April 15, 1958 F. G. CASAL 2,831,169

MICROWAVE LINE WITH VARIABLE ELECTRICAL LENGTH

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Fig. 1.

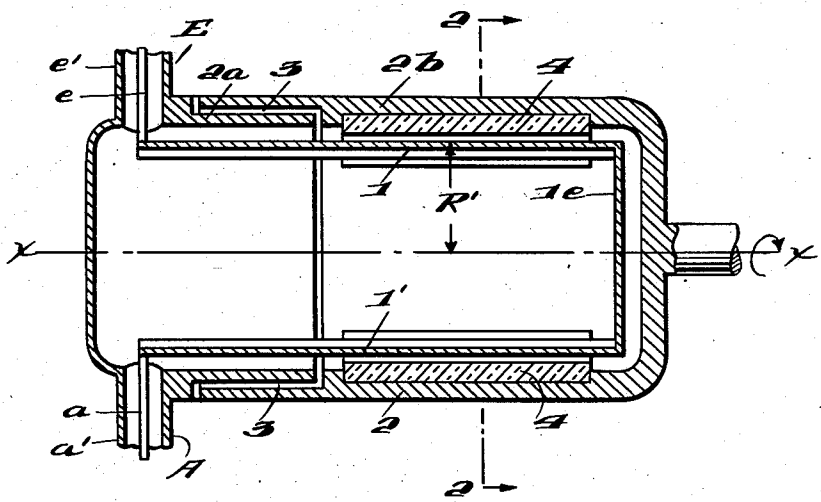
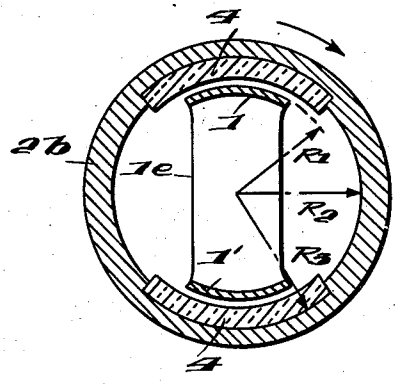


Fig. 2.



INVENTOR

Federico Guadiaro Casal

BY Pierce, Scheffler & Parker

ATTORNEYS

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Fig. 3.

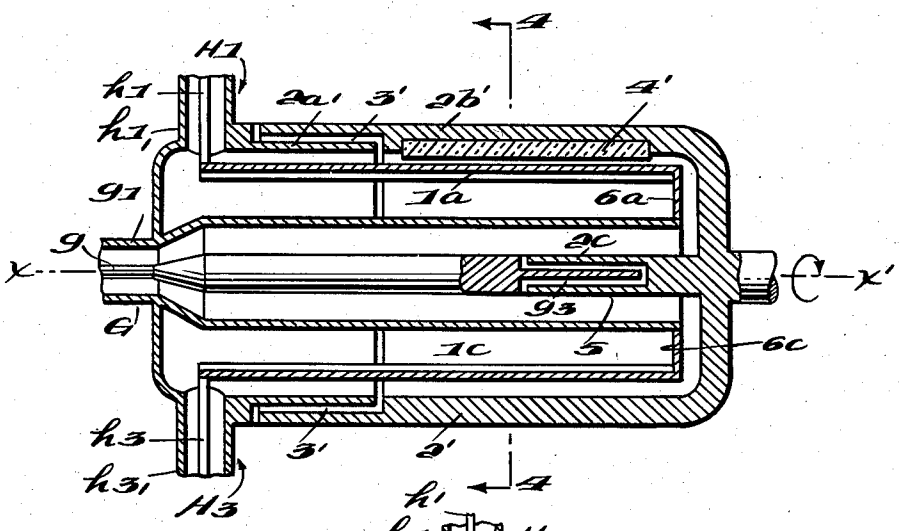
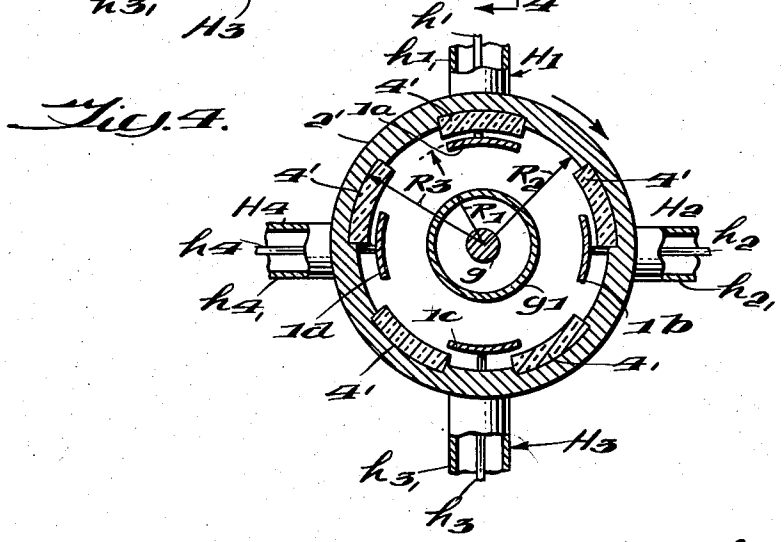


