

May 24, 1955

J. J. GIBSON

2,709,240

MULTI-MODE WAVEGUIDE SYSTEM

Filed Feb. 2, 1954

3 Sheets-Sheet 1

Fig. 1.

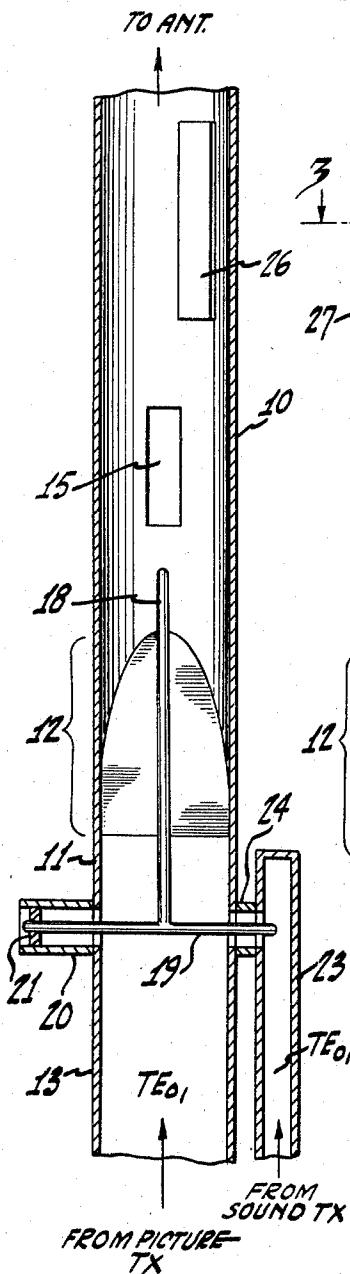


Fig. 2.

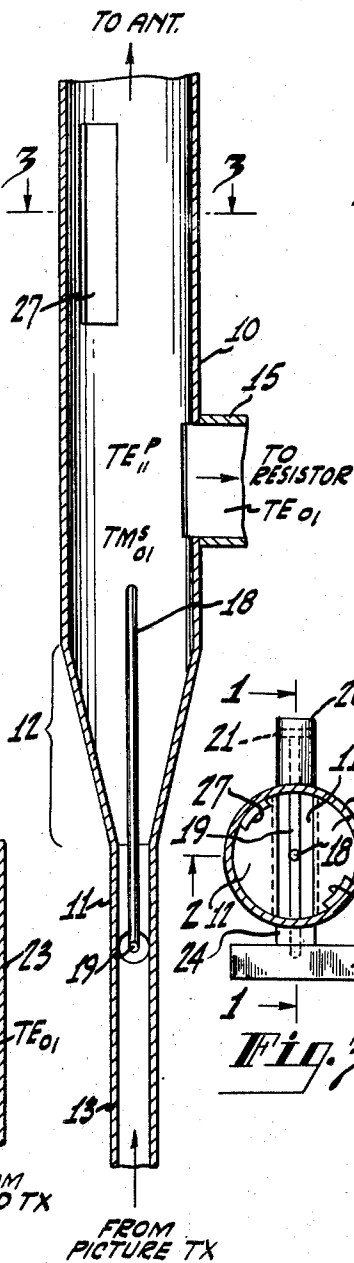


Fig. 4.

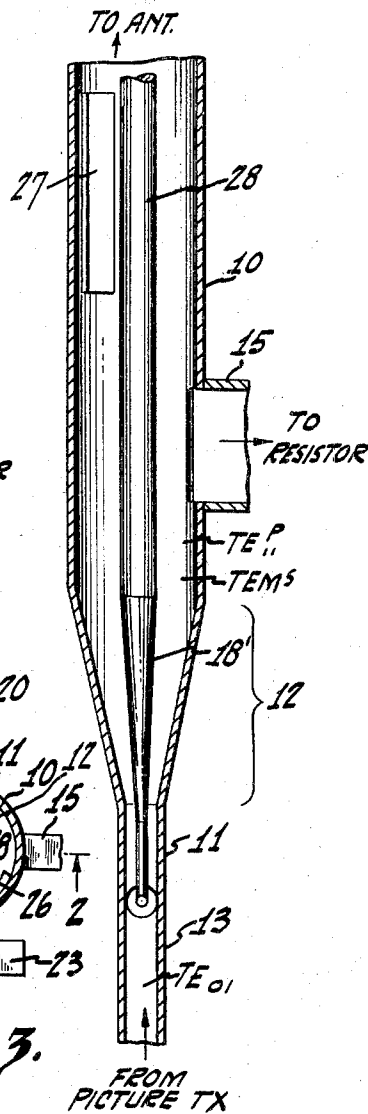
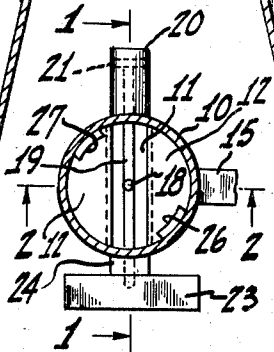


Fig. 3.



