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APPARATUS FOR SEGREGATING HARMONIC POWER IN A WAVEGUIDE SYSTEM

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2 Sheets-Sheet 1

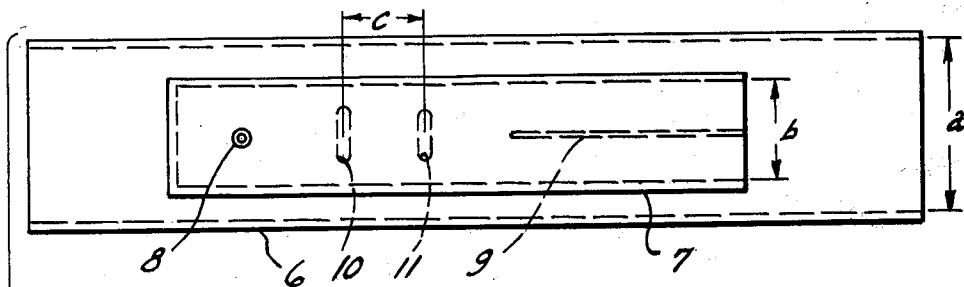


Fig. 1

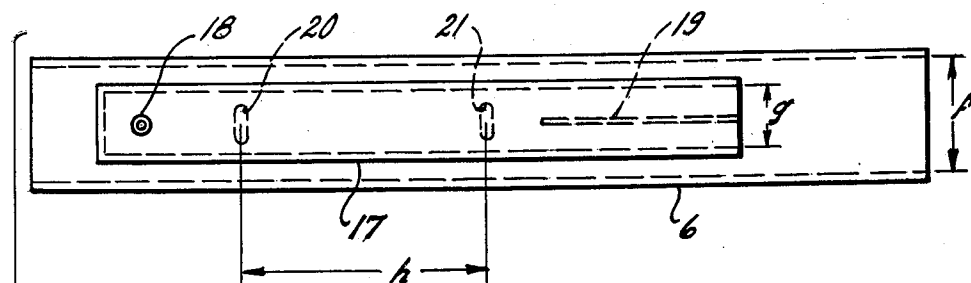
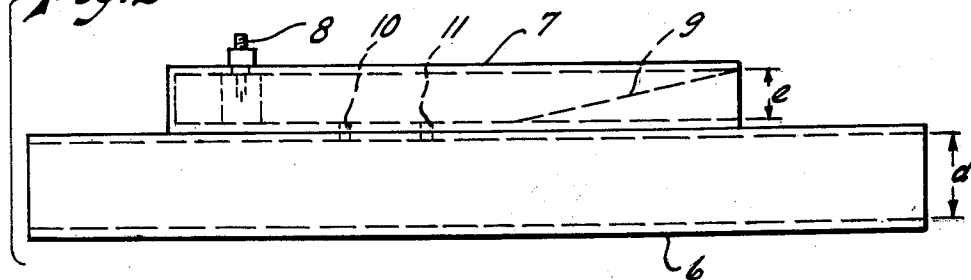
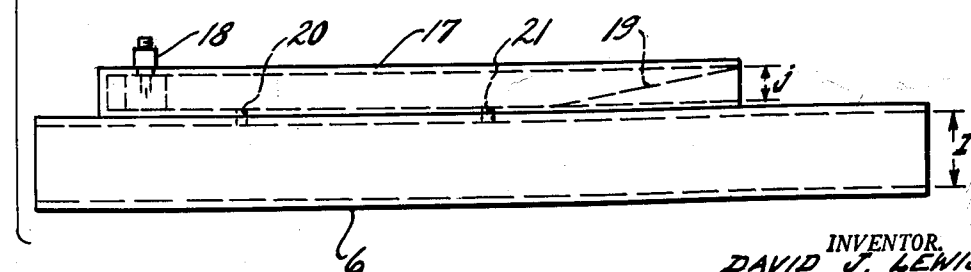