Fig. 4.



INVENTOR

Federico Guadiano Casal

BY Pierce, Scheffler & Parker

ATTORNEYS

United States Patent Office 2,831,169 Patented Apr. 15, 1958

2,831,169

MICROWAVE LINE WITH VARIABLE ELECTRICAL LENGTH

Federico Guadiaro Casal, Zurich, Switzerland, assignor to "Patelhold" Patentverwertungs- & Elektro-Holding A.-G., Glarus, Switzerland

Application July 13, 1955, Serial No. 521,842

Claims priority, application Switzerland July 31, 1954

7 Claims. (Cl. 333—31)

The present invention relates to microwave lines and is particularly concerned with lines the electrical length of which can be varied.

Microwave lines of variable electrical length can be used for example when a microwave beam with an axis that can be swung in space is to be produced by a plurality of stationary antennae. In an example of execution which is to be hereinafter described in greater detail, such lines serve to feed four antennae with voltages that are cyclically variable in phase, so that the antennae together produce a microwave beam the axis of which lies at a certain angle to a so-called guide line and rotates about the latter. The beam is usable, for example, for the guidance of aircraft flying along this guide line. Rotational frequencies for the beam of several hundred periods per second are desired in this, which can be realized only with difficulty by means of mechanically moved antennae, particularly when the direction of polarization of the waves is to remain constant.

Care must be taken that the changes in the electrical lengths of such microwave lines used for antenna phase variation do not also effect a change in their wave impedance. Instead, the most constant possible wave impedance is to be required, namely first of all with respect to perfect operation of the microwave generator (for example a magnetron) and secondly with respect to the constancy of the transmitted output.

The present invention provides for a novel manner of changing the electrical length of a microwave line in that the distance between its two conductors and the dielectric constant of the dielectric present between the conductors are changed simultaneously in such a way that the wave impedance remains constant.

As particularly advantageous in construction has proven to be a microwave line whose two conductor parts form at least parts of concentric circular cylinders, the conductors being arranged to be rotatable relative to each other about the cylinder axis, and wherein the thickness and dielectric constant of the dielectric present between the conductors are variable along the periphery of the cylinder.

The inventive concept will be illustrated by two embodiments thereof but it is understood that the principles of the invention may be put into practice through use of other embodiments or modifications of the two illustrated embodiments.

In the accompanying drawings, Fig. 1 is a view of one embodiment of the invention, the variable length microwave line being shown in central, longitudinal vertical section. Fig. 2 is a transverse view in section taken on line 2—2 of Fig. 1.

Fig. 3 is a longitudinal sectional view similar to Fig. 1 illustrating a modified construction for the variable length line incorporating the invention, and Fig. 4 is a transverse sectional view taken on line 4—4 of Fig. 3.

With reference now to the embodiment illustrated in Figs. 1 and 2, the microwave line is seen to include an inner stationary conductor comprised of two oppositely

disposed arcuate portions 1, 1′ of a circular cylinder having a radius R_1. The outer ends of the arcuate portions 1, 1′ are connected respectively to the inner conductors *e* and *a* of the coaxial lines E and A which constitute the high frequency input and output, respectively, to the variable length line. The opposite or inner ends of the arcuate conductor portions 1, 1′ are connected together by a diametrically extending conductor strip portion 1*e*. The outer conductor of the variable length line which surrounds and is concentric with the inner conductor is composed of two completely cylindrical parts 2*a*, 2*b* arranged longitudinally of the axis *x*—*x* of the line. Part 2*a* which has an inner periphery of uniform diameter is stationary and is electrically connected with the outer conductors *e*′ and *a*′ of the input and output coaxial lines E and A. Part 2*b* of the outer conductor which rotates about axis *x*—*x* partially telescopes over part 2*a* to form a rotatable coupling 3.

