NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

October 16, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,324,423

Corporate Source : Calif. Institute of Technology

Supplementary Corporate Source : Jet Propulsion Laboratory

NASA Patent Case No.: XNP-03134

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Enclosure:
Copy of Patent

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June 6, 1967 JAMES E. WEBB 3,324,423

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DUAL WAVEGUIDE MODE SOURCE HAVING CONTROL MEANS FOR ADJUSTING THE RELATIVE AMPLITUDES OF TWO MODES

Filed Dec. 29, 1964

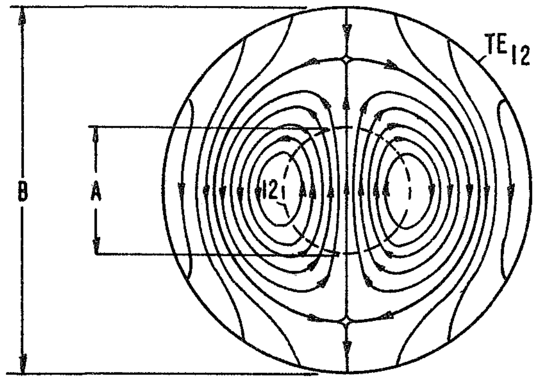

FIG. 1

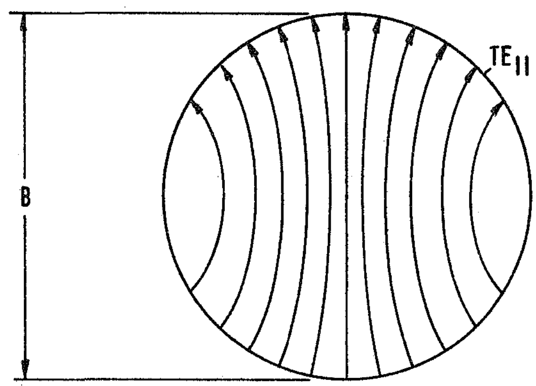

FIG. 2

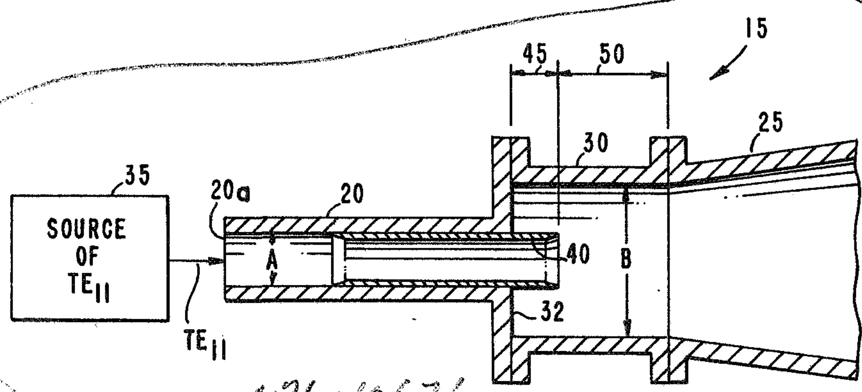

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FIG. 3

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DUAL WAVEGUIDE MODE SOURCE HAVING CONTROL MEANS FOR ADJUSTING THE RELATIVE AMPLITUDES OF TWO MODES

James E. Webb, Administrator of the National Aeronautics and Space Administration, with respect to an invention of Arthur C. Ludwig, South Pasadena, Calif.

Filed Dec. 29, 1964, Ser. No. 422,095
8 Claims. (Cl. 333—21)

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

This invention relates to microwave devices and, more particularly, to an improved waveguide mode generator.

Various microwave transmitting and receiving systems have been developed to track and/or communicate with long range missiles and other objects in space. In all such systems, antennas are used to direct the microwave energy into space, and/or collect the received energy therefrom. Each of the antennas usually includes a reflecting dish and a feed system through which the microwave energy is supplied to the reflecting dish, or received therefrom.

In order to improve a tracking, and/or communication with the objects in space, it is important to be able to control the shape of the beam of microwave energy which the reflecting dish of the antenna either reflects into space or receives therefrom. Beam shaping is generally accomplished in whole or in part by adjusting a feed system to have a certain specified field distribution over its surface or aperture. One useful method of accomplishing this is to adjust the relative phase and amplitudes of the various modes in which microwave energy will propagate through the horn of the feed system. The amplitudes and phase relationships of these various modes are controlled to insure that the shape of the beam radiated by the feed and then reflected by the antenna is of the desired configuration and magnitude.

