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J. F. McSPARRAN
VARIABLE ATTENUATOR
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3,273,084

Fig. 1.

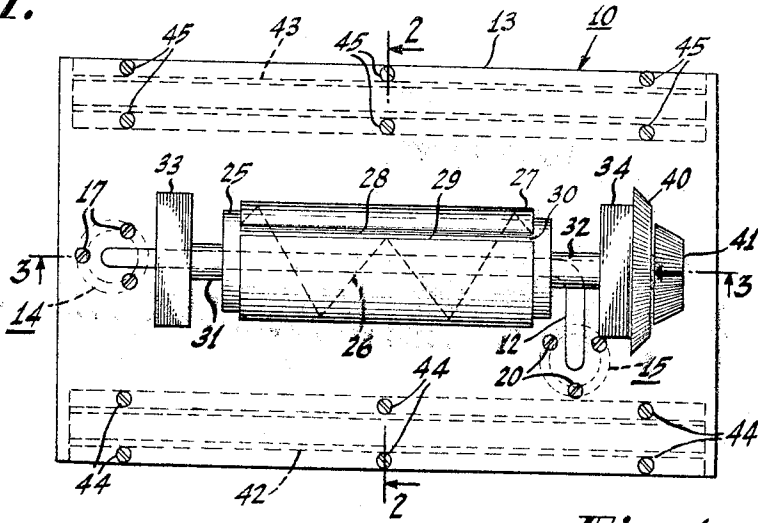


Fig. 2.

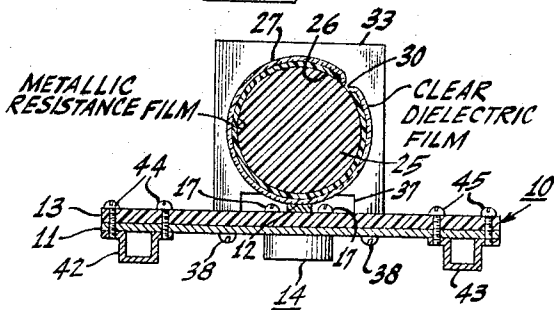


Fig. 4.

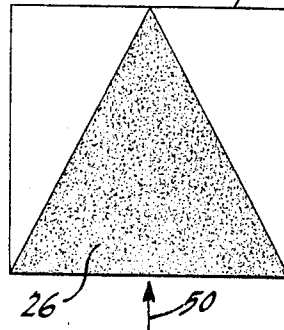


Fig. 5.

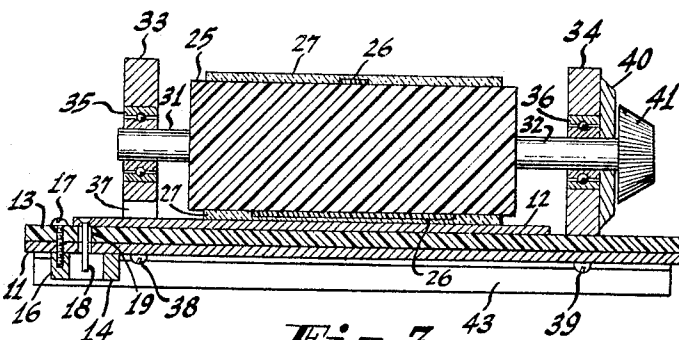
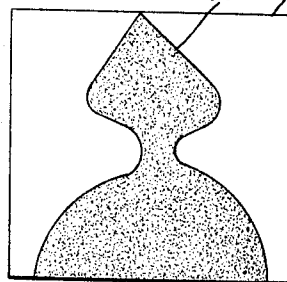


Fig. 3.

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VARIABLE ATTENUATOR

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This invention relates to radio frequency attenuators and particularly to a variable attenuator adapted for use with microwave printed circuit or strip transmission lines.

Strip transmission lines are commonly employed for the propagation of high and ultra high RF (radio frequency) energy. Such lines comprise a pair of conductors, one wider than the other, dielectrically spaced apart in parallel relation. The two conductors can be applied to a layer of dielectric material by known printed circuit techniques with one conductor taking the form of a planar conductor and the other a narrow flat ribbon-like line conductor.

