

Oct. 23, 1951

W. E. KOCK

2,572,628

WAVE-GUIDE TRANSMISSION SYSTEM

Filed April 13, 1948

3 Sheets-Sheet 1

FIG. 1
PRIOR ART

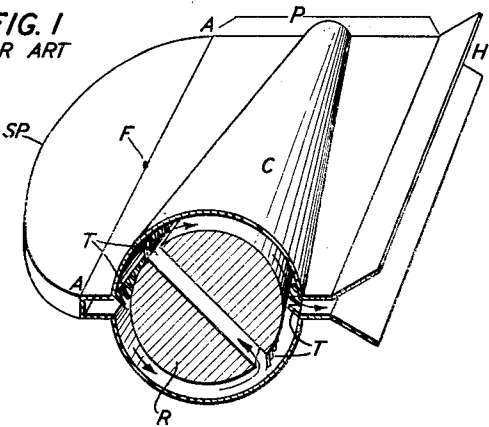


FIG. 2

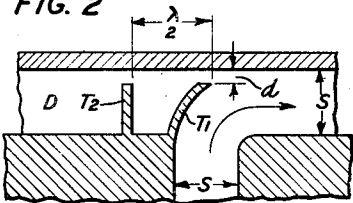


FIG. 3

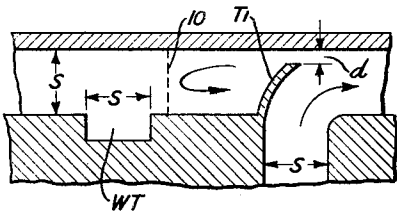


FIG. 3B

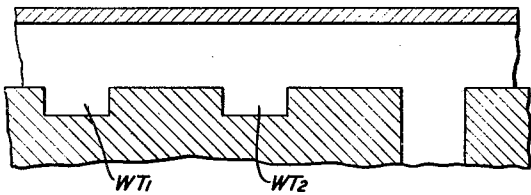


FIG. 2A

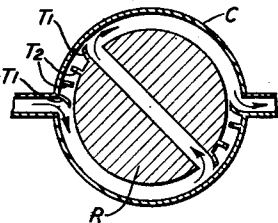
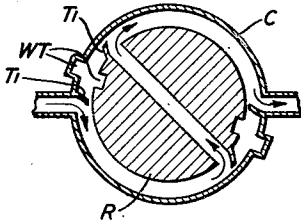


FIG. 3A



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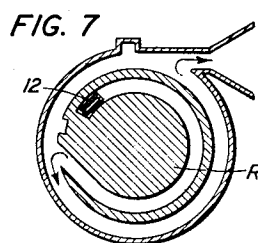
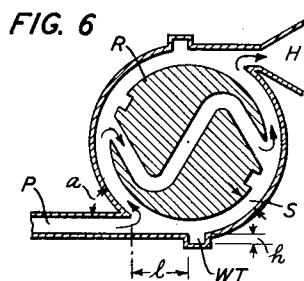
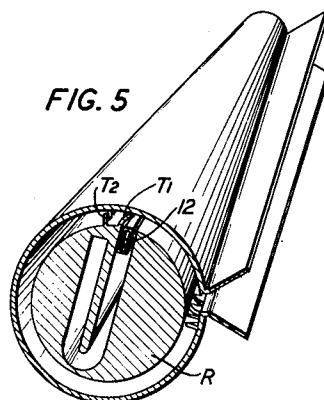
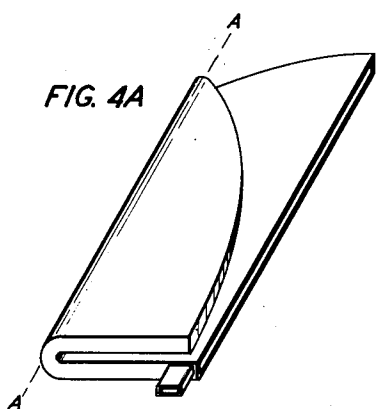
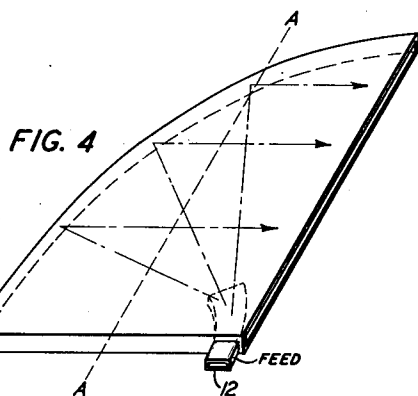
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WAVE-GUIDE TRANSMISSION SYSTEM

