June 17, 1958 J. J. GIBSON 2,839,729

MULTI-MODE WAVEGUIDE SYSTEM

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Fig. 1.

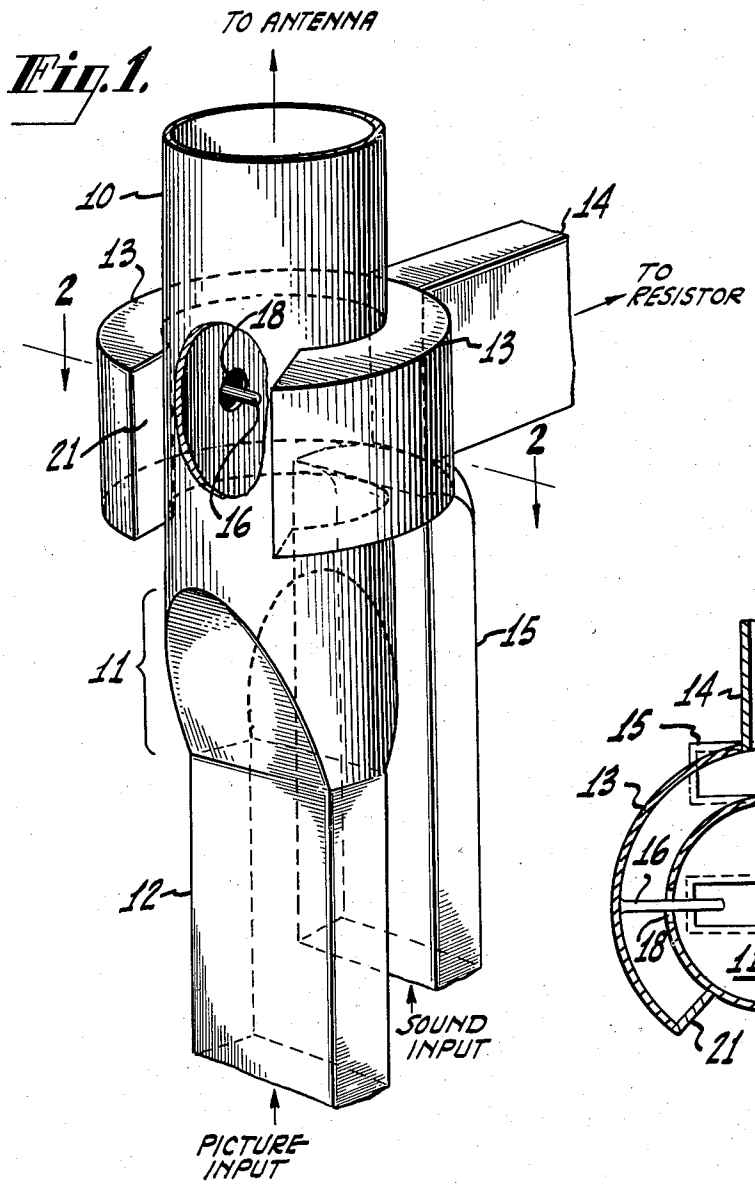
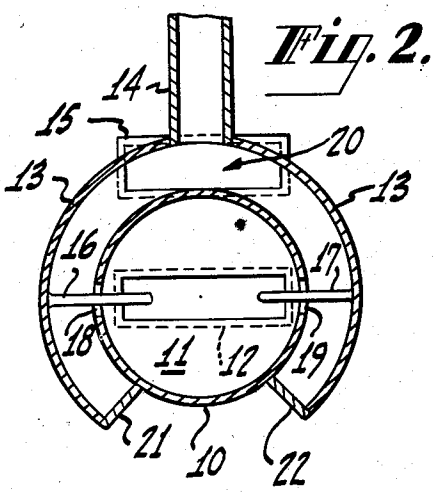


Fig. 2.