In order to control the relative characteristics of the various modes of energy, microwave guiding and transmission systems have been developed. Generally such systems comprise a plurality of stages through which the microwave energy is guided. These stages include various discontinuities at which secondary or higher order modes of microwave energy are excited from the primary or dominant mode. In all prior art mode generators, used in beam shaping applications, the power of the higher order modes produced as a result of the discontinuities is always less than the power of the dominant mode. Thus, the power ratio between the power of the dominant and higher order modes is greater than one. Yet in beam shaping applications, it is often necessary to have more energy in the secondary, or higher order modes, than in the dominant mode. Although a certain amount of energy in the dominant mode is necessary, in general unless special steps are taken, there will be an excess amount of energy in the dominant mode. However, none of the prior art waveguide mode generators used in beam shaping applications are adapted to conveniently control the relative amounts of energy or amplitudes of the dominant and secondary, or higher order modes.

Accordingly, it is an object of the present invention to provide a waveguide mode generator wherein the relative power of various modes may be controlled.

It is another object of the present invention to provide a waveguide mode generator wherein a higher order mode generated from a dominant mode is accentuated while the dominant mode is diminished in power.

A further object of the present invention is to provide a waveguide mode generator wherein the relative power

between a dominant mode and a higher order mode generated therefrom may be controllably adjusted.

Still a further object of the present invention is to provide a waveguide mode generator which is designed to accentuate the higher order mode TE_{12} and diminish the dominant mode TE_{11}, with the relative power between the two modes being controlled by these relative positions of a controlling member within the waveguide mode generator.

These and other objects of the invention are achieved in a waveguide mode generator in which a discontinuity is present so that a dominant mode supplied to the generator, is excited to generate higher order modes. The dimensions of the generator are selected to insure that a desired one of the higher order modes is generated from the input energy. In addition, the generator includes a control element which is selectively positionable within the waveguide mode generator so that the power of the dominant mode used as the input energy may be controlled with respect to the power of the higher order mode generated therein. The control element may be positioned to provide power ratios wherein the power of the dominant mode is less than that of the power of the higher order mode. Thus, the generator is capable of providing microwave energy wherein the energy of a secondary mode is accentuated with respect to the energy in a dominant mode from which the secondary or higher order mode had been produced.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is an excitation pattern diagram of energy in mode TE_{12};

FIGURE 2 is an excitation pattern diagram of energy in mode TE_{11}; and

FIGURE 3 is a side elevational view of the waveguide mode generator of the present invention.

The teachings of the present invention will be described in conjunction with a waveguide mode generator designed so as to accentuate the higher order or secondary mode TE_{12} and diminish the dominant mode TE_{11}, from which the secondary mode TE_{12} is excited. Reference is now made to FIGURES 1 and 2 which are excitation pattern diagrams of microwave energy in modes TE_{12} and TE_{11} respectively, in the E plane, propagating in cylindrical waveguide sections of diameter B. When comparing the patterns of the two modes, it is seen that within the pattern of the mode TE_{12}, a pattern identical to that of mode TE_{11} propagates within a circular area of diameter A, which is shown in FIGURE 1 by a dashed line **12**.

On the basis of mathematical analysis of microwaves, the diameter A may be determined whenever the diameter B is known. The interrelationship of the patterns of the mode TE_{12} and TE_{11} in pattern diameters B and A respectively, is used in designing the mode generator of the present invention. A waveguide section of diameter A is incorporated to carry or provide the mode TE_{11}. Such section is abruptly changed in cross-section to a section of diameter B, so that at the discontinuity mode TE_{12} is strongly excited.

Reference is now made to FIGURE 3 which is a side elevational view of a cylindrical mode generator **15** constructed in accordance with the teachings of the present invention. As seen therein, the generator **15** comprises an input section **20**, a horn-shaped output section **25**, and an excitation section **30** interposed therebetween. The cylindrically-shaped input section **20** has an internal diameter A, and an input opening **20a** through which energy in mode TE_{11} may be supplied from a source of microwave energy in mode TE_{11}, designated by numeral **35**. The energy in mode TE_{11} propagates through the input section **20** towards the other end thereof, at which the excitation section **30** with an internal diameter B is connected. Due to the difference in diameters of the two sections, a discontinuity surface **32** is created.

Assuming that the microwave energy from the source **35** is in a pure TE_{11} mode, it is apparent to those familiar with the art that the discontinuity between sections **20** and **30** will cause secondary or higher modes of the dominant mode TE_{11} to be excited therein. Diameter B, for reasons to be explained hereafter, is chosen such that the guide wavelength of mode TE_{12} is twice the guide wavelength of mode TE_{11}.