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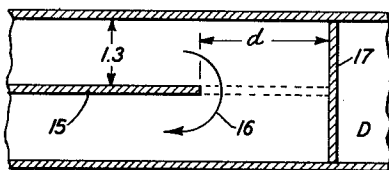


FIG. 8

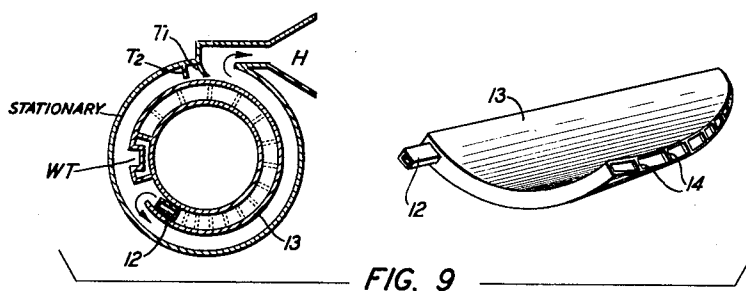


FIG. 9

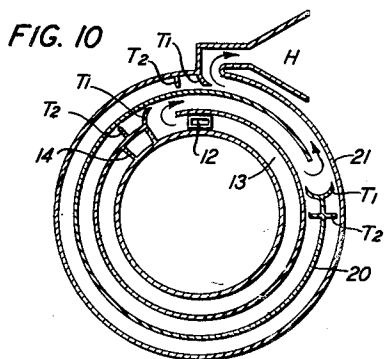


FIG. 10

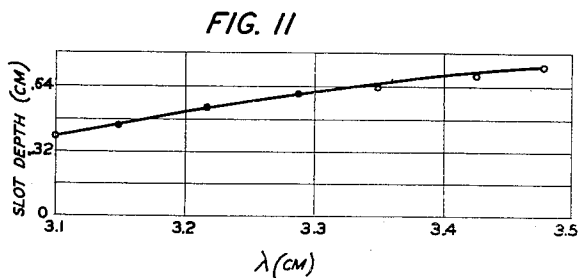


FIG. 11

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WAVE-GUIDE TRANSMISSION SYSTEM

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4 Claims. (Cl. 250—33.63)

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This invention relates to dielectric wave guide systems and particularly to branched wave guide structures having provision for directing the flow of waves into or out of certain branches and minimizing access of waves into a branch where the waves are not wanted.

An object of the invention is a branched dielectric wave guide structure, specifically one permitting movement along one wave guide of the point of branching of another guide section, with improved transmission at the junction.

Another object of the invention is an improved wave guide structure of continuously variable effective length, for scanning or similar purposes.

A known type of scanning structure comprises a relatively flat and wide wave guide structure with a trombone structure included therein comprising two parallel branches each bent around to provide together the opposing halves of a cone and having therein a coaxially mounted rotatable split cone for transferring waves across from one branch to the other to change the effective length of the wave path within the guide by different amounts across the width of the guide when the cone is rotated and so vary the tilt of the emergent wave front. To cause the waves to take the proper paths and to prevent reverse flow of wave energy in such a structure, combs, of conductive material, are mounted on opposing guide surfaces at the branching points, extending across the guide toward the opposite wall and positioned to allow the teeth on one comb to pass through the spaces of the opposite comb to permit free rotation of the cone.

Since it is mechanically impossible to have the teeth extend all the way to the opposite guide wall, a certain amount of wave energy leaks past the ends of the teeth into the guide branch where it is not wanted. This posed the problem solved by the present invention, of minimizing such leakage of wave energy by providing a more complete barrier to the waves while still permitting free mechanical movement of the rotating cone.