Various types of variable attenuators have been suggested for use with strip transmission lines. Many of these attenuators employ a member of resistive material arranged for sliding movement relative to the narrow line conductor. The member is mounted and shaped so that more or less of the member can be made to intercept the fringe field of the narrow line conductor. The position of the adjustable member determines the effective resistance of the line conductor in the vicinity of the member and, therefore, the amount of attenuation imparted to RF energy propagated along the transmission line.

For the proper operation of such an attenuator, the resistive member should be mounted so that the physical relationship between the member and the line conductor in each position of adjustment remain the same. If the position of the member relative to the line conductor is not rigidly and accurately controlled, the attenuator can be operated only on a trial and error basis, making the attenuator virtually useless for many applications. In mounting the resistive member, provision should also be made to maintain the member substantially free of microphonics due to vibrations. The presence of microphonics tends to introduce amplitude distortion in RF energy propagated along the transmission line. The problem of avoiding microphonics is of particular importance in applications where a thin, plate-like resistive member is used. Springs, pressure rollers, guides and other structure have been used in attempts to mount the resistive member for stable and accurate operation, resulting in a construction which is often complex and costly.

It is an object of the invention, therefore, to provide an improved variable attenuator for use with strip transmission lines.

Another object is to provide an improved adjustable attenuator which is rugged, simple and easily constructed.

A further object is to provide an improved variable attenuator including a movable resistive member of a construction which makes the attenuator easy to adjust with accuracy while at the same time maintaining the member substantially free of microphonics due to vibrations.

Briefly, in the embodiment of the invention described herein, a form, preferably in the shape of a cylinder, having a film of resistive material positioned about its circumferential surface area is mounted over the narrow line conductor of a strip transmission line for rotation about an axis of the form. In one embodiment, the form is a cylinder constructed of a solid dielectric material, and is mounted so that its longitudinal axis is substantially parallel to and equally spaced from the line conductor axis, i.e., an imaginary line drawn along the center of the line conductor. The resistive film on the surface of the

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cylinder is formed in the proper configuration so that, as the cylinder is rotated about its cylindrical axis, the amount of resistive film to produce the degree of attenuation desired comes into proximity with the line conductor. The resulting construction is rugged and easy to operate, involving only a small number of moving parts. Since the resistive film is backed at all positions of adjustment by the thickness of the cylinder and since the shape of the cylinder facilitates a rigid and stable mounting for the cylinder, the resistive film and, therefore, the attenuator are substantially free from the effects of vibration.

A more detailed description of the invention will now be given in connection with the accompanying drawing, in which:

FIG. 1 is a top view in plan of a variable attenuator constructed according to one embodiment of the invention;

FIG. 2 is a cross-sectional view taken along line 2-2 of FIG. 1;

FIG. 3 is a cross-sectional view taken along line 3-3 of FIG. 1;

FIG. 4 is a plane view of the resistive member used in the embodiment of FIG. 1; and

FIG. 5 is a plane view of a further example of a resistive member usable in the embodiment of FIG. 1.

A strip transmission line 10 is shown in FIGS. 1, 2 and 3. The strip transmission line 10 includes a first or planar conductor 11, a second ribbon-like line conductor 12, and a layer of dielectric material in the form of a board 13 which separates the conductors 11 and 12. The board 13 may comprise polyethylene, polystyrene, polytetrafluorethylene identified as Teflon, fiber glass impregnated with Teflon or other suitable material of dielectric quality. The planar conductor 11 is formed by a bonded copper lamination, for example, which covers the lower surface area of the dielectric board 13. The line conductor 12 may comprise a flat copper strip two-tenths of an inch wide, for example, and of a definite thickness, for example, one or two mils. (thousandths of an inch). The copper strip can be applied to the upper surface of the flat dielectric board 13 by any of the known printed circuit techniques such as silk screening, electro-plating and/or etching. The thickness of the line conductor 12 and of the planar conductor 11 are exaggerated in the drawing for clarity. The conductors 11 and 12 are normally of a thin, film-like thickness relative to that of the flat dielectric board 13.

