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MICROWAVE TRANSMISSION LINE COMPONENTS

Filed April 25, 1958

FIG. 1

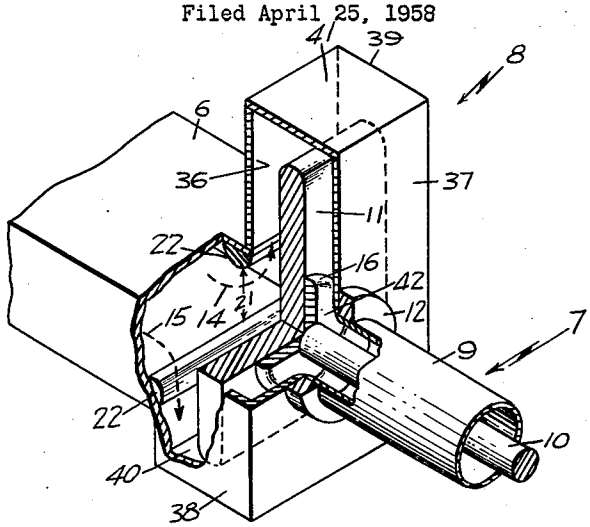


FIG. 2

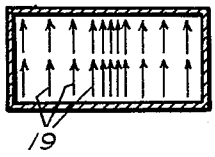
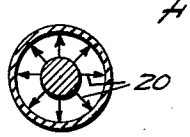


FIG. 3



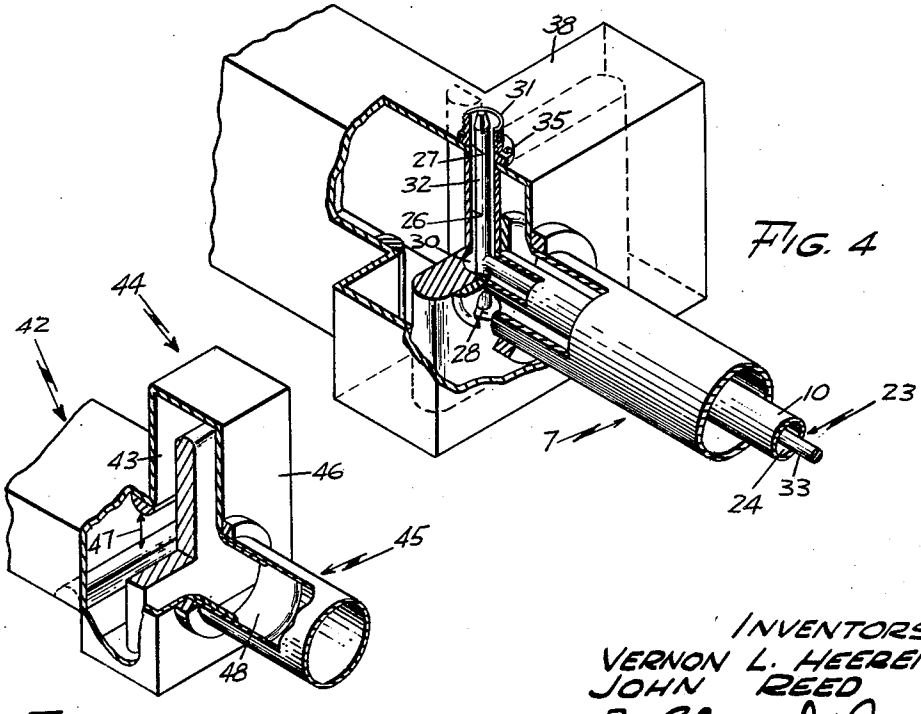


FIG. 4

FIG. 5

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MICROWAVE TRANSMISSION LINE COMPONENTS

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This invention relates generally to microwave transmission line components and, more particularly, to transitions between transmission lines having different physical configurations as, for example, between wave guides and coaxial transmission lines or between rectangular wave guides and circular wave guides.