INVENTOR.
JOHN J. GIBSON
BY
Charles H. Brown

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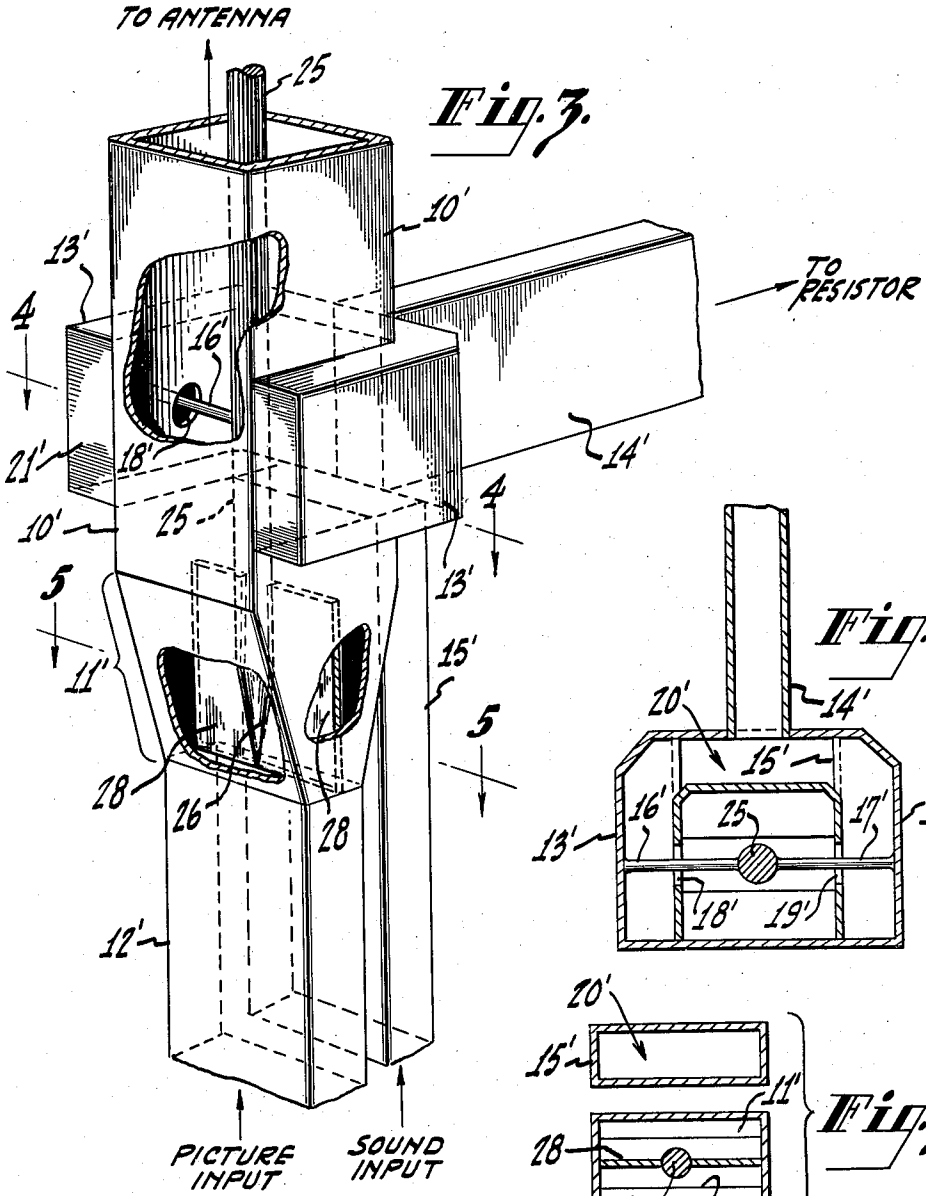


Fig. 3.

Fig. 4.

Fig. 5.

INVENTOR.
JOHN J. GIBSON
BY
Charles H. Brown

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MULTI-MODE WAVEGUIDE SYSTEM

John J. Gibson, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application February 15, 1954, Serial No. 410,302

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

11 Claims. (Cl. 333—6)

This invention relates to a multi-mode waveguide system, and particularly to means providing separate couplings for each of three decoupled signals in a single waveguide. A different construction for a similar purpose is shown in Patent No. 2,709,240, issued to me on May 24, 1955.

While not limited thereto, this 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 mis-match) to a soak-up resistor rather than back to the picture transmitter.

A very 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 ultra-high frequencies, waveguides have moderate physical dimensions which make them inexpensive and practical. Ultra-high frequency antenna arrays preferably include waveguide systems having a plurality of radiating slots, or dipoles or monopoles. One such antenna is shown and described in the U. S. Patent No. 2,807,018 issued to Oakley M. Woodward, Jr., on September 17, 1957. 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.