The line conductor 12 is terminated at one end in a coaxial connector 14 and at the other end in a second coaxial connector 15. As shown in the cross-sectional view of FIG. 3, the connector 14 includes an annular metallic ring 16 which can be threaded or otherwise arranged to receive a coaxial cable, not shown. The ring 16 is mounted on the planar conductor 11 by small threaded bolts 17 arranged to pass through the dielectric board 13 and the planar conductor 11 into matching holes provided in the ring 16. An inner metallic conductor 18 for the connector 14 passes through a hole 19 provided in the dielectric board 13 and planar conductor 11. The inner conductor 18 is soldered or otherwise connected at one end to the line conductor 12 for electrical conduction, the other end of the inner conductor 18 being positioned centrally of the ring 16. The hole 19 can be filled with Teflon or other suitable material, not shown, for properly insulating the inner conductor 18 from the planar conductor 11. In addition, suitable spacers or supports of insulating material, not shown, can be included in the ring 16 for rigidly positioning and supporting the inner conductor 18 within the connector 14. The connector 15 is identical to the connector 14 and is mounted on the planar conductor 11 by the bolts 20 shown in FIG. 1. While a particular connector 14 is

shown in FIG. 3 in cross-section for purposes of description, any desired type of coaxial connector 14 and 15 can be used according to the needs of the particular application.

In the operation of the strip transmission line 10, RF energy fed to one of the connectors, for example, connector 14, propagates along the transmission line 10 provided by the line conductor 12 and the planar conductor 11 to the other one of the connectors, for example, connector 15, from where the RF energy can be coupled to a utilization circuit. An electromagnetic field is distributed between the opposed surfaces of the conductors 11, 12 with a fringe field extending from the side and top portions of the line conductor 12 toward the planar conductor 11. A strip transmission line per se is known, and a detailed discussion of its operation is not deemed necessary.

A cylinder 25 constructed of dielectric material may be molded of glass cloth impregnated with high temperature thermosetting epoxy-resin or may be constructed in any other suitable manner. A resistive member (FIG. 4) is formed by evaporating or otherwise placing a thin but uniform metallic film of resistive material 26 on a thin, flexible, transparent sheet 27 constructed of dielectric material. The sheet 27 is, for example, .002 inch thick and can be formed of polyethylene terephthalate resin identified as Mylar or other suitable material. The resistive film may be in the order of millionths of an inch thick. The sheet 27 with the resistive film 26 placed thereon is wrapped around the cylinder 25 and can then be, for example, thermally bonded to the cylinder 25 with the resistive film 26 between the surface area of the cylinder 25 and the sheet 27.

The thickness of the sheet 27 and of the resistive film 26 are exaggerated in the drawing for purposes of illustration. From the dimensions given above by way of example, it is apparent that the actual thickness of the resistive film 26 and of the sheet 27 placed on the cylinder 25 can be made considerably smaller than indicated in the drawing. The width of the sheet 27 is determined so that it does not overlap the edges of the cylinder 25. The length of the sheet 27 is determined so that when wrapped around the cylinder 25 the adjacent edges 28, 29 of the sheet 27 do not meet or overlap, leaving a gap 30. For example, the sheet 27 may be dimensioned so that it wraps around the cylinder 25 for approximately 330 degrees.

The cylinder 25 is positioned over the strip transmission line 10 by means of shafts 31, 32 located at the opposite ends thereof. The shafts 31, 32 are supported by bearing blocks 33 and 34, respectively, so that the longitudinal axis of the cylinder 25 is parallel to and equally spaced from an imaginary line, not shown, drawn along the center of the line conductor 12.

As shown in the cross-sectional view of FIG. 2, a section 37 at the base of the bearing block 33 is removed, permitting the bearing block 33 to be mounted across the line conductor 12. The height at which the cylinder 25 is supported above the line conductor 12 by the shafts 31, 32 and the bearing blocks 33, 34 is determined so as to allow touching but free rotative movement of the cylinder 25 over the line conductor 12. The bearing blocks 33, 34 can be constructed of brass or other suitable material. The bearing block 33 is indicated in the cross-sectional view of FIG. 3 as including a ball bearing assembly 35 for supporting the shaft 31. The bearing block 34 is also indicated as including a ball bearing assembly 36 for supporting the shaft 32. In practice, any type of suitable bearing assembly may be used. The bearing blocks 33, 34 are securely fastened to the strip transmission line 10 in any desired manner. For example, a pair of bolts 38 are shown in the cross-sectional view of FIG. 2 which pass through the planar conductor 11, the dielectric layer 13 and into matching holes, not shown, in the bearing block 33. The bearing block 34 is fastened to the strip transmission line 10 in a similar manner as by

the bolts 39 indicated in the cross-sectional view of FIG. 3.

