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2,760,171

WAVE-GUIDE MODE FILTER

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FIG. 1

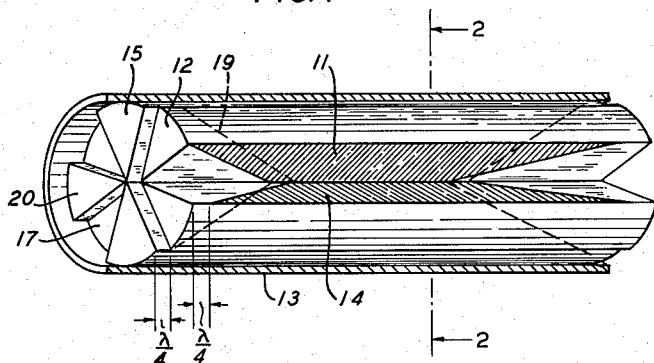


FIG. 2

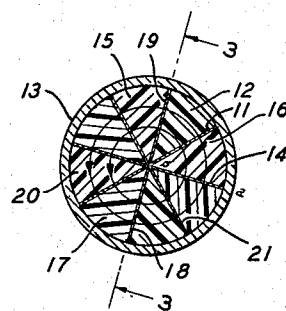


FIG. 3

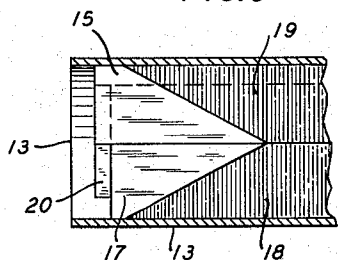


FIG. 4

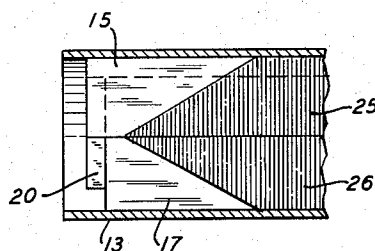


FIG. 5

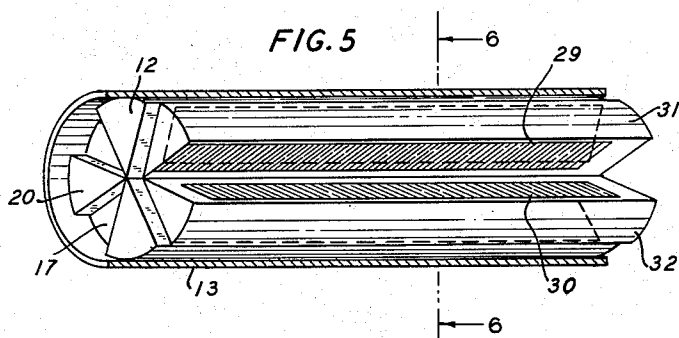
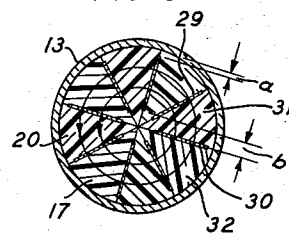


FIG. 6



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WAVE-GUIDE MODE FILTER

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7 Claims. (Cl. 333-98)

This application is a continuation in part of my copending application Serial No. 135,759, filed December 29, 1949, United States Patent 2,656,513 granted October 20, 1953, for Wave Guide Transducer, and relates to wave transmission systems for the transmission of electromagnetic microwaves through hollow metallic wave guides and more particularly, to the separation of guided waves of one mode from those of another.

Such guided waves, as is well known in the microwave transmission art, are capable of transmission in an infinitely large number of forms or modes, each mode being distinguished by the characteristic configuration of the component electric and magnetic fields comprising the waves.

These waves have been divided into two broad classes. In one class the electric component of the wave is transverse to the metallic pipe guide, and at no point does it have a longitudinal component. The magnetic component, on the other hand, has both transverse and longitudinal components. This class has been designated as "transverse electric" waves or TE waves. In the other class, the magnetic component is transverse to the pipe and at no point does it have a longitudinal component, but the electric component has in general both transverse and longitudinal components. This class has been designated as "transverse magnetic" waves or TM waves.

The waves in each of these classes have been further identified and distinguished from each other by their mode or the pattern of wave energy distribution as it appears in the cross-section of the wave guide. A complete discussion of wave mode may be found in any standard textbook of microwaves and microwave guides. For the purpose of the present disclosure, the usual convention is herein adopted of designating a transverse electric wave TE_{mn} where, in a rectangular wave guide, 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; and in a circular or cylindrical wave guide, m represents the number of whole periods of the transverse component encountered in running around the circumference of the cross-section, and n represents the number of half periods encountered in passing along the radius of the wave-guide cross-section. For example, in a rectangular wave guide, TE_{10} represents a wave having a one-half electric period variation across the width of the guide, and, since the field is uniform, there is no variation across the height of the guide. This is commonly known as the dominant mode wave.