An object of the invention is to provide a diplexer for combining two separate radio frequency signals in a single waveguide.

Another object of this invention is 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 thru 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 radio 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. One form of generally circular waveguide has a square cross-section. A generally circular waveguide having an octagonal cross-section may advantageously be employed. The upper end of the generally circular waveguide may be connected to an antenna array. The other end of the generally circular waveguide is connected thru a transformer (a tapered section) to a rectangular waveguide which may, at the other end, be connected to the output of a picture signal transmitter. A magic T is arranged with respect to the generally circular waveguide so that the main waveguide of the magic T is formed around the generally circular waveguide, the E-plane arm extends out at right angles with the axis of the generally circular waveguide, and the H-plane arm of the magic T extends downwardly in parallel spaced relation with the rectangular waveguide connected to the picture transmitter. The H-plane waveguide is adapted to be connected to the output of a sound signal transmitter, and the E-plane waveguide is adapted to be connected to a soak-up resistor for absorbing energy reflected from the antenna array. Means are provided for coupling energy from the main waveguide of the magic T at points equi-distant from the junction to points on opposite sides in the generally circular waveguide.

In another aspect, the waveguide system utilizes a generally circular waveguide having a coaxial inner conductor so that the generally circular waveguide is capable of propagating the TE_{11} mode and the TEM or coaxial line mode. In both forms of the invention, the generally circular waveguide is adapted for the propagation of two decoupled signals in the TE_{11} modes, the two modes being oriented at right angles with each other.

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 perspective view, partly broken away, of a waveguide system constructed according to the teachings of this invention and including a generally circular waveguide which is circular or cylindrical in form;

Fig. 2 is a transverse cross-sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a perspective view, partly broken away, of a multi-mode waveguide system utilizing a generally circular waveguide of square cross-section, and including a coaxial inner conductor;

Fig. 4 is a transverse sectional view taken on the line 4—4 of Fig. 3; and

Fig. 5 is a transverse sectional view taken on the line 5—5 of Fig. 3.

Figs. 1 and 2 show a multi-mode waveguide system having three independent couplings to three decoupled signals in a single generally circular waveguide. Generally circular waveguide **10** is circular in cross-section and is coupled thru a waveguide transition in the form of a tapered portion **11** to a rectangular waveguide **12**. The lower end of rectangular waveguide **12** is adapted for connection to the output of a picture transmitter of a television station. The upper end of the generally circular waveguide **10** is adapted for coupling to an antenna array.

A magic T includes a main rectangular waveguide **13**, an E-plane rectangular waveguide arm **14**, and an H-plane rectangular waveguide arm **15**. A known magic T is shown and described starting on page 259 of volume 16, "Microwave Mixers," of the Radiation Laboratory Series, 1948. The magic T has a main rectangular waveguide extending in a straight line at right angles with both the E-plane arm and the H-plane arm. Ac-

cording to the present invention, the main waveguide **13** is formed around the generally circular waveguide **10**. The E-plane arm **14** is adapted for connection to a soak-up resistor, and the H-plane arm **15** is adapted for connection to the output of a sound signal transmitter of a television station.

Energy is coupled from the main waveguide **13** to the interior of the generally circular waveguide **10** by means of probes **16** and **17** extending thru apertures **18** and **19**, respectively, into the interior of the generally circular waveguide **10**. It will be noted that the probes **16** and **17** are equi-distant from the junction **20** of the magic T. The ends of the main waveguide **13** are short-circuited at **21** and **22** at distances which are electrically in the order of a quarter-wavelength from the probes **16** and **17**, respectively.

In the operation of the multi-mode waveguide system shown in Figs. 1 and 2, as applied to a television transmitting system, energy in the TE_{01} mode from the picture transmitter is applied thru rectangular waveguide **12**, and thru tapered portion **11** to excite the TE_{11} mode in the generally circular waveguide **10**. This energy is propagated up the generally circular waveguide **10** to the antenna array from which it is radiated into space. The generally circular waveguide **10** includes fins (not shown) which translate the linearly polarized TE_{11} mode to a circularly polarized TE_{11} mode at the antenna. A small amount of energy is reflected back down the generally circular waveguide **10** because, in practice, it is difficult to match the antenna to the circular guide over a broad frequency band. The reflected energy is translated back to a linearly polarized TE_{11} mode by the fins.