A simplified arrangement for rotating the cylinder 25 through its positions of adjustment is shown in the drawing. A calibrated disc 40 is shown fastened to the bearing block 34. A tuning knob 41 is mounted on the end of the shaft 32. By turning the knob 41, the cylinder 25 can be rotated to any desired position with respect to the line conductor 12. The disc 40 and knob 41 can be replaced by a complex gear box or by any other tuning means arranged to rotate the cylinder 25 on the shaft 32. The tuning means can be designed to provide the degree of accuracy and precise adjustment desired. If needed, suitable means can be provided for locking the cylinder 25 against further rotation once an adjustment has been made. Such locking means can, for example, take the form in the case of the disc 40 and knob 41 shown in the drawing of a lock nut, not shown, arranged to hold the knob 41 tightly against the disc 40 and the block 34. In normal usage, the frictional engagement of the cylinder 25 at the Mylar sheet 27 with the line conductor 12 taken with the resistance to movement presented by the bearings 35, 36 serves to prevent miscellaneous movement of the cylinder 25.

A pair of U-shaped metallic braces 42, 43 are shown in the cross-sectional view of FIG. 2. The braces 42, 43 serve to provide rigidity to the strip transmission line 10. The brace 42 is fastened onto the planar conductor 11 of the strip transmission line 10 by the bolts 44, and the brace 43 is fastened to the planar conductor 11 of the strip transmission line 10 by the bolts 45. The braces 42, 43 are positioned at opposite edges of the strip transmission line 10 so that they each extend in a direction parallel to the line conductor 12. Thus, the brace 42 is shown in the cross-sectional view of FIG. 3 as extending substantially the length of the strip transmission line 10. The braces 42, 43 tend to prevent warping of the strip transmission line 10, particularly, along a line crossing the line conductor 12 which would result in variations in the spacing between the resistive film 26 and the line conductor 12. The braces 42, 43 also provide a means for readily mounting the strip transmission line 10 on a wall or other support. The braces 42, 43 may be replaced by any suitable means designed to strengthen the strip transmission line 10 or, if not needed, such structure can be eliminated. A cover, not shown, can be provided which fits over the cylinder 25 and fastens to the dielectric layer 13. In the alternative, the attenuator including the cylinder 25 and the strip transmission line 10 can be assembled in a housing, not shown, of the type which comprises a cover and a base plate.

In designing the variable attenuator for use in a particular application, the attenuation versus angular rotation curve desired is determined. The resistance value of the resistive film 26 and the shape of the resistive film 26 are selected to provide the proper response curve. A simple triangular shaped resistive film 26 is shown in the embodiment of FIG. 4 and indicated by the dashed line in FIG. 1. Assuming that the cylinder 25 is rotated in a clockwise direction so as to cause the film 26 to move in the direction of the arrow 50 shown in FIG. 4, past the line conductor 12, a gradually and continuously increasing amount of the resistive film 26 intersects the fringe field of the line conductor 12. Since the attenuation is a function of length of resistive material over the line conductor 12, the amount of attenuation imparted to RF energy propagated along the strip transmission line 10 increases a corresponding amount. Upon the cylinder 25 being rotated in a counter-clockwise direction, the amount of resistive film 26 and therefore the amount of attenuation decreases a corresponding amount. The tuning knob 41 can be operated to set the cylinder 25 at the desired position of adjustment for the amount of attenuation desired.

The presence of the gap 30 formed on the cylinder 25 by a break in the resistive film 26 and in the Mylar sheet

27 serves to space the operating point of the attenuator at which the minimum amount of the resistive film 26 is present from that at which the maximum amount of the resistive film 26 is present. By this construction, a clear and abrupt change in the resulting attenuation takes place between the two operating points or positions of adjustment. Without the gap 30, both the maximum amount of the resistive film 26 and the minimum amount of the resistive film 26 could appear at the same time over the line conductor 12, distorting the amount of attenuation achieved at this setting of the cylinder 25.