Likewise, in a cylindrical wave guide, TE_{01} represents a wave whose electric field is wholly tangential and forms a series of circles concentric with the axis, and wherein no variations in the electric field are encountered around the circumference of the cross-section, but rather, a one-half period is encountered along the radius thereof. This latter wave mode is commonly known as a circular electric wave.

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It is a particular object of the present invention to convert multimode wave power to substantially pure wave power of the circular electric mode by filtering or absorbing therefrom spurious mode power having an undesirable form.

It is a further object of the present invention to dissipate electrical wave power having electrical mode configurations different from the mode configurations of the circular electrical wave.

The nature of the present invention, its various objects, features, and advantages, will appear more fully upon consideration of the embodiments illustrated in the accompanying drawings and the following detailed description thereof.

In the drawings:

Fig. 1 shows in detail a perspective view of one form of the spurious mode absorber in accordance with the invention;

Fig. 2 shows a cross-sectional view of Fig. 1 as indicated;

Fig. 3 shows a cross-sectional view of Figs. 1 and 2 as indicated on Fig. 2;

Fig. 4 illustrates an alternate embodiment of the invention taken in cross-sectional view at the position of Fig. 3;

Fig. 5 shows in a perspective view a refined embodiment of the spurious mode wave absorber in accordance with the invention; and

Fig. 6 shows the cross-sectional view of Fig. 5 as indicated.

In general, the spurious mode wave absorber comprises a plurality of thin vanes of resistive material disposed radially in a circular wave-guide section in such a way that the plane surface of the resistive material is normal to the lines of electrical field of a circular electric wave. This particular field distribution is, therefore, unaffected by the resistive material while other field distributions induce electrical currents in the material and are thereby dissipated. Certain refinements, in accordance with the invention, will be shown relating to the shape of and means for supporting the vanes to improve the characteristics of the absorber in the manner to be described.

While the spurious mode wave absorber is of importance in absorbing spurious modes generated by a circular electric wave transducer as shown and described in the above-mentioned copending application, it is by no means limited to this application. Spurious modes may arise as the result of an imperfect transmission line due to small deviations from circularity or slight impedance irregularities in the line. Further, they may be developed by terminal devices, tapers, or other components which introduce either by reflection or by transmission, modes other than the desired one. In each of these cases the spurious mode power may be suppressed by the use of the absorber employed in conjunction with the device tending to produce the undesired modes.

To insure complete elimination of the spurious modes, the reflection coefficient of the absorber should be low; otherwise the reflected component may produce undesired mode interference effects. At the same time it is required that the effect on the desired mode, in this case the TE_{01} , be a minimum, or that the attenuation of the TE_{01} wave be a small value. Further, the spurious mode wave absorber should possess the additional characteristic that no new modes are introduced or that one spurious mode will not be converted into another mode. These factors are all substantially met in the spurious mode absorbers now to be shown and described in detail.

Fig. 1, and its cross-sectional views, Figs. 2 and 3, each taken as indicated on the drawing, illustrate one form of novel and advantageous construction of a spurious mode wave absorber in accordance with the invention. Casing 13 is a section of a circular wave guide

constructed of an electrically conductive material. Radially disposed in guide 13 and symmetrically arranged about the axis thereof are a plurality of resistive film cards or vanes such as 11, 14, 18 and 19, each extending in its transverse dimension from the axis of guide 13 to the inner surface of guide 13 and extending in its longitudinal dimension along a length of guide 13. These cards or vanes are very thin sheets of low dielectric material, for example, polystyrene, coated with a film of resistive material, for example, carbon black. The thickness of the cards may be of the order of 0.003 inch and they should have a resistivity in the range of 100 to 1000 ohms per square inch of surface.

To improve the matching of the absorber to the coupled transmission system and to reduce the reflection coefficient, the resistive cards may be staggered in the guide, alternate cards being offset from the remainder by one-quarter wavelength of the mean frequency of the waves to be conducted by the absorber. Thus, as shown in Fig. 1, cards 11, 21, etc. are located one-quarter wavelength to the left of the alternate cards 14, 18, 19, etc. When employing this staggered feature, it will be desirable to use an even number of cards. The exact number of cards required depends in general upon the highest order sectorial wave to be absorbed. For example, in the case of a TE_{21} wave where the electrical configuration is repeated in four quadrants of the guide cross-section, preferably eight or more cards should be used. For a TE_{41} wave in which the electric configuration is repeated eight times around the circumference, at least sixteen cards should be used. In general, a much larger number of cards than the apparent minimum should be used to assure complete cancellation of all higher order modes.