The incident TE_{11} mode in the generally circular waveguide **10** is so oriented that it does not couple to the probes **16** and **17**. The reflected TE_{11} mode, however, is polarized at right angles to the incident wave, due to the action of the fins, so that reflected energy is coupled thru the probes **16** and **17** to the two ends of the main waveguide **13** of the magic T. At an instant of time, the reflected TE_{11} mode in the generally circular waveguide **10** couples the positive potential to probe **16** and a negative potential to probe **17**. This results in energy flowing from the two ends of the main waveguide **13** toward the junction **20** from which the energy is coupled to the E-plane waveguide **14**. The waveguide **14** is connected to a soak-up resistor which absorbs the energy reflected from the antenna. The reflected wave in the main waveguide **13** is so oriented that it cannot couple to the H-plane waveguide **15** which is connected to the sound transmitter.

Energy from the sound signal transmitter is applied in the TE_{01} mode thru the H-plane waveguide **15** to the junction point **20** of the magic T. From the junction **20**, the energy divides in both directions along the main waveguide **13** and excites the probes **16** and **17**. The probes **16** and **17**, at an instant of time, are both excited positively. The energy is therefore such as to excite the TM_{01} mode in the generally circular waveguide **10**. This energy is propagated up the generally circular waveguide **10** to the antenna from which it is radiated into space. The sound signal energy in the H-plane waveguide **15** is so oriented that it cannot couple to the E-plane arm **14**. The sound signal energy in the generally circular waveguide **10** is in the TM_{01} mode and is thus decoupled from the two TE_{11} picture signals simultaneously propagated in opposite directions thru the generally circular waveguide **10**.

Figs. 3, 4 and 5 show a modified form of the invention wherein the corresponding parts bear the same numerals as that used in Figs. 1 and 2 except that prime designations are added. The generally circular waveguide **10'** has a square cross-section, and the main waveguide **13'** of the magic T is formed in an angular configuration. The form of the invention shown in Figs. 3, 4 and 5 also differs from the form already described in that the generally circular waveguide **10'** includes an inner coaxial conductor **25** having a tapered end **26** in the tapered portion **11'**. As shown to advantage in Fig. 4, the probes **16'** and **17'** connect directly to the inner conductor **25**. The two TE_{11} modes in the generally circular waveguide **10'** coupled from the picture input waveguide **12'** and coupled to the reflected signal output waveguide **14'** are essentially unaffected by the presence of the inner conductor **25** and its tapered end **26**. The sound signal applied thru the waveguide **15'** and the main waveguide **13'** of the magic T to the probes **16'** and **17'** excites the TEM or coaxial line mode in the generally circular waveguide **10'**. This energy is then conveyed or propagated in the coaxial line mode to the antenna.

Figs. 3 and 5 also illustrate a construction including a baffle **28** extending in a plane and connecting the tapered end **26** of the inner conductor to the opposite parallel sidewalls of the tapered portion **11'**. The baffle **28** lies in the equi-potential plane for the TE_{01} mode propagated thru the tapered portion **11'** from the rectangular waveguide **12'**. The baffle **28** therefore has no effect on the propagation of the picture signal from the transmitter to the antenna array. The baffle **28**, however, serves to produce a short circuit for the reflected TE_{11} mode and to the TM_{01} mode at a location with respect to the probes **16** and **17** favorable from a bandwidth viewpoint. Furthermore, the baffle reduces the cross-coupling between the waveguide **12** and the waveguide **13**.

It will be understood that the form of the invention shown in Figs. 1 and 2 may be modified for the propagation thru the generally circular waveguide **10** of a coaxial line mode by incorporating the construction shown in Figs. 3 thru 5 including a coaxial inner conductor **25** having a tapered end **26**, probes **16'** and **17'** connected to the inner conductor **25**, and a baffle plate **28**. The TEM or coaxial line mode is employed for the propagation of a sound signal to the antenna array.

By the use of the coaxial line mode for this purpose, the waveguide system is useful over a broader range of frequencies. This is due to the fact that the coaxial line mode has no lower cut-off frequency, whereas the TM_{01} mode has a fairly high lower cut-off frequency. A waveguide system operative over a broad range of frequencies is of considerable commercial importance when, for example, it is desired to build a system for television broadcasting in such a way that a structure of a given size may be used for any one of the considerable number of television channel frequencies.