Previously, in making transitions from wave guide transmission lines to coaxial transmission lines, for example, it has been conventional to arrange the transition so that the principal axis of the wave guide is substantially perpendicular to the principal axis of the coaxial transmission line. In some applications, however, mechanical space limitations make it desirable to arrange the transition so that the principal axis of the coaxial transmission line is substantially aligned with the principal axis of the wave guide. One way in which this has been accomplished has been to extend the inner conductor of the coaxial line into the wave guide and, thence, to attach it to one of the walls of the wave guide having the wider dimension. In doing so, the inner conductor must make a substantially smooth 90° bend. Such a construction offers, however, some unavoidable disadvantages. In the first place, it is difficult mechanically to construct the 90° bend in such a way as to avoid undesirable reflections of the electromagnetic wave being transmitted. In addition, dimensional tolerances are difficult to maintain in production and the system is sensitive to small changes in dimensions. In many applications where it is desirable to use a second coaxial line concentrically placed inside the first coaxial line for the purpose of transmitting more than one signal, it is difficult to provide an easily accessible path through which to feed and to align the auxiliary coaxial line.

This invention, however, allows the construction of a transition wherein the alignment of the principal axes of the wave guide and coaxial line is accomplished with much less difficulty in mechanical fabrication than has been encountered previously. The insertion of an additional coaxial line inside and concentric with the inner conductor of the coaxial line is much more easily done. Voltage breakdown is much less apt to occur and dimensional tolerances can be considerably eased.

In this invention the transition is achieved by inserting a transition section between the rectangular wave guide and the coaxial line which are to be joined. This transition section is arranged to provide two paths for the electromagnetic wave energy that is being transmitted. One of the paths is longer than the other path by a distance substantially equal to one-half a wave length, corresponding to the frequency of operation of the electromagnetic energy that is being transmitted. The energy that is being transmitted in either direction between the wave guide and the coaxial line is divided into two substantially equal portions, one of said portions being transmitted through one of said paths and the other of said portions being transmitted through the other of said paths. Because one of these portions must travel a half wave length further than the other, it receives an additional 180° phase shift with respect to the other portion, and, hence, a favorable condition for the transmission of energy is achieved. The ability to use conventional matching techniques allows such a construction to provide nearly total transmission with only negligible absorption loss. Good broad band matching can be accomplished and sufficient power-handling capacity is also assured. Other advantages of the invention will be pointed out as the invention is further described below.

The invention can best be described with the help of the following drawing, in which:

FIG. 1 shows a cutaway view of a particular embodiment of the invention; wherein a transition structure is shown between a rectangular wave guide and a coaxial line;

FIG. 2 shows a sectional view of the embodiment of FIG. 1 taken along the line 2—2 of FIG. 1;

FIG. 3 shows a sectional view of the embodiment of FIG. 1 taken along line 3—3 of FIG. 1;

FIG. 4 shows another embodiment of the invention in which a second coaxial line is inserted inside and concentric with the first coaxial line;

FIG. 5 shows another embodiment of the invention wherein a transition structure is provided between a rectangular wave guide and a circular wave guide.

In FIG. 1 there is shown a rectangular wave guide **6** and a coaxial transmission line **7** that are connected by a transition structure **8**. Side **36** of transition structure **8** to which the wave guide is attached has a rectangular opening coincident with the rectangular opening of the wave guide **6** and side **37** of the transition structure **8** to which the coaxial line **7** is attached has a circular opening coincident with the circular opening of the coaxial line **7**. Transition structure **8** is further enclosed by the sides **38**, **39**, **40** and **41**. The coaxial line **7** is made up of outer conductor **9** and inner conductor **10** and is attached to the transition structure by means of cylindrical ring **12**. Mounted within transition structure **8** is a rectangular panel **11** attached to opposite sides **38** and **39** of the transition structure. Panel **11** thereby provides two paths through the transition structure between the wave guide and the coaxial line. These paths are designated by the dashed lines **14** and **15**. On the coaxial side of rectangular panel **11** is mounted a circular plate **16**, the center of which substantially coincides with the principal axis of the coaxial line. The inner conductor **10** is firmly attached to the surface **42** of the circular plate **16** by suitable means such as silver solder.