Fig. 2



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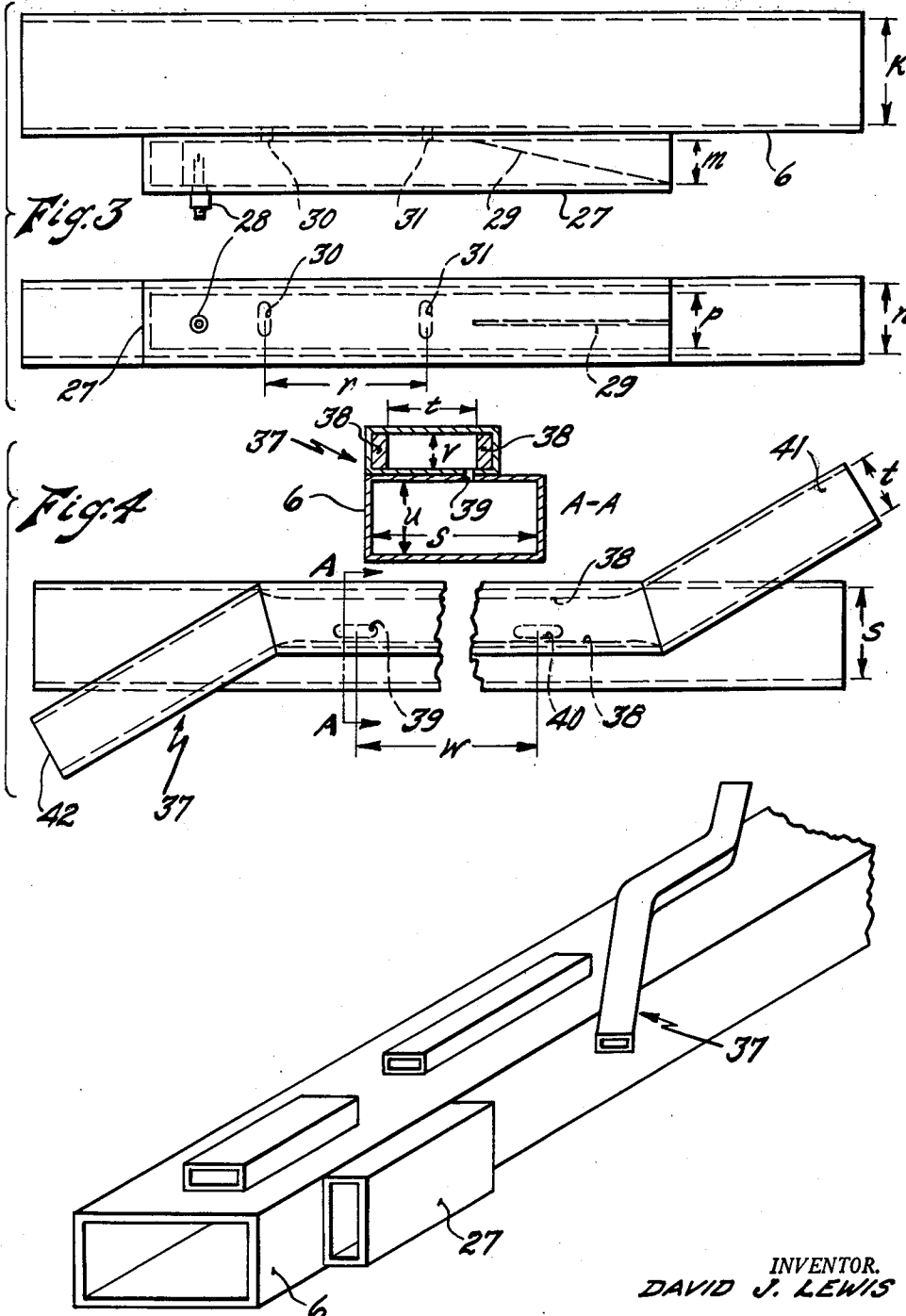


Fig. 5

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APPARATUS FOR SEGREGATING HARMONIC POWER IN A WAVEGUIDE SYSTEM

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5 Claims. (Cl. 333—6)

This invention relates to waveguide transmission systems for the transmission of electrical wave energy and more particularly to the segregation of the total energy being propagated at any discrete harmonic frequency of the fundamental wave in a waveguide system.

The theory relating to electromagnetic propagation in wave-guides is well established in the microwave transmission art, therefore, only such basic principles as are germane to the present invention will be recited here.

Any hollow rectangular wave guide may propagate energy by an infinite number of possible modes which are characterized by particular field configurations. The configuration of such fields within the wave guide must be a solution of Maxwell's equations and satisfy the boundary conditions.