While this specific prior art structure has been cited for illustrating the nature of the problem, the solution provided in accordance with this invention is not limited in its application to this type of structure but is capable of general application to branched wave guides, especially where relative movement of one branch along another is desired.

The invention is applicable to the type of scanning structure referred to and when applied

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thereto achieves an improved overall performance. The invention, in other of its aspects, includes other types of wave scanning structures of improved performance as will be described.

The nature and objects of the invention will appear more fully from the following detailed description of typical embodiments illustrated in the accompanying drawings, in which:

Fig. 1 is a perspective view, partly in section, of the prior art wave scanning structure referred to above;

Figs. 2 and 3 are detail sectional views of different structures according to this invention for incorporation into the Fig. 1 structure in the manner illustrated in the diagrams shown in the respective Figs. 2A and 3A;

Fig. 3B shows a modification of the Fig. 3 construction;

Figs. 4, 4A and 5 are perspective views of a modified structure according to this invention for use as a wave scanner;

Figs. 6 and 7 show, in part perspective, modified types of wave scanners according to this invention;

Fig. 8 is a diagram of a wave reflecting system, and Fig. 9 shows how this type of reflecting system can be built into a scanner in accordance with this invention;

Fig. 10 shows a further type of scanning structure (in diagram) using the type of reflecting structure of Fig. 8, in accordance with this invention; and

Fig. 11 shows a graph to be referred to in connection with the description of Fig. 3.

Reference will first be made to Fig. 1 which shows a known type of wave scanning structure. A sectoral parabola SP is fed at its focus F to produce a plane wave front across its aperture A—A. At the aperture a parallel plate region P is attached comprising a conical section C with an interior rotating section R. The plane wave front arriving from the parabola is constrained to follow the path indicated by the arrows by means of the obstructions or combs having teeth

T. As the inside split cone is rotated, the length of the prescribed path becomes successively greater at the large end of the cone and thus a varying tilt is imparted to the wave front as it emerges from the horn H. The fan beam produced by the aperture is thus made to scan linearly in one direction by a uniform rotation of the inside cone. For continuous operation the obstructions T must pass each other and they are, therefore, made in the form of teeth to permit this. Two scans per revolution are obtained

and the total angular scan is approximately the angle whose tangent is the difference of the mean circumferences of the two ends of the cone divided by the aperture length.

The Fig. 1 structure requires, for the best tooth design, very small mechanical tolerances. Applicant set out to devise a structure which would not only ease the mechanical requirements but also result in improved electrical characteristics.

Referring to Fig. 2 which shows one form of construction in accordance with the invention, two rows of teeth are used, the first set T_1 being at 45 degrees and placed at proper position to give a smooth right angle bend assuming that they act as a solid sheet, and the second set T_2 being placed one-half wavelength behind the first row to produce an effective short-circuit at the opening at d . In one example, the separation s between the plates or opposite walls of the wave guide was one-half inch and the wavelength used was 3.4 centimeters. The teeth T_2 extended about two-thirds the way across the wave guide and acted in the manner of tuned quarter wavelength probes. It was found that their length was not critical. It is understood that each row of teeth T_1 and T_2 extends the full length of the cone, that is, in the direction perpendicular to the plane of the paper in Fig. 2, and that the half wavelength referred to is measured between the points of the teeth of one row and the points of the teeth of the adjacent row. The teeth in each row are spaced along the row a greater distance than the tooth diameter and less than one-half wavelength of the operating frequency.

Tests were made to see whether the row of teeth T_2 could be omitted if the first row of teeth T_1 were designed as quarter wavelength resonant probes. A flat wave guide structure similar to Fig. 2 was set up with the second row of teeth T_2 omitted. A value for the gap d of about one-eighth inch was considered nearly the optimum for mechanical reasons. When this tooth length was used and waves were fed in from the bottom branch of Fig. 2, a piston in the dead section D was found to set up large standing waves as the piston was moved through positions corresponding to an odd number of quarter wavelengths from the gap d . The teeth T_1 were given different lengths and for each length it was always found possible to set up large standing waves in the feed by means of a piston in the section D. Similar tests were then made using both rows of teeth with the teeth T_2 situated a half wavelength behind the teeth T_1 as in Fig. 2, and it was found that movement of the piston behind it did not affect the standing waves. Other tests tended to show that lobes in the radiation pattern produced by reflection at the teeth T_1 over a 15 per cent variation in wave band were considerably minimized when both rows of teeth were used.