By so choosing the diameter of section **30**, modes of order TM_{12} and higher will be beyond cutoff in the excitation section and therefore will not propagate through it without severe attenuation. Assuming the incidence of a pure TE_{11} mode, due to the circular symmetry of the generator, only modes *ln*, where $n=1, 2, 4$ etc. will be excited. But since modes of the order TM_{12} and higher will be beyond cutoff only modes TE_{11}, TM_{11} and TE_{12} will be excited and propagate through section **30**. The TM_{11} mode is also excited and controlled by the generator. However, the control of modes TM_{11} and TE_{12} is not independent, with only one mode being adjustable to a specified value relative to the TE_{11} mode. The generator used as the example to explain the teachings of the present invention is primarily related to control the relative amplitudes of modes TE_{11} and TE_{12} excited therefrom.

In the absence of additional means, the generator so far described is similar to prior art generators, in that a dominant mode is propagated through a waveguide discontinuity so that secondary higher order modes may be generated. As previously stated, in prior art mode generators, the power of the second modes is always less than that of the dominant mode. However, in the novel generator of the present invention, as shown in FIGURE 3, additional control means are provided in order to control the power relationship or power ratio between that of the dominant and secondary modes.

As seen in FIGURE 3, the generator of the present invention further includes a cylindrically-shaped control element **40** which is insertable within the input section **20**. The wall thickness of the control element **40** is small so that the small change in the effective diameter A of the input section **20** does not adversely affect the energy in mode TE_{11} propagating therethrough. The control element **40** is adjustably positioned within the input section **20** so that only a selected portion thereof, designated in FIGURE 3 by numeral **45**, may extend beyond the input section **20** into the excitation control section **30**.

From FIGURE 3, it is seen that the energy in mode TE_{11} propagating through section **20** does not enter the excitation section **30** at the point of discontinuity therebetween. Rather, the energy enters the excitation section at the end face of the control element **40**. Therein, modes TE_{11} and TE_{12} in a waveguide section of a diameter B are excited. Some of this energy will propagate towards the horn-shaped section **25**. However, some of the energy will be reflected towards the surface of discontinuity between the sections **20** and **30**. Therefrom, the energy will be reflected back towards the horn-shaped section **25**. Thus, the energy directed towards the horn-shaped section comprises energy propagating directly in a forward direction from the element **40**, as well as energy reflected back from the surface of discontinuity between the sections **20** and **30**. The two wave fronts will reinforce or subtract from the total energy in each one of the modes depending on the guide wavelength of each mode and the dimension designated by arrow **45**. Namely, the extent to which the control element **40** is inserted into the excitation section **30** will control the relative amplitudes and power of the modes propagating therethrough.

As previously assumed, the diameter B is chosen so that the guide wavelength of the secondary modes TE_{12} is twice the guide wavelength of mode TE_{11}. Thus, if the dimension designated by arrow **45** is adjusted to be one-quarter wavelength of the mode TE_{12} and one-half wavelength of the mode TE_{11}, the reflected back wave reinforces for TE_{12} and cancels for mode TE_{11}. Consequently, the amplitude or power of the dominant mode TE_{11} will be greatly reduced with respect to the amplitude or power of the secondary mode excited therefrom.

The relative amplitudes of the two modes can be adjusted by properly positioning the control element **40** so that the dimension designated by arrow **45** is equal to a predetermined portion of the guide wavelength of either of the modes. The distance from the end face of the control element **40** to the end of the excitation section **30**, designated in FIGURE 3 by arrow **50**, is controlled to provide the desired relative phase relationship between the dominant mode TE_{11} and the secondary mode TE_{12} excited therein.

From the foregoing, it is seen that the present invention provides a mode generator wherein a secondary mode such as TE_{12} is not only excited from a dominant mode such as TE_{11}, but the relative amplitudes of such modes are conveniently controllable. Such control is accomplished by limiting the distance between the discontinuity surface **32** and the end of the control section **40** through which energy propagates, namely, the distance indicated by arrow **45** to be related to the guide wavelengths of the modes to be controlled.

The invention has been described in conjunction with a cylindrical waveguide mode generator wherein the relative amplitudes of a dominant mode and a simple secondary mode excited therefrom are controlled. However, it is apparent to those familiar with the art that the teachings disclosed herein are not limited to a cylindrical waveguide mode generator. The control element **40** may similarly be incorporated in other generators such as square or rectangular. Also, the generator need not be limited to exciting and controlling modes TE_{11} and TE_{12}. Rather, the generator of the invention may be used to control the relative amplitudes of other modes. For example, the relative amplitudes of modes TM_{11} and TM_{12} described hereinbefore, the only requirement being that the modes be interrelated.

There has accordingly been shown and described herein, a novel and useful mode generator wherein the relative amplitudes of a mode excited from a primary mode are controllable. Such control is extremely useful in the shaping of beams, in particular, and in the radiation of microwave energy in general.