This structure may be used to transmit energy in either direction between the rectangular wave guide section and the coaxial line section for any desired purpose. For example, the energy can be fed directly to an antenna from a transmitter or from an antenna to a receiver. It may be fed, if desired, through a conventional rotary joint mounted in conjunction with the coaxial line section **7**.

The transmission of energy through the transition structure may be best understood by considering particular modes of operation that may be desired in the wave guide and the coaxial line sections. Usually, the principal mode of operation of the rectangular wave guide is the TE_{10} mode in which the electric field is transverse to the axis of the wave guide and extends from one wide side of the guide to the other. The principal mode of operation of the coaxial line is the conventional TEM mode. This mode corresponds to the TM_{01} mode of the circular wave guide. The electric field of the TEM mode of the coaxial line is radially symmetric and is directed outward from the inner to the outer conductor. FIG. 2 shows the TE_{10} mode that exists in the rectangular wave guide. FIG. 3 shows the TM_{01} mode that exists in the coaxial line. The use of the TM_{01} mode in the coaxial line provides symmetrical distribution of microwave energy in all directions at the antenna so that if a rotary joint is used the rotating antenna will provide uniform energy transmission in all directions. Therefore, the transition structure **8** must provide a mode shift

from the rectangular wave guide to the coaxial line. This mode shift is accomplished in the following manner.

In FIG. 2 the vectors **19** represent the relative directions of the electric field vectors in the wave guide. It can be seen that the average phase difference between the electric energy existing in the upper half of the wave guide and the electric energy existing in the lower half of the wave guide is zero. In FIG. 3 the vectors **20** represent the relative directions of the electric field vectors in the coaxial line. It can be seen that the average phase of energy in the upper half of the coaxial line, however, is 180° out of phase with the average phase of the energy in the lower half of the coaxial line.

If, for example, the transmission of energy from the wave guide to the coaxial line is considered, it can be seen that upon reaching the junction of the transition structure with the wave guide the energy divides into two substantially equal portions. The energy in the upper half of the wave guide thereby being transmitted in the direction of the path designated by the dashed line **14** and the energy in the lower half of the wave guide thereby being transmitted in the direction of the path designated by the dashed line **15**. Path **14** continues around the panel **11** through the upper portion of the transition structure **8** and path **15** continues around the panel **11** through the lower portion of transition structure **8**, and ultimately both portions arrive at the coaxial line **7**. The phase of the transmitted energy through either path varies by 180° as the wave travels a distance of one-half a wave length, said wave length corresponding to the frequency of the microwave energy being transmitted. The transition structure **8** containing panel **11** is constructed so that the path **14** is longer than the path **15** by a distance substantially equal to one-half a wave length.

Thus, since the portion of the energy transmitted through the upper path designated by dashed line **14** travels one-half a wave length further than that transmitted through the lower path **15**, the upper and lower portions of energy which are in phase at the wave guide arrive at the coaxial line 180° out of phase with each other. This transmission of the two portions of energy thereby provides a favorable condition for the transmission of the total energy into the coaxial line.

This invention offers a number of advantages when compared to the conventional transition in which a 90° bend is necessary for the inner conductor of the coaxial line. In the first place, the structure of the invention is mechanically easier to fabricate. The rectangular panel **11** and the circular plate **16** may be machined by standard techniques, whereas it has been found in the conventional transition that the 90° bend may not be constructed directly by standard machining methods, but, in most cases, must be further refined in a cut-and-try fashion. It has been found that the construction of the invention has been less sensitive to small changes in dimensions than has the conventional type of transition.

Relatively simple matching techniques may be used with this invention as shown in FIGURE 1. In this figure, a capacitive iris **21** can be placed at the junction point of the wave guide section and the transition section. This iris is formed in the embodiment shown in FIGURE 1 by extending semi-cylindrical pieces **22** across the top and bottom of the wave guide at the junction point. Matching is obtained for the coaxial line by the circular plate **16** attached between the rectangular panel **11** and the inner conductor **10**. These matching techniques have been found to give good broad band matching.