Fig. 3 shows a type of structure according to the invention in which, instead of the second row of teeth, a transverse wave trap WT is used of such dimensions as to provide a substantial short-circuit across the guide at the gap d . The effective piston position for the trap WT is shown by the dotted line IQ and when the trap was properly proportioned it was found that this piston position was always .125 inch in front of the trap over a considerable range of wavelengths. The graph in Fig. 11 shows the relation between wavelength and the depth of the slot for a wavelength range corresponding to 3.1 to 3.5 centimeters. The width of the slot in each case was the same as the separation s between the guide walls and was

one-half inch in the case in which the measurements plotted in Fig. 11 were taken. The optimum ratio of slot depth to wavelength as given by this graph of Fig. 11 is seen to vary from roughly one-eighth to one-sixth over the wavelength range plotted.

Fig. 3B shows a construction in which no teeth are used but a wave trap, or in this case two wave traps, WT_1 and WT_2 are employed. The purpose of the second wave trap slot WT_2 is to give more complete suppression of the reverse propagation, analogous to a piston.

Figs. 2A and 3A show in diagram how the two rows of teeth of Fig. 2 or the wave traps of Fig. 3 may be applied in practice to a wave scanner of the Fig. 1 type. Each row of teeth T of Fig. 1 is replaced by the two rows of teeth T_1 and T_2 of Fig. 2A or by the row of teeth T_1 plus the wave traps WT as in Fig. 3A. In either case the mechanical tolerances are eased and superior electrical transmission performance is achieved.

With the type of parabolic reflector shown in Fig. 1 with the wave feed at its focus, it was found in some cases that considerable energy is reflected back into the wave guide feed, the feed being in the direct path of the radiation. A type of reflector in which the feed is removed from the direct radiation path is the sectoral half-parabola shown in Fig. 4 with its feed in one corner at 12. This structure lends itself to use in a scanning antenna particularly if it is folded along the line A—A, as in Fig. 4A, and the folded structure then placed inside the rotating conical section of the scanner itself as shown in Fig. 5. Such a structure halves the number of sets of teeth required and reduces the blind time, that is, the interval during which the teeth pass one another and thus interfere with proper operation of the scanner. (In one case constructed the blind time was 4 per cent of the rotation.) On the other hand, this structure gives but one scan per revolution so that the rotational speed must be doubled. While the double rows of teeth in accordance with the invention are shown in Fig. 5, the second row of teeth can be replaced by a wave trap as in Fig. 3A. Since the feed must be brought in at the end of the rotating cone near its outer edge a rotating joint in the feed guide must be provided in the case of the Fig. 5 structure.

Fig. 6 shows in diagram a modified form for the rotating member of the structure of Fig. 1 in which the channel through the rotating member instead of being straight has an S shape. The parallel plate section P and the horn section H make the same angle with the wave guide at the junction as does the S passage through the cone. One such angle is indicated as α in the figure. In a typical case this had a value of 28 degrees. The plate separation s was in this case one-half inch and the distance l , from the apex of the angle α to the near edge of the slot WT was in this case 1.403 inches. The dimension h of the slot (the depth) was in this case .320 inch. This gave good results when used over the wavelength range extending from 3.3 to 3.5 centimeters.

A small branching angle affords a compact design where the folded half parabola is included in the rotating element as in Fig. 5, the construction in this case taking the form indicated in Fig. 7. The half parabola instead of being folded back on itself is bent around just inside the circumference of the rotating cone. The same type of wave trap is used in this figure as in Fig. 6. In the constructions indicated in Figs.

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6 and 7 the teeth T_1 were omitted entirely and the wave traps were depended upon for suppression of the reverse wave. A more complete suppression of the undesired wave component could be realized by using two traps, one behind the other as already described in connection with Fig. 3B.