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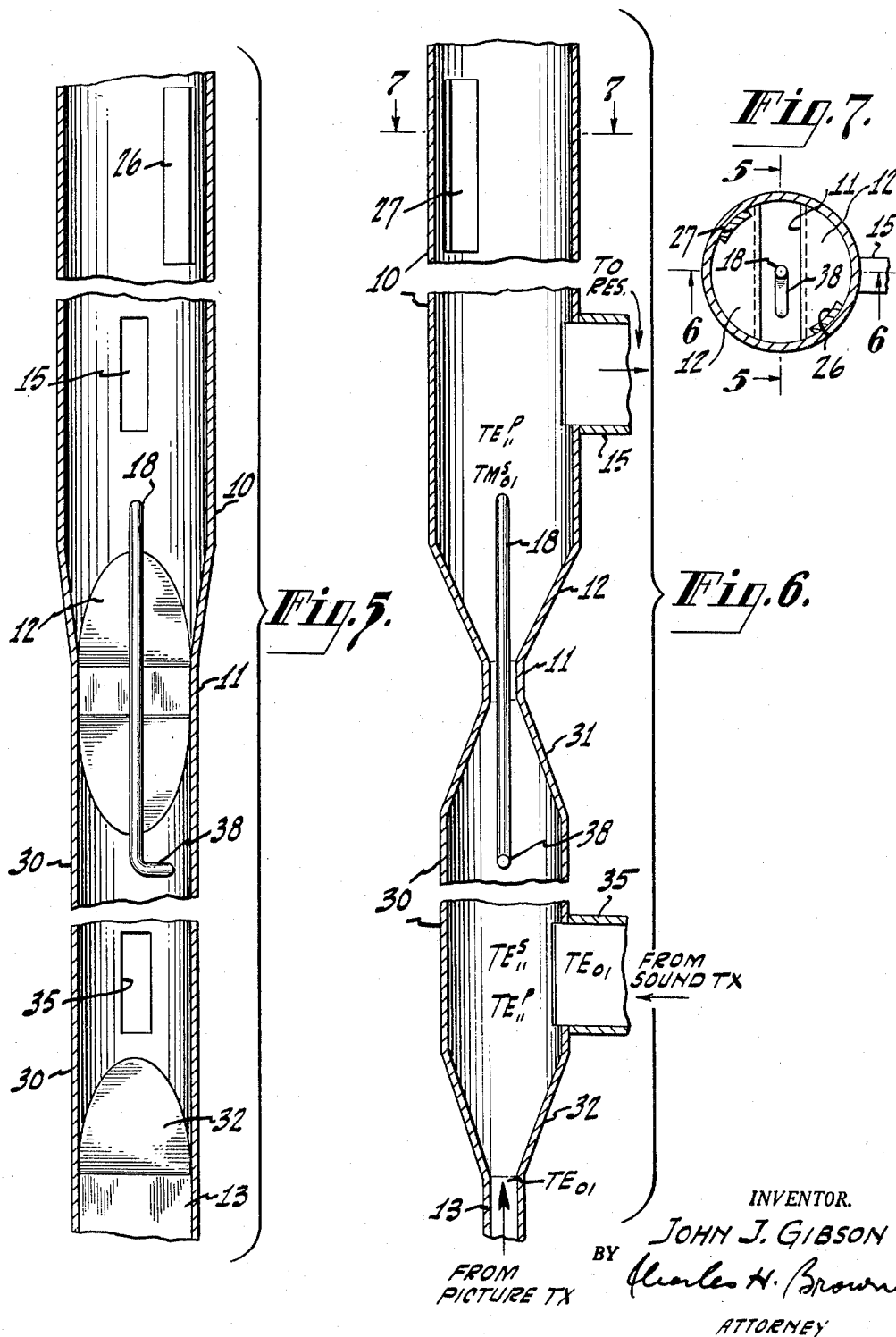
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3 Sheets-Sheet 2