To facilitate the handling of high power it has been found that protruding corners existing within the transition or existing at the junctions of the transition section with the wave guide and the coaxial line sections may be provided with relatively large radii and that such rounding off of these corners improves the power handling capacity. In addition, because the energy is divided into two paths through the transition, there is less chance for high voltage breakdown at points along the transition than there would be in the conventional transition wherein the total energy is transmitted along a single path.

Another advantage of the type of transition construction shown in the invention is realized in applications in which it is desirable to utilize a second coaxial line to supply a signal of a different frequency in the same system in which a signal is being supplied through the first coaxial line. Normally such a second coaxial line is inserted within the inner conductor of the first coaxial line and placed substantially concentric with that inner conductor. In the conventional type of transition utilizing the 90° bend, the alignment of the second coaxial line along the bend becomes very difficult. However, the geometry of the transition structure shown in the invention makes the alignment of the second coaxial line relatively easier.

In FIG. 4 there is shown an embodiment of the transition structure of the invention utilizing a second coaxial line **23** that has been inserted within the transition structure and the first coaxial line **7**. In the cutaway view of FIG. 4 the transition structure, and the associated portions of the wave guide and coaxial line are shown rotated 90° clockwise with respect to embodiment shown in FIG. 1. In FIG. 4 a cylindrical channel **24** has been provided within the inner conductor **10** of coaxial line **7**. Channel **24** runs along the axis of and is concentric with the inner conductor **10**. Channel **24** extends through the circular plate **16**, and partially extends into the rectangular panel **11** at the coaxial line side of said panel. A cylindrical channel **26** is provided within the rectangular panel **11** substantially perpendicular to channel **24**. Channel **26** extends from an opening **27** in the side **38** of transition structure **8** to an end point **28** within panel **11**. In this way channel **24** and channel **26** meet at a junction point **30**. The distance from junction point **30** to end point **28** of channel **26** is a quarter wave length. In the embodiment shown, the walls of channels **24** and **26** may act as the outer conductor of the second coaxial line. It should be pointed out, however, that the outer conductor of the second coaxial line may be constructed completely independent of the walls of channels **24** and **26** and inserted as a complete entity into these channels. The inner conductor of this second coaxial line is made up of two sections. One section **32** extends from a conventional connector **31** at the opening **27** through channel **26** to the end point **28** where it is firmly attached, for example, by soldering. Thus, a quarter-wave stub support is provided from junction point **30** to the end point **28**. The other section **33** extends through channel **24** and is firmly attached to section **32** at the common junction point **30** of channels **26** and **24**. At the opening **27**, connector **31** is attached to the transition structure in a suitable fashion as, in this case, by means of screws, one of which is shown at **35**. Thus, it can be seen that no particular difficulties are involved in aligning the inner conductor section **32** with the principal axis of channel **26** and the inner conductor section **33** with the principal axis of channel **24**. Because the second coaxial line is shielded by the metallic structures of the inner conductor **10**, the circular plate **16** and the rectangular panel **11**, a field free path is provided for the second coaxial line.

FIG. 5 shows another embodiment of the invention wherein a transition structure is provided between a rectangular wave guide and a circular wave guide. Rectangular wave guide **42** is attached at side **43** of transition structure **44** and circular wave guide **45** is attached at side **46** of transition structure **44**. Impedance matching is provided at the junction of the rectangular wave guide and transition structure by the capacitive iris **47** in a manner similar to that shown in FIGS. 1 and 4. Impedance matching is provided at the junction of the circular wave guide and the transition structure by the inser-

tion of the capacitive ring 48 mounted on the inner wall of and concentric with the circular wave guide. The edges of the ring are rounded off to facilitate the power handling capabilities of the system. The operation of the transition structure is similar to that described above for the transition structure shown in FIG. 1.