The possible modes may be further divided into two fundamental types. In the first type, the electric field lies in a plane at right angles to the longitudinal axis of the guide and has no component anywhere in the direction of said longitudinal axis, while the magnetic field at the same time has components in the direction of said longitudinal axis as well as at right angles to it. These wave, are termed transverse electric or TE waves. In the second type the electric field has components in the direction of the longitudinal axis and the magnetic field is everywhere only transverse to said longitudinal axis. These waves are termed transverse magnetic or TM waves.

The different types of configuration under each class are designated by the subscripts mn where m represents the number of half period variations of the transverse component encountered in passing across the width of the wave-guide cross-section and n represents the number of half periods of transverse components encountered in passing across the height of the wave guide. As an example, TE_{10} ($m=1$, $n=0$) represents a wave having a one half electric field variation across the width of the guide, and since the field is uniform there is no variation across the height of the guide.

It is also noted that a wave guide acts as a high pass filter and has a cut-off frequency determined by the dimensions of the guide and the particular field configurations involved. All waves having a frequency higher than the cut-off frequency will be propagated down the wave guide with the resultant transmission of energy.

The preferred mode of operation of a wave guide is at the lowest cut-off frequency. This is called the dominant mode and has the longest cut-off wave length of an infinite series of possible field configurations that can be propagated down the wave guide. The next higher modes include waves of both the transverse magnetic type and the transverse electric type. These higher order modes are ordinarily produced whenever energy is delivered to or abstracted from a wave guide.

It is oftentimes necessary in the microwave art to measure the energy present in some discrete harmonic of the fundamental wave being propagated in a waveguide system. The measurement of energy in such a harmonic is complicated by the fact that energy is propagated in every mode consistent with the frequency and the waveguide dimensions. Conventional means for coupling to a primary waveguide to measure the energy of a particular harmonic usually results in coupling to

several modes simultaneously thereby making useful and reliable measurement impossible.

Accordingly a primary object of the invention is to teach a novel and improved method of segregating the energy in any particular harmonic wave being propagated in a waveguide system. The method aspects of the invention are claimed in my co-pending application, Serial No. 235,900, filed November 6, 1962.

Another object of the present invention is to provide novel apparatus with which the energy of any harmonic being propagated in a waveguide system may be segregated.

These and other objects will become apparent from the following specifications and illustrations of which:

FIG. 1 illustrates a plan and side view of one auxiliary waveguide used in one embodiment of my invention.

FIG. 2 illustrates a plan and side view of a second auxiliary waveguide used in said embodiment of my invention.

FIG. 3 illustrates a plan and side view of a third auxiliary waveguide used in said embodiment of my invention.

FIG. 4 illustrates a plan and side view of a fourth auxiliary waveguide used in said embodiment of my invention.

FIG. 5 illustrates an isometric view of said embodiment of my invention in which all of said auxiliary waveguides are shown in their proper relation to the primary waveguide.

I have discovered that the total energy propagated in a rectangular waveguide by any harmonic wave or by any discrete group of modes other than the dominant mode may be determined by measuring separately the energy in each constituent mode of said discrete group of modes and summing the results either electronically or analytically.

My invention comprises apparatus designed to segregate, for the purpose of measurement the energy present in each discrete mode of a preselected group of modes propagating in a rectangular waveguide. A novel combination of mode suppression devices and techniques ensures accurate detection of the energy propagated in the desired mode only, with all unwanted modes being effectively rejected.

The subject measuring apparatus consists of a plurality of secondary waveguides, said secondary waveguides having particular geometric configurations and means for coupling to the primary waveguide in accordance with the principles of my invention as hereinafter described.

A certain amount of selectivity of the modes which will propagate in a given waveguide is possible by taking advantage of the electromagnetic field configuration to discriminate against one or more modes of propagation.

In a rectangular waveguide for any particular mode of transmission the cut-off wavelength λ_c is given in terms of the waveguide dimensions a (width) and b (height) by

$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}} \quad (1)$$

In this formula m and n are the subscripts denoting the particular mode under consideration. The equation holds for either TE or TM modes of transmission.

The dimensions of the aforementioned secondary waveguides are therefore determined for any given mode by the solution of Equation 1.