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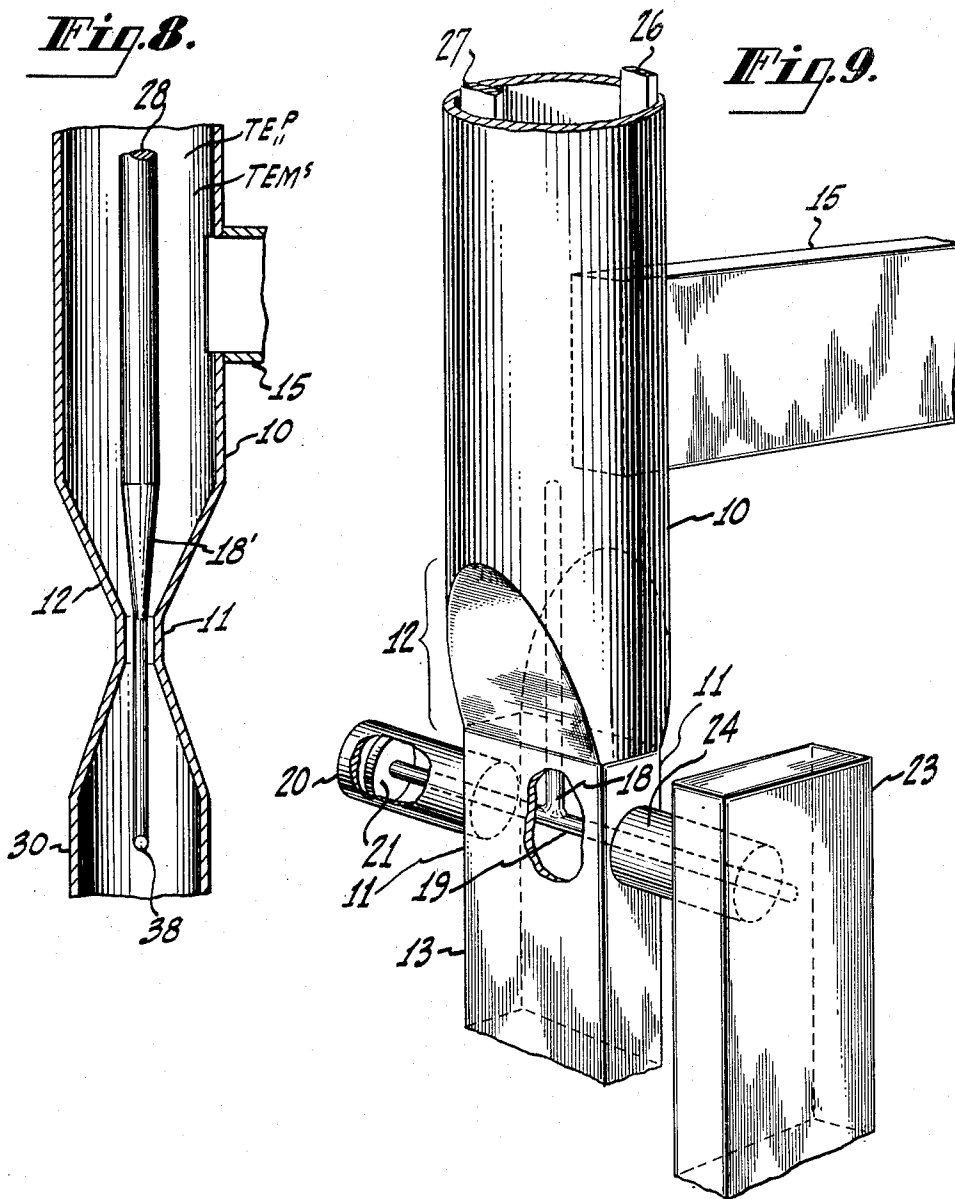
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3 Sheets-Sheet 3



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MULTI-MODE WAVEGUIDE SYSTEM

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Application February 2, 1954, Serial No. 407,634

The terminal 15 years of the term of the patent to be granted has been disclaimed

10 Claims. (Cl. 333—6)

This invention relates to a multi-mode waveguide system, and more particularly to means providing separate couplings for each of three decoupled signals in a single waveguide.

While not limited thereto, the invention is particularly useful in the field of television broadcasting where separate transmitters are used to generate the sound modulated and the picture modulated radio frequency signals, and a single antenna is employed to radiate the combined or composite radio frequency signal. It is important that the means for coupling the two transmitters to the common antenna be such as to isolate the transmitters from each other, and to direct energy reflected from the antenna (due to mismatch) to a soak-up resistor rather than back to the picture transmitter.

The most effective way to feed high power ultra-high frequency signals to a radiating antenna is by means of a waveguide. A waveguide can transmit very high power, and at the ultra-high frequencies, waveguides have low loss and moderate physical dimensions which make them inexpensive and practical. Ultra-high frequency antenna arrays preferably include waveguide systems having a plurality of radiating slots, dipoles or monopoles. One such antenna is shown and described in U. S. patent application of Oakley M. Woodward, Jr., Serial Number 370,423, filed July 27, 1953, entitled "Slotted Waveguide Antenna," and assigned to the assignee of this present application. The waveguide system of this invention is particularly useful in coupling two transmitters to an antenna array of the type including a central waveguide from which energy is coupled to the radiating elements of the antenna array.

It is a general object of this invention to provide an improved system employing separate couplings for each of three decoupled signals in a single waveguide.

It is another object to provide an improved single waveguide system within which three decoupled signals may be propagated, and three individual transmission lines connected to the single waveguide to selectively couple to the three signals in the single waveguide.

It is a further object to provide a waveguide system including a generally circular waveguide which at one end forms an integral part of an antenna array and which at the other end is connected to three rectangular waveguides two of which are adapted to be connected to the respective outputs of two transmitters, and the third of which is adapted to be connected to a soak-up resistor which absorbs energy reflected back from the antenna.

It is a still further object to provide an improved waveguide system for coupling the outputs of two transmitters to a single generally circular waveguide extending a considerable distance to an antenna array.

In one aspect, the invention comprises a generally circular waveguide capable of propagating the TE_{11} mode and the TM_{01} mode at the desired frequencies of operation. The term "generally circular," as used herein, means a cylindrical or prismatic waveguide having a circular or polygonal cross-section. A generally circular

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waveguide having an octagonal cross-section may advantageously be used. The lower end of the generally circular waveguide is constricted to a neck having a rectangular cross-section which is connected thru a rectangular waveguide to the output of a picture modulated radio frequency transmitter. The output of the picture transmitter excites the TE_{01} mode in the rectangular waveguide, and this is translated to the TE_{11} mode in the generally circular waveguide. An inner conductor in the rectangular neck extending at least partially into the generally circular waveguide, together with a transverse conductor extending out from the rectangular neck provides a coupling from a rectangular waveguide connected to the output of a sound modulated radio frequency transmitter to excite a TM_{01} mode in the generally circular waveguide. The TE_{11} mode from the picture transmitter in the generally circular waveguide is propagated along the waveguide to a utilization device such as an antenna. Fins in the generally circular waveguide cause a rotation of the field so that energy reflected back down the generally circular waveguide from the antenna is oriented in such a way that it couples to a rectangular waveguide connected to a soak-up resistor. This reflected energy is prevented from returning to the picture transmitter because its orientation is such that it is prevented from going thru the rectangular neck.