What is claimed is:

1. In a waveguide mode generator wherein energy supplied in a dominant mode is excited to produce energy in a secondary order mode related thereto the improvement comprising a first cylindrical waveguide section to which said energy is supplied in said dominant mode, having a diameter sufficiently large to enable the energy in said dominant mode to propagate therethrough; a second cylindrical waveguide section having a diameter greater than the diameter of said first section coupled to said first section so as to produce a discontinuity therebetween; and a cylindrical control waveguide element positioned within said first waveguide section and extending into said second waveguide section said cylindrical control waveguide element having a diameter large enough for enabling the energy in said dominant mode to propagate into said second section through said element at a predetermined distance from said discontinuity to be excited therein so as to generate said secondary mode said distance being a function of the guide wavelengths of said dominant and secondary modes, so as to control the relative power of the energy in said modes propagating out of said second waveguide section.

2. In a waveguide mode generator wherein energy supplied in a dominant mode is excited to produce energy in a secondary mode related thereto, the improvement comprising a first waveguide section having a first diameter sufficiently large to enable energy in said secondary mode to be propagated therethrough, but small enough to suppress other higher order modes; a second waveguide section having a second diameter smaller and related to said first diameter, said second diameter being sufficient to propagate energy in said dominant mode therethrough, including means for coupling said second section to said first section so as to form a discontinuity therebetween; and a control waveguide section adjustably extendable into said first waveguide section from said second waveguide section for controlling the position from said discontinuity at which energy propagating through said second waveguide section enters said first waveguide section so as to control the relative amplitudes of energy in said dominant mode and said secondary mode generated therein.

3. In a waveguide mode generator as recited in claim 2 wherein each of said first, second and control waveguide sections are cylindrical in shape, said first diameter being sufficiently large to enable energy in mode TE_{12} to be excited therein from energy in mode TE_{11} propagating through said second waveguide section, and wherein the portion from said discontinuity at which energy in said TE_{11} mode enters into said first waveguide section is related to the guide wavelengths of said TE_{11} and TE_{12} modes.

4. In combination with a waveguide mode generator having a discontinuity between first and second waveguide sections so that at least one secondary mode is excited from a dominant mode propagating through said first section into said second section, a control element selectively positionable within said first section with a portion thereof extending into said second section so as to control the relative amplitudes of said dominant and secondary modes in said second section, as a function of the relative position of said control element in said second section from said discontinuity.

5. In combination with a waveguide mode generator having a first cylindrical waveguide section through which energy in a first dominant mode propagates and a second cylindrical waveguide section coupled to said first section so as to form a discontinuity for generating a selected secondary mode related to said dominant mode, a cylindrical control member adjustably positioned in said first section, having a selected portion thereof extend into said second waveguide section to an extent related to the guide wavelengths of said dominant and secondary mode so as to affect the relative amplitudes of the dominant and secondary modes propagating in said second cylindrical waveguide section.

6. In a waveguide mode generator wherein energy supplied in a dominant mode is excited to produce energy in said dominant mode and in at least one secondary mode related thereto, the arrangement comprising a source of energy in a dominant mode; a first waveguide section having a first internal dimension; means for connecting said source of energy to said first waveguide section for supplying said energy thereto, said first dimension of said first section being sufficiently large to enable energy in said dominant mode to propagate through said first section; a second waveguide section having a second dimension greater than said first dimension for exciting said dominant and secondary modes connected to said first section so as to form a waveguide discontinuity surface therebetween; a control waveguide section having a third dimension mounted within said first section and having a portion along the longitudinal axis thereof extending into said second section for controlling the position within said second section at which energy in said dominant mode propagating through said first section and control section enters said second section, so as to control the amplitude relationship between said dominant and secondary modes excited in said second section.

7. In a waveguide mode generator wherein energy supplied in a dominant mode is excited to produce energy in said dominant mode and in at least one secondary mode related thereto, the arrangement comprising a source of energy in a dominant mode; a first cylindrical waveguide section having a first diameter; means for connecting said source of energy to said first waveguide section for supplying said energy thereto, said first diameter of said first section being sufficiently large to enable energy in said dominant mode to propagate through said first section; a second cylindrical waveguide section having a second diameter greater than said first diameter for exciting said dominant and secondary modes connected to said first section so as to form a waveguide discontinuity surface therebetween; a cylindrical control waveguide section having a third diameter mounted within said first section and having a portion along the longitudinal axis thereof extending into said second section at which energy in said dominant mode propagating through said first section and control section enters said second section, so as to control the amplitude relationship between said dominant and secondary modes excited in said second section.

8. In a waveguide mode generator as recited in claim 7 wherein said dominant mode is TE_{11} and said second diameter is large enough so that modes TM_{11} and TE_{12} are excited in said second section, said portion of said control section extending into said second section being related to the guide wavelengths of modes TE_{11} and TE_{12} so as to control the relative amplitudes of the energy in modes TE_{11} and TE_{12} which are excited in said second section.

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