Further selectivity is possible by orienting the apertures which couple said secondary waveguides to the primary waveguide in the manner taught by the present inven-

tion wherein either transverse magnetic or transverse electric modes are admitted.

A hole or aperture in a waveguide wall will enable energy to leak from the guide into space or another guide or cavity. The coupling thus introduced by a hole or aperture in the guide wall may be either to the electric or magnetic fields. Electric coupling occurs when electrostatic flux lines that would normally terminate on the guide wall are able to pass through the hole. Magnetic coupling results when the hole interferes with the current flowing in the guide wall. The nature and magnitude of the coupling in any particular case depend upon the size, shape, and orientation of the coupling hole. An elongated slot which is oriented transverse to the magnetic field inside the primary waveguide produces a minimum of interference with current in the guide wall and introduces little or no magnetic coupling. It will, however, readily permit electric coupling. An elongated slot which is orientated parallel to the magnetic field in the primary waveguide on the other hand permits easy escape of magnetic flux lines and interferes to a maximum extent with the guide wall current. Coupling in this manner permits maximum magnetic coupling while causing little or no electric coupling.

Still further selectivity is possible by applying the well known duplexing principle to phase out unwanted modes. This is accomplished in the present invention by the use of two coupling apertures being so located with respect to each other that unwanted modes admitted by the said coupling apertures are in phase opposition and cancel out.

The foregoing principles have been applied in the specific embodiment of my invention as herein described and while said specific embodiment relates to apparatus adapted to determine the second harmonic energy present in the TE_{10} , TE_{20} , TE_{11} and TM_{11} modes of an S band rectangular waveguide my invention is not to be taken as being limited thereto.

Since substantially all of the second harmonic energy in an S band rectangular waveguide will travel in the TE_{10} , TE_{20} , TE_{01} , and TM_{11} modes an accurate measurement of said energy is obtained, in accordance with my invention, by the application of secondary waveguides illustrated in FIGURES 1-5.

FIGURE 1 illustrates auxiliary waveguide 7 which is coupled to primary waveguide 6 by elongated coupling apertures 10 and 11. Auxiliary waveguide 7 is dimensioned such that the fundamental mode present in primary waveguide 6 is rejected. Coupling apertures 10 and 11 are oriented to admit only energy present in the TM_{11} mode to auxiliary waveguide 7. In the instant embodiment of the invention dimension a has been determined to be 2.84", b to be 1.216", c to be 2.54", d to be 1.34", and e to be .872". To prevent reflection of said TM_{11} mode back into primary waveguide 6 auxiliary waveguide 7 is terminated with absorbing material 9. Said absorbing material may be polycron, aquadag or any equivalent microwave attenuating material. Measurement of TM_{11} energy present in auxiliary waveguide 7 is made through coaxial to waveguide coupler 8.

FIGURE 2 illustrates auxiliary waveguide 17 having coupling apertures 20 and 21, termination absorbing material 19 and coaxial to waveguide coupling 18. The dimensions of auxiliary waveguide 17 and orientation of coupling apertures 20 and 21 are such that the TE_{10} mode is coupled to the auxiliary waveguide while all others are rejected. In the instant embodiment of the invention dimension f has been determined to be 2.84", g to be 1.612", h to be 12.31", j to be .872", and i to be 1.34".

FIGURE 3 illustrates auxiliary waveguide 27 having coupling apertures 30 and 31, termination absorbing material 29 and coaxial to waveguide coupling 28. Said auxiliary waveguide 27 as illustrated couples strongly to the TE_{11} mode. Dimension k has been determined to

be 2.84", m to be .872", n to be 1.34", p to be 1.216" and r to be 9".

FIGURE 4 illustrates auxiliary waveguide 37 having coupling apertures 39 and 40, termination absorbing material 38 and output ports 41 and 42. Auxiliary waveguide 37 couples to both TE_{20} and TE_{01} modes depending upon which output port is used. Dimension t has been determined to be 1.872", u to be 1.34", s to be 2.84", v to be .872", and w to be 19.89".

FIGURE 5 presents an isometric view of primary waveguide 6 showing the relative location of auxiliary waveguides 7, 17, 27 and 37.

The outputs of auxiliary waveguides 7, 17, 27 and 37 may be taken by any conventional means and summed either analytically or electronically to determine the total second harmonic energy present in the primary waveguide system.