In another aspect, the invention comprises a generally circular waveguide capable of supporting the TE_{11} and the TM_{01} modes at the two desired frequencies of operation. The lower end of the generally circular waveguide is gradually constricted to a neck of rectangular cross-section which is then enlarged to a second generally circular waveguide having a lower end constricted to a rectangular waveguide which is connected to a picture transmitter. The picture transmitter excites the TE_{11} mode in the second generally circular waveguide and passes thru the neck to also excite the TE_{11} mode in the first generally circular waveguide. A second rectangular waveguide connected to the output of a sound transmitter is connected at right angles with the second generally circular waveguide to excite the TE_{11} mode in the second generally circular waveguide. An inner conductor couples this energy via a coaxial line mode to the first generally circular waveguide and excites the TM_{01} mode therein. A rectangular waveguide connected at right angles to the first generally circular waveguide receives energy in the TE_{11} mode reflected back from the antenna and applies it to a soak-up resistor.

These and other objects and aspects of the invention will be apparent to those skilled in the art from the following more detailed description taken together with the appended drawings wherein:

Fig. 1 is a longitudinal sectional view of a waveguide system constructed according to the teachings of this invention;

Fig. 2 is a second longitudinal sectional view of the system of Fig. 1 taken on a plane at right angles to that on which Fig. 1 is taken.

Fig. 3 is a transverse sectional view taken on the line 3—3 of Fig. 2 and showing the line on which Figs. 1 and 2 are taken;

Fig. 4 is a longitudinal sectional view similar to Fig. 2 but showing a modified construction wherein an inner conductor extends throughout the generally circular waveguide.

Fig. 5 is a longitudinal sectional view of a modified form of the invention;

Fig. 6 is a second longitudinal sectional view of the system of Fig. 5 taken on a plane at right angles to that on which Fig. 5 is taken;

Fig. 7 is a transverse sectional view taken on the line

7—7 of Fig. 6 and showing the lines on which Figs. 5 and 6 are taken;

Fig. 8 is a longitudinal sectional view of a modified form of the invention shown in Figs. 5, 6 and 7; and

Fig. 9 is a perspective view of the waveguide system of Figs. 1 to 4.

Figures 1, 2 and 3 show a waveguide system for coupling the outputs of two transmitters to a utilization device such as an antenna, and a coupling for reflected energy from the antenna to a soak-up resistor. In a broader aspect, the figures show a single generally circular waveguide capable of supporting three decoupled signals therein, and means for feeding in or coupling out the three signals from the circular waveguide. The term "generally circular waveguide," as used herein, means a cylindrical or prismatic waveguide having a circular or polygonal cross-section. A generally circular waveguide having an octagonal cross-section is effective and desirable.

A generally circular waveguide 10 is dimensioned to permit the propagation therethrough of the TE_{11} and the TM_{01} modes at the desired frequency or frequencies of operation. These waveguide modes are defined and described on page 258 of Terman's "Radio Engineers Handbook," 1st edition, 1945. The upper end of the generally circular waveguide 10 is connected to a utilization device such as an antenna (not shown). The lower end of the generally circular waveguide is constricted in one cross-sectional dimension to a rectangular neck 11 having dimensions capable of propagating the TE_{01} rectangular waveguide mode at the same frequency as the TE_{11} mode signal in the generally circular waveguide 10. The waveguide tapered portion connecting the generally circular waveguide 10 with the rectangular neck 11 is designated 12. A rectangular waveguide having the same dimensions as the rectangular neck 11 is connected at one end to the neck 11 and may be connected at the other end to a source of radio frequency energy such as the output of a picture signal transmitter of a television station.

A rectangular waveguide 15 is connected at right angles with the generally circular waveguide 10. The rectangular waveguide 15 is oriented to have its longitudinal direction at right angles with the longitudinal direction of the rectangular waveguide 13 and rectangular neck 11. The rectangular waveguide 15 is also oriented so that its greater cross-sectional dimension extends at right angles with the greater cross-sectional dimension of the rectangular waveguide 13 and neck 11, and its lesser cross-sectional dimension extends at right angles with the lesser cross-sectional dimension of the rectangular waveguide 13 and neck 11.