The Mylar sheet 27 positioned between the resistive film 26 and the line conductor 12 serves to prevent abrasion of the resistive film 26 by the line conductor 12. Instead of positioning the Mylar sheet 27 on the cylinder 25, the Mylar sheet 27 can be bonded to or otherwise placed on the dielectric board 13 over the line conductor 12. In this case, the resistive film 26 is placed directly on the surface area of the cylinder 25 by any suitable technique.

In a typical example of a variable attenuator constructed according to the embodiment shown in FIGS. 1 through 4, the attenuator was designed to provide a change in attenuation of 0 to 20 db (decibels) at an operating frequency within the frequency range of 4.4 to 5 kmc. (thousand megacycles per second). The cylinder 25 including the two shafts 31, 32 was seven inches long with the cylinder 25 itself being five inches long. The cylinder 25 was three-quarters of an inch in diameter, and the shafts 31, 32 were each one-quarter of an inch in diameter. The resistive film 26 was composed of chromium, nickel and rhodium mixed to provide a resistance value of fifty ohms per square inch ± 10 percent. The resulting construction was found to permit rigid mounting of the cylinder 25, while at the same time permitting accurate and precise setting of the attenuator to provide the amount of attenuation desired.

Since the resistive film 26 is at any setting of the attenuator backed by the thickness of the cylinder 25, the resistive film 26 is maintained substantially free from vibration. This construction is to be contrasted to that in which the resistive member is formed as a thin, flat sheet-like member mounted in a plane perpendicular to the line conductor for lateral movement past the line conductor. Since in the latter case the resistive member is both thin and wide, it is particularly susceptible to vibration. The use of such a resistive member has required additional structure which is often complex and costly to implement for reducing the tendency of the resistive member to vibrate. The need for such additional structure is avoided by the present invention.

A variable attenuator constructed in the manner shown in FIGS. 1, 2 and 3 can be adapted for use in a wide range of applications. By determining the diameter and length of the cylinder 25 so that the cylinder 25 supports a resistive film 26 of given resistance value and shape, a desired attenuation versus angular rotation curved for the attenuator is achieved. The cylinder 25 is not limited to the dimensions given above. Assuming that a triangularly shaped resistive film 26 as shown and described in connection with FIG. 4 is used and that the attenuator is to be operated at a higher range of frequencies than cited above by way of example, a greater loss per unit length of the resistive film 26 takes place since more wavelengths are present along the resistive film 26. Therefore, not as much resistive film is needed to achieve a given amount of attenuation. The axial length of the cylinder 25 and of the resistive film 26 can be correspondingly reduced.

Any desired response curve is readily achieved. A simple design has been described in connection with FIG. 4 by which the amount of attenuation continuously increases or decreases according to the direction in which the cylinder 25 is rotated. Applications exist in which a more complex response curve is desired. It may be

desirable for the attenuation to change irregularly and in different directions for succeeding settings of the attenuator so as to compensate or otherwise offset some characteristic of the RF energy. By way of example, a resistive film 51 is shown in FIG. 5 which can be evaporated or otherwise placed on a Mylar or other suitable sheet 52 in the manner previously described. Assuming that the resistive film 51 and the sheet 52 are placed on the cylinder 25 and that the cylinder 25 is rotated in a direction to cause the resistive film 51 to pass over the line conductor 12 in the direction of the arrow 53 shown in FIG. 5, the attenuation achieved will increase to a first value, then decrease to a lower value greater than zero, and finally increase to an even higher value. Any desired amount of attenuation at the different settings of the attenuator can be obtained by shaping the resistive film according to the needs of the particular application.

Also, it is not essential that a gap in the manner of the gap 30 shown in FIG. 1 be provided. Mechanical stops can be provided at the settings of minimum and maximum attenuation to limit rotation. In other applications, the resistive film can be shaped so that it forms a succession of attenuator settings completely around the cylinder 25. In such an application, the turning of the attenuator provides attenuation for the full 360 degree angular rotation of the cylinder 25. Since the possible appearance of different amounts of the resistive film over the line conductor 12 at the same time in an objectionable manner is not encountered, no gap in the resistive film or provision of mechanical stops is necessary.