It will be understod that the invention is useful in applications other than television broadcasting and that it may be utilized for energy flow in either direction between the generally circular waveguide and each of the rectangular waveguides.

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 waveguide having one cross-sectional dimension smaller than the cross-sectional dimension of said generally circular waveguide, a waveguide transition connecting one end of said generally circular waveguide to one end of said rectangular waveguide, a magic T having a main waveguide, an E-plane arm and an H-plane arm connected together at a junction, said main waveguide being formed around said generally circular waveguide, and means coupling energy from said main waveguide at points equi-distant from said junction to points on opposite sides of said generally circular waveguide.

2. The combination as defined in claim 1 wherein said H-plane arm of said magic T is arranged in parallel spaced relation with said rectangular waveguide, the plane of the larger sidewall of one being parallel with the plane of the larger sidewall of the other.

3. The combination as defined in claim 1, and in addition, a coaxial inner conductor extending longitudinally

in said generally circular waveguide and having a tapered end in said transformer.

4. The combination as defined in claim 1 wherein said means for coupling energy from said main waveguide to said generally circular waveguide comprises probes extending from said main waveguide thru apertures into said generally circular waveguide.

5. The combination as defined in claim 4, and in addition, a coaxial inner conductor extending longitudinally in said generally circular waveguide and having a tapered end in said transformer, said probes extending to and making contact with said inner conductor.

6. The combination as defined in claim 5, and in addition, a baffle plate extending in a plane in both directions from said tapered end of the inner conductor to opposite sidewalls of said transformer.

7. A broadband high-power waveguide system for coupling the output of a television picture transmitter and the output of a television sound transmitter to a single antenna, comprising, a generally circular waveguide adapted at one end for coupling to a transmitting antenna, a rectangular waveguide having one cross-sectional dimension smaller than the cross-sectional dimension of said generally circular waveguide, a tapered portion connecting the other end of said generally circular waveguide to one end of said rectangular waveguide, a magic T having a main waveguide, an E-plane arm and an H-plane arm connected together at a junction, said main waveguide being formed around said generally circular waveguide, a coaxial inner conductor in said generally circular waveguide, and means coupling energy from said main waveguide at points equi-distant from said junction to points symmetrically disposed in said generally circular waveguide.

8. A waveguide system as defined in claim 7 wherein said coupling means comprise transverse conductors axially aligned with each other and extending from said inner conductor thru apertures in said generally circular waveguide on opposite sides thereof to sidewalls of said main waveguide.

9. A diplexer for combining two decoupled signals in a single waveguide, comprising, a generally circular waveguide, a first rectangular waveguide having one cross-sectional dimension smaller than the cross-sectional dimension of said generally circular waveguide, a waveguide transition connecting one end of said generally circular waveguide to one end of said first rectangular waveguide, a second rectangular waveguide wrapped at least partially around said generally circular waveguide with the greater cross-sectional dimension parallel with the longitudinal axis of said generally circular waveguide, a third rectangular waveguide connected to an intermediate junction point on said second rectangular waveguide, and means coupling energy from said second waveguide at points equi-distant from said junction point to opposite sides in said generally circular waveguide, whereby TE_{01} modes in said first and third rectangular waveguides excite decoupled modes in said generally circular waveguide.

10. A diplexer for combining two decoupled signals in a single waveguide, comprising, a generally circular waveguide, a magic T having a main waveguide, an E-plane arm and an H-plane arm connected together at a junction, said main waveguide being formed around said generally circular waveguide, and means coupling energy from said main waveguide at points equi-distant from said junction to points on opposite sides in said generally circular waveguide, whereby TE_{01} modes in said E-plane and H-plane arms excite decoupled modes in said generally circular waveguide.

11. A diplexer for combining two decoupled signals in a single waveguide, comprising a generally circular waveguide, a first rectangular waveguide, a waveguide transition connecting one end of said generally circular waveguide to one end of said first rectangular waveguide, a second rectangular waveguide wrapped at least partially around said generally circular waveguide, means for short-circuiting the ends of said second rectangular waveguide, a third rectangular waveguide connected to said second rectangular waveguide at a point substantially equidistant from said ends of said second rectangular waveguide, and means coupling energy from said second rectangular waveguide at points substantially equidistant from said ends of said second rectangular waveguide to opposite sides in said generally circular waveguide.

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