Another type of wave guide junction is the fold-back, or 360-degree bend, shown in diagram in Fig. 8. A central septum 15 divides the wave guide into an upper and a lower portion. Suitable supports in the form of posts (not shown) may be provided for this center plate 15. From analogy to circular bends it appears that the path length at the bend in Fig. 8 indicated by the arrow 16 is an integral number of half wavelengths and in one case was about 1.9 centimeters where the wavelength employed was 3.3 centimeters. The piston 17 in Fig. 8 would in practice be replaced by a row of teeth or by a wave trap as in the previous figures.

A wave scanner using the type of wave guide junction indicated in Fig. 8 is shown in Fig. 9. In this case the rotating conical element contains a core section around which is wrapped a half parabolic reflector of the general type shown in Fig. 4. This reflector, partly bent, is shown at 13 in Fig. 9. As an aid in the mechanical construction the reflecting surface need not be continuous but may consist of supports shown at 14 spaced apart something less than a wavelength. A wave trap slot is shown at WT in the rotor (to take the place of the piston 17 of Fig. 8) and for a similar purpose teeth T_1 and T_3 , two rows, are disclosed where the parallel plate portion joins the exit into the horn H. In this construction a rotary joint must be provided for the feed 12.

A modified construction in which a stationary feed can be used is shown in Fig. 10. In this case there is an inner double cone 13 similar to that in Fig. 9 but in this case stationary. There are in all four conical sheets or surfaces. The third cone, 20, counting from the center, is the only one that rotates. The waves are fed in at 12 and pass around within the guide portion 13 clockwise in the figure, undergo reflection at the reflecting surface made up of the struts 14 and pass counterclockwise around in the figure until they strike the 360-degree bend portion shown by the arrow where their direction is reversed. The next 360-degree bend is provided by the rotating cone 20 and thus the path length between the mouth of the guide portion 13 and the exit into the horn H is continuously varied in length by the rotation of the cone 20. Double rows of teeth are used at each of the guide junction points. Rolling up the parabola as in Figs. 7, 9 and 10 instead of folding it gives smaller overall dimensions. In one antenna using the Fig. 10 construction, the length of the cone was 30 inches, and the diameter varied from $8\frac{1}{2}$ inches at the large end to 3 inches at the small end. This structure gave a 20-degree scan angle and had 10 per cent dead time.

The invention is not to be construed as limited to the specific structures or details shown or to the magnitudes given throughout the disclosure since these are to be considered as illustrative, and the scope of the invention is defined in the claims.

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What is claimed is:

1. A microwave guide of adjustable effective length which comprises two relatively movable walls, a branch guide opening into said first guide through one of said walls, and a reflecting impedance element in said first guide comprising a plurality of rows of conductive teeth, each tooth being conductively fixed to one of said walls and extending therefrom substantially one-quarter wavelength toward the opposite guide wall, adjacent rows extending transversely of the direction of wave propagation and being spaced apart substantially one-half wavelength, at the operating frequency, in the direction of propagation, the tooth spacing in each row being greater than the tooth diameter and less than one-half wavelength at the operating frequency.

2. A reflecting impedance element for use in a dielectric wave guide of elongated cross-section which comprises a plurality of rows of teeth, each tooth being conductively fixed to one elongated guide wall and extending therefrom substantially one-quarter wavelength toward the opposite guide wall, adjacent rows being spaced substantially one-half wavelength apart, at the operating frequency, in the direction of propagation, the tooth spacing in each row being greater than the tooth diameter and less than one-half wavelength at the operating frequency.

3. A branched T wave guide with one branch movable along another at the junction, combs mounted on the branch members at the junction and passing through each other as the one branch moves relative to the other, each comb consisting of conducting teeth of such dimensions as to constitute virtually a conducting surface for directing wave energy into or out of one branch from or into the other, the ends of the teeth approaching but not touching the opposite guide wall, and means located in transverse relation to a branch behind the respective comb for counteracting leakage of wave energy past the comb in the direction different from that of the desired wave propagation comprising a row of substantially quarter wavelength metal pins aligned with the teeth of the respective comb and situated substantially a half wavelength behind said comb, the wavelength mentioned being in each case referred to the operating frequency.

4. A wave guide structure as claimed in claim 3 in which the teeth of said combs are each substantially a quarter wavelength long at the operating frequency.

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REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
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