It is to be understood that the above-described arrangement is illustrative of the principles of my invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. Apparatus for simultaneous segregation of a plurality of different modes present in the total second harmonic energy being propagated by a preselected group of modes in a waveguide transmission system comprising a primary waveguide constituting the principal energy conducting path for said total energy entering said waveguide and also comprising a waveguide for each mode in said group of modes, each of said waveguides having a geometrical configuration based on a particular second harmonic of the fundamental wave being propagated adapted to propagate a different mode of said group of modes, and two irises coupling each of said waveguides to said waveguide transmission system, said irises being positioned to admit each mode of said group of modes to the particular waveguide adapted to propagate said mode while retaining in said primary waveguide all components of the harmonic wave other than those components conforming to said diverted modes.

2. Apparatus to segregate the second harmonic energy present in any discrete harmonic wave propagating in a microwave transmission system comprising a primary waveguide constituting the principal energy conducting path for any said discrete harmonic wave entering said waveguide and being compatible to said microwave transmission system having a plurality of auxiliary waveguides affixed thereto, the dimensions of each of said auxiliary waveguides being predetermined based on a particular second harmonic of the fundamental wave being propagated in said primary waveguide, each of said auxiliary waveguides having a cutoff frequency greater than the cutoff frequency of said primary waveguide, and two elongated apertures coupling each of said auxiliary waveguides to said primary waveguide, said elongated apertures being located to admit energy from each discrete constituent mode of the second harmonic being measured to the auxiliary waveguide adapted to propagate said constituent mode while retaining in said primary waveguide all components of the harmonic wave other than those components conforming to said diverted modes.

3. Apparatus for simultaneous segregation of a plurality of different modes present in the energy present in a particular second harmonic wave propagating in a primary rectangular waveguide constituting the principal energy conducting path for said particular harmonic wave entering said waveguide comprising a plurality of auxiliary rectangular waveguides each of said auxiliary rectangular waveguides having dimensions based on a particular mode of the fundamental wave being propagated in said primary waveguide and so adapted to propagate a different mode of the group of modes which constitute said particular harmonic wave, said auxiliary rectangular waveguides being contiguous to said rectangular wave-

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guide and coupled thereto by iris coupling means, said iris coupling means consisting of two elongated apertures located between each auxiliary rectangular waveguide and said rectangular waveguide and oriented to admit each mode of said group of modes to the particular waveguide adapted to propagate said mode while retaining in said primary waveguide all components of the harmonic wave other than those components conforming to said diverted modes.

4. Apparatus to segregate the second harmonic energy present in an S band rectangular waveguide comprising a primary rectangular waveguide having dimensions adapted to propagate energy at S band frequencies, a first auxiliary rectangular waveguide contiguous to one broad wall thereof, having two coupling slots therebetween and dimensions adapted to admit and support the TM_{11} mode of propagation, a second auxiliary rectangular waveguide contiguous to one broad wall of said primary rectangular waveguide having two coupling slots therebetween and dimensions adapted to admit and support the TE_{10} mode of propagation, a third auxiliary rectangular waveguide contiguous to one broad wall of said primary rectangular waveguide having coupling slots therebetween and dimension adapted to admit and support the TE_{20} mode of operation, a fourth auxiliary rectangular wave guide contiguous to one narrow wall of said primary rectangular waveguide having coupling slots therebetween and dimensions adapted to admit and support the TM_{11} mode of operation, and means for terminating said auxiliary rectangular waveguides in their characteristic impedances.

5. Apparatus for a simultaneous segregation of a plu-

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ality of different modes present in a second harmonic wave in a waveguide transmission system for the transmission of electrical wave energy comprising a primary waveguide having dimensions adapted to propagate energy of a harmonic wave of the fundamental wave constituting the only source of energy entering said primary waveguide, a plurality of auxiliary waveguides contiguous to said primary waveguide, each of said plurality of auxiliary waveguides having two mode selecting coupling slots between each particular auxiliary waveguide and said primary waveguide, each auxiliary waveguide also having dimensions based on a particular second harmonic of the fundamental wave being propagated in said primary waveguide and thereby adapted to admit and support the selected mode of propagation, and means for terminating said auxiliary waveguides in their characteristic impedances while retaining in said primary waveguide all components of the harmonic wave other than those components conforming to said diverted modes.

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