A longitudinal inner conductor 18 extends coaxially from the generally cylindrical waveguide 10, thru the waveguide taper 12 and into the rectangular neck 11 where it is connected to a transverse conductor 19. Transverse conductor 19 extends in one direction thru an aperture in the wall of the rectangular neck. The portion outside the neck 11 is surrounded by an outer conductor 20 to provide a coaxial line tuning (impedance matching) stub. The stub is tuned by moving a shorting ring 21 which connects the outer conductor 20 with the conductor 19. The other end of the transverse conductor 19 extends out the opposite side of the rectangular neck 11 into a rectangular waveguide 23. An outer conductor 24 around the transverse conductor 19 provides communication between neck 11 and the rectangular waveguide 23 for the transfer of energy therebetween in the coaxial line or TEM mode. The rectangular waveguide 23 may be connected to the output of a second transmitter, such as the sound transmitter of a television broadcasting station. Alternatively, the waveguide 23 may be eliminated and the coaxial line 19, 24 connected to the sound transmitter.

Fins 26 and 27 are mounted in the interior of generally circular waveguide 10 to cause a rotation of the signals in the TE_{11} mode which are propagated therethru.

The orientation of fins 26 and 27 relative to the rectangular neck 11 and the rectangular waveguide 15 are clearly shown in Fig. 3 of the drawings. It will be noted that the fins 26 and 27 are positioned on opposite sides of the generally circular waveguide 10 and are angularly displaced 45 degrees with respect to the orthogonal axes of the neck 11 and the rectangular waveguide 15.

In the operation of the waveguide system shown in Figs. 1, 2 and 3, a television picture signal from a transmitter is applied in the TE_{01} mode thru the rectangular waveguide 13, thru the rectangular neck 11, thru the waveguide taper 12, to the generally circular waveguide 10. The energy from the neck 11 appears in the circular waveguide 10 as a linearly polarized signal in the TE_{11} waveguide mode, wherein the electric field vector lies in the plane of the paper of Fig. 2. Because of the direction of the field configuration of this signal, no energy is coupled to the longitudinal inner conductor 18 and the transverse conductor 19. The energy can not flow out through the rectangular waveguide 15 because this waveguide is oriented in such a direction as to prevent the coupling of energy from the generally circular waveguide 10.

The energy from the picture transmitter is propagated thru the generally circular waveguide 10 toward an antenna (not shown) from which the energy is radiated into space. As the energy passes the fins 26 and 27, the resultant electric field vector is caused to rotate to produce a circularly polarized wave in the TE_{11} mode. This results from the fact that the electric field vector may be considered to be made of two orthogonal components, one of which is relatively slowed down in the section including the fins 26 and 27. If the fins are of the proper length, one component will be delayed 90 degrees with respect to the other component. The resulting circularly polarized signal in the TE_{11} mode is applied to the antenna to provide for the phase rotational or quadrature or turnstyle feeding of the antenna which is particularly advantageous in that it results in uniform radiation in all directions in the horizontal plane.

As a practical matter it is usually impossible to exactly match an antenna to the generally circular guide 10 over the entire frequency band desired. Therefore, some energy is reflected back from the antenna. The reflected energy in returning past the fins 26 and 27 is translated from a circularly polarized wave back to a linearly polarized TE_{11} wave. The reflected signal, however, differs from the transmitted signal in that its electric field vector is in the direction of the plane of the paper of Fig. 1, and is therefore at right angles with the electric field vector of the transmitted wave. The transmitted wave travels up the generally circular waveguide 10, and the reflected wave travels down the waveguide 10 without any coupling or interference between the two waves. The reflected wave is oriented in such a way that the energy couples to and passes out thru the rectangular waveguide 15. The reflected wave is prevented from going down thru the waveguide tapered portion 12 because its orientation is such that the wave cannot be propagated thru the narrow end of the taper 12. It is thus apparent that two decoupled signals can be propagated thru the generally circular waveguide 10 and that couplings to the waveguide 10 are provided for respective ones of the two separate signals therein.

Radio frequency energy from a source, such as the sound transmitter of a television station, is applied to the rectangular waveguide 23. This energy is coupled to the transverse conductor 19 extending into the waveguide 23, and the longitudinal inner conductor 18 which extends from the neck 11 thru the waveguide tapered portion 12 into the generally circular waveguide 10. The energy in the rectangular waveguide 23 is in the TE_{01} mode, and the energy conveyed by the conductors 18 and 19 is in what appears to be a TEM or coaxial line mode. The co-

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axial line mode is translated to the TM_{01} mode in the circular waveguide 10. The sound signal in the TM_{01} mode does not couple with the rectangular waveguide 15, and is propagated up the generally circular waveguide 10 without any interference with the transmitted and reflected waves in the TE_{11} mode. The orientation of the transverse conductor 19 in the link between the rectangular waveguide 23 and the generally circular waveguide 10 is such that energy from the sound transmitter cannot be coupled back to the picture transmitter thru the rectangular waveguide 13. The conductors 18 and 19 are oriented in such a way that they in no way interfere with the propagation of the picture signal in the TE_{01} mode in waveguide 13 or the TE_{11} mode in the generally circular waveguide 10.

Another form of the invention is shown in Fig. 4 of the drawings which differs from that shown in Figs. 1, 2 and 3 in that the inner conductor 18' is continued as an inner conductor 28 throughout the length of the generally circular waveguide 10, so that the energy from the sound transmitter is propagated thru the generally circular waveguide 10 in the TEM mode, rather than in the TM_{01} mode. In other respects, Fig. 4 is similar to Fig. 2 and the same reference numerals have been applied to corresponding parts in the two drawings.

