots are two so that said antenna exhibits a stable radiation pattern and good impedance characteristics over a relatively broad frequency band.

12. A broadband frequency antenna as set forth in claim 8 wherein said radiating slots are spaced apart integral multiples of substantially one-half guide wavelength at the operating frequency.

13. A broadband frequency antenna as set forth in claim 7 wherein said radiating slots are positioned on alternate sides of the waveguide center line.

14. A broadband frequency antenna as set forth in claim 13 and further comprising; a shorting plate positioned on either end of said rectangular waveguide so that said broad-band frequency antenna exhibits a stable radiation pattern over a relatively broad frequency band.

15. An antenna comprising; a rectangular waveguide; a loading ridge mounted on and extending internally of one long wall; at least one radiating slot located adjacent to the loading ridge in the same wall that the loading ridge is mounted on for radiating energy at a first frequency;

at least one other slot located in the same wall that the loading ridge is mounted on and within the area bounded by said loading ridge for radiating energy at another frequency so that said antenna may scan in a horizontal and vertical direction simultaneously.

16. An antenna as set forth in claim 15 wherein said at least one radiating slot located adjacent to said ridge and said at least one other slot located within the area bounded by said ridge are parallel to the axis of propagation of energy in said waveguide.

17. An antenna as set forth in claim 16 wherein said at least one radiating slot located adjacent to the loading ridge has a physical length greater than one-half free space wavelength at the operating frequency.

18. An antenna as set forth in claim 16 wherein said loading ridge constitutes a separate waveguide and wherein said at least one other radiating slot located within the area bounded by said loading ridge has a physical length which is greater than one-half the free space wavelength of said another frequency.

19. An antenna as set forth in claim 18 wherein said at least one other radiating slot length is substantially one-half guide wavelength of said another frequency coupled to said loading ridge.

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HERMAN KARL SAALBACH, *Primary Examiner.*