The thin resistive cards, such as 11, 14, 18, 19 and 21, are held in place sandwichwise between wedge-shaped or sectorial cross-sectioned supporting spacers, such as 12, 15, 16, 17, 20, etc. For example, resistive card 11 is held between the surfaces of spacers 12 and 16, and resistive card 19 is held between the surfaces of spacers 12 and 15. This is clearly seen in the cross-sectional view of Fig. 2. The spacers are made of any material of low dielectric constant. The plastic materials of polyfoam or styrofoam have proven satisfactory.

In order to improve the TE_{01} impedance match and to lower the reflection coefficient, the spacers are staggered one-quarter wavelength in the manner of resistive cards. As shown in Fig. 1 and the cross-sectional view of Fig. 3, spacers 15 and 20 are located one-quarter wavelength to the left of spacers 12 and 17, respectively, and the other spacers are arranged in like manner alternately around the guide.

Even though the resistive cards are very thin and are constructed from material of very small dielectric constant, there will be a certain amount of reflection from the edges of each card. This effect is, of course, minimized by the quarter wave staggering described above. It may be further minimized by tapering the edges of each card over a distance of several wavelengths, thus making the flat plane of each card a trapezoidal shape. This is most clearly seen in the cross-sectional view of Fig. 3 which is taken through the resistive fins 18 and 19 and shows one of the tapered radial end portions of cards 18 and 19. Cards 18 and 19 are disposed in the wave guide 13 with the longer of the trapezoidal bases adjacent to the inner surface of wave guide 13, and the shorter of the bases at the center, along the axis thereof.

Fig. 4 shows an alternative taper arrangement for the resistive cards and may be considered as a modified view of Fig. 1 taken at the position of and in substitution of the cross-sectional view of Fig. 3. In Fig. 4 resistive cards 25 and 26 are shown as trapezoidal shaped and disposed in guide 13 with the shorter base of the trapezoid located adjacent to the inner surface of guide 13 and the longer base at the center along the axis of guide 13.

Numerous other card shapes may be employed with similar effect and improvement. For example, instead of a linear taper, a curved radial end would serve to minimize reflection, the important principle being that each point of the radial edge appears at a different position along the length of guide 13 so that reflections from one point will be in phase opposition with a reflection from some other point and thus, the total reflection will be cancelled. Whether the disposition shown in Fig. 3 or the disposition shown in Fig. 4 is employed, the cards should be of such total longitudinal dimension that either of the trapezoidal bases will extend along the axis of wave guide 13 for several wavelengths.

The operation of the spurious mode absorber depends on the electric field distribution of the desired TE_{01} mode relative to the undesired modes. The electric field of the TE_{01} wave is circular, having only tangential electric field components which are limited to the transverse plane, as shown on Fig. 2. This is also true of the higher order circular electric waves. If therefore a thin strip of resistive material, such as card 14, is placed radially along the line Oa as shown on Fig. 2, it will lie along equipotentials of the electric field and will absorb only a negligible amount of power. When such a strip is extended longitudinally along the guide, the performance remains the same for all similar electric wave components. The transverse waves, such as the TE_{11} , have transverse and/or radial components of electric field. Such fields will induce currents in the resistive strip and thereby dissipate the wave power. Also TM waves which have longitudinal electric fields will cause a current to flow longitudinally in the card and will also be dissipated thereby.

Having thus described the principles of the invention with reference to a specific embodiment, certain refinements thereof may be pointed out which are of particular application when the spurious mode absorbers of the type described are employed at very high frequencies in small diameter wave guides. When a large plurality of resistive cards of the type described are disposed in the smaller wave guides, there results a large concentration of both dielectric and resistive material in the center area of the wave guide. The concentration of dielectric material tends to distort the field configuration of the TE_{01} wave and to introduce new or spurious modes.

A further difficulty presents itself at very high frequencies in small guides in that it is extremely difficult to maintain a uniform electrical contact between the longitudinal edge of a very thin resistive card and the inner wall of the wave guide at each and every point along the longitudinal length of several wavelengths. If the cards at one point are in contact with the inner surface and not at another, the transmission line becomes asymmetrical and tends to introduce transmission loss to the circular electric wave.