By the construction shown in Fig. 4, the waveguide system is useful over a broader range of frequencies than is practical according to the construction shown in Figs. 1, 2, and 3. The generally circular waveguide 10 must be designed to have a diameter such that signals may be propagated therethru in both the TE_{11} picture signal mode and the TM_{01} sound signal mode. With a given mechanical structure, there is a limited range of frequencies which can be propagated thru the generally circular waveguide 10. At frequencies at the low end of this range, it becomes impossible to transmit the sound signal in the TM_{01} mode. By using the coaxial line construction as shown in Fig. 4, there is no lower frequency or cut-off frequency for the sound signal in the TEM mode. Therefore, a given physical structure of predetermined size, when constructed according to Fig. 4, is useful over a broader range of frequencies. This is of commercial importance when, for example, it is desired to build waveguide systems for television broadcasting in such a way that a structure of a given size may be used for any one of a considerable number of television channel frequencies.

Reference will now be made to another form of the invention shown in Figs. 5, 6 and 7. This form of the invention as regards all parts above the neck 11 is exactly the same as has been described in connection with Figs. 1, 2 and 3. The same reference numerals have been used for corresponding parts in the two forms of the invention. A second generally circular waveguide 30 is constricted at its upper end by means of taper section 31 to a rectangular cross-section the same as, and connected to, the rectangular neck 11. The lower end of generally circular waveguide 30 is constricted thru a taper section 32 to a similar rectangular cross-section the same as, and connected to, the rectangular waveguide 13 from the output of the picture transmitter. A rectangular waveguide 35 is connected at right angles to the second generally circular waveguide 30. The rectangular waveguide 35 is oriented so that its longer cross-sectional dimension is at right angles with the longer cross-sectional dimension of the picture signal waveguide 13, and its shorter cross-sectional dimension is at right angles with the shorter cross-sectional dimension of the waveguide 13.

The coaxial inner conductor 18 extends down thru the rectangular neck 11, thru the taper section 31 and into the generally circular waveguide 30. The lower end of conductor 18 is bent at right angles to form a probe 38 extending in a direction parallel with the direction of the shorter dimension of the rectangular waveguide 35 connected to the sound transmitter.

In the operation of the system shown in Figs. 5, 6 and 7, a picture signal in the TE_{01} mode in rectangular wave-

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guide 13 is applied thru the taper section 32 to the generally circular waveguide 30 to excite the TE_{11} mode therein. This signal continues on thru the taper section 31, thru the neck 11, and the taper section 12 to the generally circular waveguide 10. This picture signal in the TE_{11} mode is then transmitted up the generally circular waveguide past the fins 26 and 27 which cause the signal to become a circularly polarized wave. The wave reflected down the generally circular waveguide 10 from the antenna due to mismatch is translated by the fins 26 and 27 from a circularly polarized wave to a linearly polarized TE_{11} wave. Due to the wave having twice passed by the fins 26 and 27, the wave is rotated so that it couples to the rectangular waveguide 15 and is applied to a soak-up resistor (not shown). Because of the orientation of the reflected wave, it cannot pass thru the constricted or tapered section 12 back to the picture transmitter.

Energy from the sound transmitter in the rectangular waveguide 35 is in the TE_{01} mode which excites the TE_{11} mode in the generally circular waveguide 30. This TE_{11} mode is oriented so that it cannot pass thru the constricted neck 11 but so that it can couple energy to the probe 38 at the lower end of the inner conductor 18. The energy from the sound transmitter is thereby transmitted from the generally circular waveguide 30 to the generally circular waveguide 10 in the coaxial line mode. The coaxial line is constituted by the inner conductor 18 and the outer conductor formed by the taper sections 31 and 12 and the rectangular neck 11. The energy from the sound transmitter is then translated to the TM_{01} mode in the generally circular waveguide 10. The nature of the TM_{01} mode is such that it is unaffected by the fins 26 and 27 in the generally circular waveguide 10. The nature of the sound signal is also such that it cannot couple thru the rectangular waveguide 15 to the soak-up resistor.

The construction shown in Figs. 5, 6 and 7 is particularly advantageous for use between a television transmitter at the base of a tower and an antenna at the top of the tower. The antenna may be located at the top of a tower having a height of, say, 300 feet. It is therefore desirable to be able to convey the power from the television transmitter at the base of the tower to the top of the tower thru a single waveguide. It will be noted that the form of the invention shown in Figs. 1, 2 and 3, uses two rectangular waveguides for conveying energy from the transmitters to the waveguide system which is mounted near the base of the antenna. The generally circular waveguide 30 in Figs. 5, 6 and 7 may be of extended length such as 300 feet. The rectangular waveguides 13 and 35 may be connected from the two transmitters to the bottom of the generally circular waveguide 30, and the generally circular waveguide 30 may extend up the tower to the radiating antenna located at the top of the tower. The TE_{11} modes for the sound and picture signals may be transmitted thru the same generally circular waveguide 30 for a considerable distance without slight mechanical imperfections in the waveguide causing one signal to interfere or couple with the other. By this construction, a single generally circular waveguide 30 may be used to carry the energy over a considerable distance in place of using two separate rectangular waveguides both extending the entire distance. A single waveguide is, of course, more economical than two waveguides.