Other embodiments of this invention will be devised by those skilled in the art without destroying the scope of the invention. For instance, other methods of matching impedances may be used and the size of the structures used need not necessarily be limited to a particular band of frequencies. In addition, the lengths of the two paths in the transition structure may differ by an odd multiple of half wave lengths without limiting the scope of the invention. Therefore, this invention is not to be construed as being limited by the embodiment shown in the drawing except as defined by the appended claims.

What is claimed is:

1. A microwave transmission system including, in combination, a first transmission line being adapted to transmit microwave energy having a first predetermined mode of operation; a second transmission line being adapted to transmit microwave energy having a second predetermined mode of operation, said second transmission line having its principal axis aligned with the principal axis of said first transmission line; and a transition structure attached to said first and to said second transmission lines for transmitting microwave energy between said first and said second transmission lines; said transition structure comprising means for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to an odd multiple of half wave lengths corresponding to the frequency of said microwave energy.

2. A microwave transmission system including, in combination, a first transmission line being adapted to transmit microwave energy having a first predetermined mode of operation; a second transmission line being adapted to transmit microwave energy having a second predetermined mode of operation, said second transmission line having its principal axis aligned with the principal axis of said first transmission line; and a transition structure attached to said first and to said second transmission lines for transmitting microwave energy between said first and said second transmission lines; said transition structure comprising means for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said two portions is transmitted through said first path and the other of said two portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wavelength corresponding to the frequency of said microwave energy.

3. A microwave transmission system including a first transmission line being adapted to transmit microwave energy of the TE_{10} mode; a second transmission line being adapted to transmit microwave energy of a different mode, said second transmission line having its principal axis aligned with the principal axis of said first transmission line; a transition structure attached to said first and to said second transmission lines for transmitting microwave energy between said first and said second transmission lines whereby said TE_{10} mode is transmitted in said first transmission line and said different mode is transmitted in said second transmission line, said transition structure comprising means for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half wavelength corresponding to the frequency of said microwave energy.

4. A microwave transmission system including a first transmission line being adapted to transmit microwave energy having a radially symmetric mode; a second transmission line being adapted to transmit microwave energy of a different mode, said second transmission line having its principal axis aligned with the principal axis of said first transmssion line; and a transition structure attached to said first and to said second transmission lines for transmitting microwave energy between said first and said second transmission lines whereby said radially symmetric mode is transmitted in said first transmission line and said different mode is transmitted in said second transmission line, said transition structure comprising means for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wavelength corresponding to the frequency of said microwave energy.

5. In combination, a microwave transmission system including a first transmission line having a transverse rectangular cross section and being adapted to transmit microwave energy of the TE_{10} mode; a second transmission line having a transverse circular cross section being adapted to transmit microwave energy having a radially symmetric mode, said second transmission line having its principal axis aligned with the principal axis of the said first transmission line; and a transition structure attached to said first and to said second transmission lines for transmitting microwave energy between said first and said second transmission lines, whereby said TE_{10} mode of operation is maintained in said first transmission line and said radially symmetric mode of operation is maintained in said second transmission line; said transition structure comprising means for separating microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wavelength corresponding to the frequency of said microwave energy.

6. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode; a coaxial line being adapted to transmit energy of the TEM mode, said coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; a transition structure attached to said rectangular wave guide and to said coaxial line for transmitting microwave energy between said wave guide and said coaxial line, whereby said TE_{10} mode of operation is maintained in said wave guide and said TEM mode of operation is maintained in said coaxial line; and said transition structure comprising means for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy.

7. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode; a circular wave guide being adapted to transmit microwave energy of the TM_{01} mode, siad circular wave guide having its principal axis substantially aligned with the principal axis of said wave guide; and a transition structure attached to said rectangular wave guide and to said circular wave guide for transmitting microwave energy between said

wave guide and said circular wave guide, whereby said TE_{10} mode of operation is maintained in said wave guide and said TM_{01} mode of operation is maintained in said circular wave guide; said transition structure comprising means for separating microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy.

8. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of a predetermined frequency wherein the average phase of the electric field energy in the upper half of said wave guide is in phase with the average phase of the electric field energy in the lower half of said wave guide; a coaxial line being adapted to transmit microwave energy of a predetermined frequency equal to that of said energy in said wave guide wherein the average phase of the electric field energy in the upper half of said coaxial line is 180° out of phase with the average phase of the electric field energy in the lower half of said coaxial line; said coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; and a transition structure attached to said rectangular wave guide and to said coaxial line for transmitting microwave energy from said wave guide to said coaxial line; said transition structure comprising means for separating said electric energy in the upper half of said wave guide from said electric energy in the lower half of said wave guide, a first path and second path within said transition structure whereby said electric energy in the upper half of said wave guide is transmitted through said first path and said electric energy in the lower half of said wave guide is transmitted through said second path; said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to said predetermined frequency of said microwave energy, whereby said electric energy from the upper half of said wave guide and said electric energy from the lower half of said wave guide arrive at said coaxial line 180° out of phase with each other.

9. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode; a coaxial line being adapted to transmit energy of the TEM mode, said coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; and a transition structure attached to said rectangular wave guide and to said coaxial line for transmitting microwave energy between said wave guide and said coaxial line, whereby said TE_{10} mode of operation is maintained in said wave guide and said TEM mode of operation is maintained in said coaxial line; said transition structure comprising means for separating microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy; a first impedance matching means mounted at the junction of said rectangular wave guide and said transition structure; and a second impedance matching means mounted at the junction of said coaxial line and said transition structure.

10. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode; a coaxial line being adapted to transmit energy of the TEM mode, said coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; and a transition structure attached to said rectangular wave guide and to said coaxial line for transmitting microwave energy from said wave guide to said coaxial line, whereby said TE_{10} mode of operation is maintained in said wave guide and said TEM mode of operation is maintained in said coaxial line; said transition structure comprising panel means mounted perpendicular to the direction of propagation of said microwave energy in said wave guide for separating said microwave energy from said wave guide into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy.

11. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode, a first coaxial line being adapted to transmit energy of the TEM mode, said first coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; a transition structure attached to said rectangular wave guide and to said first coaxial line for transmitting microwave energy from said wave guide to said first coaxial line; said transition structure comprising panel means mounted perpendicular to the direction of propagation of said microwave energy for separating said microwave energy from said wave guide into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy; a second coaxial line for transmitting energy of a different frequency than said energy in said first coaxial line, said second coaxial line comprising two sections; a first channel means within said first coaxial line, said first section of said second coaxial line being mounted within said first channel means substantially concentric with said first coaxial line; and a second channel means within said panel means substantially perpendicular to said first channel means, said second section of said second coaxial line mounted within said second channel means and attached to said first section of said second coaxial line.

12. In combination, a microwave transmission system including a rectangular wave guide being adapted to transmit microwave energy of the TE_{10} mode; a first coaxial line being adapted to transmit energy of the TEM mode, said first coaxial line having its principal axis substantially aligned with the principal axis of said wave guide; a transition structure attached to said rectangular wave guide and to said first coaxial line for transmitting microwave energy from said wave guide to said first coaxial line; said transition structure comprising panel means mounted perpendicular to the direction of propagation of said microwave energy for separating said microwave energy into two portions, a first path and a second path within said transition structure whereby one of said portions is transmitted through said first path and the other of said portions is transmitted through said second path, said first path being longer than said second path by a distance substantially equal to one-half a wave length corresponding to the frequency of said microwave energy; a second coaxial line for transmitting energy of a different frequency than said energy in said first coaxial line, said second coaxial line comprising two sections each section having an inner and an outer conductor; first channel means within said first coaxial line, said first section of said second coaxial line being mounted within said first channel means substantially concentric with said first coaxial line; and a second channel means within said panel means substantially perpendicular to said first

channel means, said second section of said second coaxial line mounted within said second channel means and connected to said first section of said second coaxial line, said second channel means extending from an opening at one side of said transition structure to an end point substantially one-quarter wave length beyond the junction point of said first and said second sections of said second coaxial line; said inner conductor of said second section of said second coaxial line being shorted to said outer conductor of said second section of said second coaxial line at said end point.

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