Both of these difficulties are overcome in the refined embodiment of the invention shown in Fig. 5. The resistive cards, such as 29 and 30 of Fig. 5, are disposed in wave guide 13 and supported in small recesses in the radial faces of the spacers, for example, spacers 31 and 32, in a similar manner to that described with reference to Figs. 1, 2 and 3 above. Resistive cards, for example, cards 29 and 30, have a transverse dimension, i. e., a dimension along the radius of guide 13 which is somewhat shorter than the radius of the guide. This dimension is sufficiently shorter than the guide radius that cards 29 and 30 may be centered along the radius in such a manner as to leave a small gap, for example, one per cent of one wavelength, between the outer longitudinal edge of the card and the inner surface of guide 13, and a center gap, for example, in the range of one-quarter of a wavelength, between the axis of guide 13 and the inner longitudinal edge of the card. This is most readily seen in the cross-sectional view of Fig. 6, taken at the position indicated on Fig. 5. Thus, the small gap at wave-guide wall 13 is

indicated by the dimension a and the larger gap at the center is indicated by the dimension b . Since the undesirable spurious modes have longitudinal and transverse components distributed throughout the guide as well as in the center portion and the portion immediately adjacent to the wave-guide wall, a resistive film extending partially along the radius is substantially as effective in absorbing these waves as one extending along the entire radius. Thus, the unnecessary dielectric material from the center section of the wave guide has been removed in the embodiment of Fig. 6, removing the distorting concentration of dielectric material. The unnecessary portion of the resistive film at the outside edge is removed and this eliminates the possibility of uneven contact between the cards and the inner surfaces of the guide, providing instead the uniform clearance of gap a .

The cards 29 and 30 of Fig. 6 have been illustrated as rectangular, but it should be apparent that the tapered cards of Figs. 3 and 4 or the curved cards above-mentioned, may likewise be employed in the embodiment of Fig. 6 in order to reduce the reflection of wave energy from the radial edges of the cards.

In wave guides of relatively large diameter it is possible to use resistive cards of sufficient thickness as to be self-supporting and to eliminate the supporting spacers. For this purpose the cards may be in the order of 0.025 inch thick. In many of the smaller wave-guide sizes, the effect of the dielectric constant of the thick strips becomes appreciable and thus tends to introduce higher order circular electric waves. In these cases it is preferable to use the thin, supported cards.

In all cases, it is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In a transmission system for electromagnetic waves having transverse electrical field components and waves having circular electric field components, a section of shielded transmission line, a plurality of resistive surfaces disposed within said shield, said surfaces each being normal to the electrical components of said circular electric waves, said surfaces extending several wavelengths along the longitudinal length of said shield and dividing a given transverse cross-section of said shield into a multiplicity of sectors.

2. In a transmission system for electromagnetic waves having transverse electrical field components and waves having circular electrical field components, a section of shielded transmission line of circular cross-section, a multiplicity of resistive surfaces disposed within said shield, the longitudinal dimension of each of said surfaces extending several wavelengths along the length of said shield, the transverse dimension of each of said surfaces extending radially within said shield.

3. The combination in accordance with claim 2, wherein said transverse dimension of each of said surfaces is equal to the radial dimension of said shield.

4. The combination in accordance with claim 2, wherein said transverse dimension of each of said surfaces is less than the radial dimension of said shield.

5. In combination, a length of wave guide of circular cross-section, a plurality of electrically resistive films radially disposed in said guide and arranged symmetrically about the axis of said guide, and a plurality of low-dielectric constant spacers each having a transverse sectorial cross-section included between said films, said films being supported sandwichwise between adjacent spacers, alternate spacers of said plurality being offset one-quarter wavelength along said axis from the remainder of said spacers.

6. In a transmission system for electromagnetic waves having transverse electrical field components and waves having circular electrical field components, a section of shielded transmission line of circular cross-section, a plurality of low-dielectric constant vanes disposed within said shield, the longitudinal dimension of each of said vanes extending several wavelengths along the length of said shield, the transverse dimension of each of said vanes extending radially within said shield, the radial edges of each of said vanes forming an acute angle with the axis of said shield, and a thin coating of electrically resistive material upon a surface of each of said vanes.

7. Means for substantially absorbing electromagnetic wave power having transverse electrical field components comprising, a length of wave guide of circular cross-section, a plurality of trapezoidally-shaped low-dielectric constant vanes radially disposed in said guide and arranged symmetrically about the longitudinal axis thereof, said vanes having a thin coating of electrically resistive material.

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