Fig. 8 shows a modified form of the invention of Figs. 5, 6 and 7 wherein the inner conductor 18' is extended as a coaxial line inner conductor 28' throughout the entire length of the generally circular waveguide 10. By this construction, the sound signal is propagated thru the generally circular waveguide 10 as a TEM or a coaxial line mode rather than as a TM_{01} mode. By this construction, the resulting system is useful over a broader range of frequencies than can be utilized with the construction shown in Figs. 5, 6 and 7. The presence of the inner

conductor 28 in no way interferes with the propagation thru the generally circular waveguide 10 of the TE₁₁ picture signal modes.

By way of example, a waveguide system according to Figs. 1, 2 and 3 of the drawings was constructed and tested for operation at frequencies in the order of 820 megacycles. The generally circular waveguide 10 was octagonal in cross-section and had an inner dimension between opposite side surfaces of 11.4 inches. The rectangular waveguides 13, 15 and 23, and the rectangular neck 11 had inner dimensions of 5.75 inches and 11.5 inches. The transverse inner conductor 19 was 1 inch in diameter, and the outer conductors 20 and 24 were 3 inches in diameter. The longitudinal inner conductor 18 was 32 inches long and was 2 inches in diameter for reasons of mechanical rigidity. A construction according to Fig. 4 could utilize a longitudinal inner conductor 18' and 28 having the same diameter throughout its entire length. The diameter could be 1 inch on the basis of electrical characteristics, but the diameter should be sufficient to provide mechanical rigidity. The inner conductors were coaxially supported by dielectric members not shown in the drawings. The longitudinal dimension of the neck 11 from the taper portion 12 to the transverse inner conductor 19 was 12.5 inches. The taper portion 12 had a longitudinal length of 16 inches. The longitudinal length of the taper portion 12 should preferably be in the order of 1 wavelength to provide a broadband characteristic. The distance from the taper 12 to the axes of the waveguide 15 was 12.5 inches. This dimension is determined experimentally so that there is an odd number of quarter wavelengths from a waveguide 15 to the point in the taper portion 12 where an equivalent electrical short circuit is presented to the picture wave reflected from the antenna. It was found that the waveguide system operated very well for picture signals in the TE₁₁ mode at frequencies in the range of from 680 to 870 megacycles, and for sound signals in the TM₀₁ mode at frequencies in the range of from 800 to 860 megacycles. When an inner conductor 28 extending throughout the length of the generally circular waveguide 10 is used as shown in Fig. 4 (and Fig. 8) there is no frequency limitation on the sound signal in the TEM mode, and the system is useful over the entire frequency range of from 680 to 870 megacycles.

The fins 26 and 27 for causing the linearly polarized TE₁₁ mode to be translated to a circularly polarized TE₁₁ mode may be 5 feet in length, 4½ inches in width and ⅞ of an inch in thickness.

In a construction according to Figs. 5 thru 8, the corresponding dimensions may be the same as has been described in connection with Figs. 1 thru 4. The diameter of the generally circular waveguide 30 is smaller than the diameter of the generally circular waveguide 10. In a system using the dimensions given in the above example, the diameter of the generally circular waveguide 30 may be 10 inches. This dimension is selected to be small enough so that the generally circular waveguide 30 cannot propagate the TM₀₁ mode. Therefore, there is substantially no cross coupling between the sound signal and the picture signal in the generally circular waveguide 30.

What is claimed is:

1. Means to provide separate couplings for each of three decoupled signals in a single waveguide, comprising: a generally circular waveguide; a rectangular neck consisting of a first rectangular waveguide having one cross-sectional dimension smaller than the diameter of said generally circular waveguide; a tapered section connecting one end of said generally circular waveguide to said neck; a first coupling means for coupling a TE₀₁ mode to said neck, whereby to couple from said neck to a TE₁₁ mode in said generally circular waveguide; a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its

longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, whereby to couple a TE₀₁ mode in said rectangular waveguide with a TE₁₁ mode in said generally circular waveguide; a first inner conductor in said rectangular neck and extending coaxially at least partially into said generally circular waveguide; and a third coupling means coupled to said inner conductor and said neck, whereby to couple to a coaxial line mode in said neck and in at least a portion of said generally circular waveguide.

2. The combination as defined in claim 1 wherein said first coupling means comprises a third rectangular waveguide directly connected to said rectangular neck.

3. Means to provide separate couplings for each of three decoupled signals in a single waveguide, comprising: a generally circular waveguide; a rectangular neck consisting of a first rectangular waveguide having one cross-sectional dimension smaller than the diameter of said generally circular waveguide; a tapered section connecting one end of said generally circular waveguide to said neck; a first coupling means for coupling a TE₀₁ mode to said neck, whereby to couple from said neck to a TE₁₁ mode in said generally circular waveguide; a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, whereby to couple a TE₀₁ mode in said rectangular waveguide with a TE₁₁ mode in said generally circular waveguide; a first inner conductor in said rectangular neck and extending coaxially at least partially into said generally circular waveguide; and a third coupling means including a coaxial line having an outer conductor connected to the sidewall of lesser dimension of said neck, and having a second inner conductor extending transversely to and connected with one end of said first inner conductor, whereby to couple to a coaxial line mode in said neck and in at least a portion of said generally circular waveguide.