What is claimed is:

1. A variable attenuator for transmission lines of the type including a first conductor, a second conductor, and means disposing said conductors in close dielectrically spaced parallel relation using a flat board of dielectric material comprising, in combination,

a solid cylinder constructed of dielectric material,

a thin, flexible sheet of dielectric material having a resistive film thereon wrapped around and bonded to said cylinder with said resistive film between said cylinder and said sheet,

support posts mounted on said flat board of dielectric material, means for mounting said cylinder to said support posts for close but free rotative movement over said first conductor with the longitudinal axis of said cylinder being parallel to and equally spaced from said first conductor.

2. A variable attenuator for transmission lines of the type including a line conductor, a planar conductor, and a flat board of dielectric material spacing said conductors in close parallel relation comprising, in combination,

a solid cylinder constructed of dielectric material,

a thin, flexible sheet constructed of dielectric material and having a resistive film evaporated on a portion thereof wrapped around and secured to said cylinder,

means mounted on said board for supporting said cylinder for free rotative movement over said line conductor with the longitudinal axis of said cylinder being equally spaced from and parallel to said line conductor, and a tuning means connected to one end of said cylinder arranged to rotate said cylinder and thereby determine the amount of said resistive film present over said line conductor.

3. In combination,

a first conductor ribbon-like in configuration,

a second conductor wider than said first conductor to present thereto a planar surface,

a flat board of dielectric material interposed between said conductors to maintain them in close, dielectrically spaced parallel relation,

whereby an electromagnetic field is distributed be-

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with a fringe field extending from side and top between the opposed surfaces of said conductors portions of said first conductor toward said second conductor,

a solid cylinder of dielectric material, 5

a thin flexible sheet of dielectric material having a resistive film evaporated on only a portion thereof wrapped around and secured to said cylinder with said film between said sheet and said cylinder, support posts mounted on said board, means for mounting 10 said cylinder to said support posts for close but free rotative movement over said first conductor with the longitudinal axis of said cylinder being equally spaced from and parallel to said first conductor and with said cylinder being spaced to cause said resistive 15 film to intersect said fringe field as said cylinder is rotated,

and means secured to said cylinder for rotating said cylinder over said first conductor so as to determine the position of said cylinder and said film relative to 20 said first conductor.

4. A variable attenuator comprising, in combination, a section of transmission line of the type including a first ribbon-like conductor, a second conductor 25 wider than said first conductor to present a planar conducting surface to said first conductor, and a flat board of dielectric material disposing said conductors in close dielectrically spaced parallel relation,

a first coaxial connector mounted on said line in a manner to couple radio frequency energy to said 30 line and a second coaxial connector mounted on said line at a point removed from said first connector in a manner to couple said energy from said line, whereby an electromagnetic field is distributed between opposed surfaces of said conductors upon 35 said energy being coupled to said line with a fringe field extending from side and top portions of said first conductor toward said second conductor,

a solid cylinder of dielectric material, 40

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a thin, flexible sheet of dielectric material having a film of resistive material on a portion thereof wrapped around and secured to said cylinder with said film between said sheet and said cylinder,

said film being arranged in a definite pattern on said sheet so that differing amounts of said film occur at succeeding positions around said cylinder,

two support posts mounted on said board, means for mounting said cylinder to said support posts for close but free rotative movement over said first conductor intermediate said first and second conductors with the longitudinal axis of said cylinder being equally spaced from and parallel to said first conductor and with said cylinder being spaced to cause said resistive film to intersect said fringe field as said cylinder is rotated,

and means secured to said cylinder for rotating said cylinder over said first conductor to determine the position of said cylinder relative to said first conductor and thereby the amount of said film present in said fringe field of said first conductor.

References Cited by the Examiner

UNITED STATES PATENTS

2,537,671	2/1951	Jack et al.	338—142
2,714,147	7/1955	Reid	338—150
2,803,805	7/1957	Wilson	333—81
2,909,736	10/1959	Sommers et al.	333—81
2,924,793	2/1960	Englemann et al.	333—81
2,961,621	11/1960	Tanenbaum et al.	333—81
3,120,650	2/1964	Blanco	338—150

FOREIGN PATENTS

949,834 9/1956 Germany.

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