4. Means to provide separate couplings for each of three decoupled signals in a single waveguide, comprising: a generally circular waveguide; a rectangular neck consisting of a first rectangular waveguide having one cross-sectional dimension smaller than the diameter of said generally circular waveguide; a tapered section connecting one end of said generally circular waveguide to said neck; a first coupling means for coupling a TE₀₁ mode to said neck, whereby to couple from said neck to a TE₁₁ mode in said generally circular waveguide; a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, whereby to couple a TE₀₁ mode in said rectangular waveguide with a TE₁₁ mode in said generally circular waveguide; a first inner conductor in said rectangular neck and extending coaxially at least partially into said generally circular waveguide; and a third coupling means including a coaxial line having an outer conductor connected to the sidewall of lesser dimension of said neck, and having a second inner conductor extending transversely to and connected with one end of said first inner conductor; and a fourth rectangular waveguide connected to said coaxial line with said second inner conductor extending into said waveguide as a probe therein, whereby to couple to a coaxial line mode in said neck

and in at least a portion of said generally circular waveguide.

5 5. Means to provide separate coupling for each of three decoupled signals in a single waveguide, comprising; a generally circular waveguide; a rectangular neck consisting of a first rectangular waveguide having one cross-sectional dimension smaller than the diameter of said generally circular waveguide; a tapered section connecting one end of said generally circular waveguide to said neck, a first coupling means for coupling a TE_{01} mode to said neck, whereby to couple from said neck to a TE_{11} mode in said generally circular waveguide; a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, whereby to couple a TE_{01} mode in said rectangular waveguide with a TE_{11} mode in said generally circular waveguide; a first inner conductor in said rectangular neck and extending coaxially throughout said generally circular waveguide; and a third coupling means coupled to said inner conductor and said neck, whereby to couple to a coaxial line mode in said neck and in at least a portion of said generally circular waveguide.

6. Means to provide separate couplings for each of three decoupled signals in a single waveguide, comprising; a generally circular waveguide; a rectangular neck consisting of a first rectangular waveguide having one cross-sectional dimension smaller than the diameter of said generally circular waveguide; a tapered section connecting one end of said generally circular waveguide to said neck; a first coupling means for coupling a TE_{01} mode to said neck, whereby to couple from said neck to a TE_{11} mode in said generally circular waveguide; a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, whereby to couple a TE_{01} mode in said rectangular waveguide with a TE_{11} mode in said generally circular waveguide; a first inner conductor in said rectangular neck and extending coaxially at least partially into said generally circular waveguide; a third coupling means coupled to said inner conductor and said neck, whereby to couple to a coaxial line mode in said neck and in at least a portion of said generally circular waveguide; and fins mounted on the inside surface of said generally circular waveguide to cause a linearly polarized TE_{11} mode propagated therethru to be translated to a circularly polarized TE_{11} mode.

7. The combination as defined in claim 1, wherein said first and third couplings comprise a second generally circular waveguide having one end constricted to the same rectangular cross-section as said neck and being connected thereto, and wherein said other end is similarly

constricted to a rectangular cross-section oriented in the same planes with said neck, said first inner conductor extending partially into said second generally circular waveguide and being provided with a terminal probe extending in the direction of the longer cross-sectional dimension of said rectangular neck, a third rectangular waveguide for a first signal extending coaxially from said constricted other end of said second generally circular waveguide, and a fourth rectangular waveguide for a third signal connected to said second generally circular waveguide and having a longitudinal axis extending at right angles with the longitudinal axis of said second generally circular waveguide with the lesser and greater dimensions of said fourth rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively, of said neck.

8. The combination as defined in claim 7 wherein said first inner conductor extends coaxially throughout the length of said first generally circular waveguide.

9. The combination as defined in claim 7, and in addition, fins mounted on the inside surface of said first mentioned generally circular waveguide to cause a linearly polarized TE_{11} mode propagated therethru to be translated to a circularly polarized TE_{11} mode.

10. A broadband waveguide system for coupling the outputs of a television picture transmitter and a television sound transmitter to an antenna, comprising, a generally circular waveguide adapted at one end for coupling to a transmitting antenna, a rectangular neck having one cross sectional dimension smaller than the diameter of said generally circular waveguide, a tapered section connecting the other end of said generally circular waveguide to said neck, a first coupling means consisting of a first rectangular waveguide connected at one end to said rectangular neck and adapted for coupling at the other end to the output of a television picture transmitter, a second coupling means comprising a second rectangular waveguide connected to said generally circular waveguide with its longitudinal direction at right angles to the longitudinal direction of said generally circular waveguide and with the lesser and greater cross-sectional dimensions of said rectangular waveguide at right angles with the lesser and greater cross-sectional dimensions respectively of said rectangular neck, one end of said second rectangular waveguide being adapted for coupling to a soak-up resistor, a first inner conductor in said rectangular neck and extending coaxially into said generally circular waveguide, and a third coupling means comprising a coaxial line having an outer conductor connected at one end to the sidewall of lesser dimension of said neck, and having a second inner conductor extending transversely to and connected with one end of said first inner conductor, the other end of said coaxial line being adapted for coupling to the output of a television sound transmitter.

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