As is best seen from Fig. 2, the inner periphery of the outer conductor part 2*b* is purposely, in accordance with the inventive concept, arranged in such manner as to establish a non-uniform thickness and dielectric constant of the dielectric between it and the outer periphery of the inner arcuate conductor portions 1, 1′. Thus, two oppositely disposed arcuate sections of the inner periphery of the outer conductor part 2*b* have a radius of R_2 greater than radius R_1, and two other oppositely disposed arcuate sections of the inner periphery of conductor part 2*b* have a greater radius of R_3 which thus form recesses in the inner surface of part 2*b*. The inner peripheral sections of radius R_2 are arranged normal to the peripheral sections of radius R_3. The recessed portions of the outer conductor corresponding to radius R_3 have placed therein arcuate inserts 4 of a dielectric material such as an insulating material which has a dielectric constant greater than 1, the latter being the dielectric constant for air. Moreover, the thickness of the inserts 4 is such as to establish an inner radius for the latter between R_1 and R_2. Consequently it will now be clear that the thickness and also the dielectric constant of the dielectric between the inner conductor parts 1, 1′ and the outer conductor part 2*b* vary along the periphery of the outer conductor part 2*b*. In a vertical direction, looking at Fig. 2, there are two peripherally spaced sections wherein the thickness of the dielectric amounts to R_3 minus R_1 and includes the thickness of the insert 4 which has a dielectric constant greater than 1 and also a narrow air gap of dielectric constant 1. In the horizontal direction there are two peripherally spaced sections wherein the thickness of the dielectric between the inner conductor surfaces 1, 1′ and inner periphery of conductor 2*b* amounts to R_2 minus R_1 and such dielectric consists only of air, which has a dielectric constant of 1. In accordance with the invention, as the outer conductor part 2*b* is rotated about the inner stationary conductor sections 1, 1′ by means not shown since they are not essential to the present invention, the thickness and dielectric constant of the dielectric between the inner and outer conductor therefore varies cyclically and in such manner that the ensuing cycle change in the electrical length of the line is achieved without any significant change in the wave impedance. In other words, the impedance remains substantially constant.

In the arrangement illustrated in Figs. 1 and 2 the change in electrical length of the line passes through two periods for each revolution of the outer conductor part 2*b*. Instead of the dual, diametrally disposed, inserts of higher constant dielectric material, more than two such inserts can be utilized so as to correspondingly increase the number of periodic changes in line length for each revolution of the outer conductor of the line. The invention thus makes it possible to effect changes in the elec-

trical length of the microwave line with relatively high frequencies without exceeding a moderate rotational rate for the outer conductor. The form of the curve for the change in electrical line as a function of time can be arranged to suit any particular need by the selection of suitable center angles for the cylindrical parts of the conductor and by selection of particular widths for the insulating inserts 4. The change of line length with time, i. e. with rotation of conductor part 2*b* can be made to follow a sine curve, a sawtooth form, or approximately rectangular form.

The second embodiment of the invention illustrated in Figs. 3 and 4 is especially designed for a plurality of microwave lines. This arrangement which is especially useful for feeding four fixed antennas with voltages of such phase positions that the antennae produce a microwave beam rotating about a guide line. In principle, the embodiment of Figs. 3 and 4 is identical with that of Figs. 1 and 2 and hence basically similar reference characters have been utilized to identify corresponding components of the two embodiments.

The high frequency input to the variable length line takes place over the coaxial input conductor G comprising an inner rodlike conductor *g* and an outer cylindrical tubular conductor *g*1. The inner conductor of the variable length line is stationary and comprised of four equally peripherally spaced arcuate portions 1*a*, 1*b*, 1*c* and 1*d* arranged concentrically about the coaxial input conductor G. The outer ends of the arcuate conductor portions 1*a*–1*d* are connected respectively to the inner conductors *h*1–*h*4 of four coaxial output lines H1–H4 leading to four fixed antennas, respectively. Only two of the output lines H1 and H3 can be seen in Fig. 3 but all four can be seen in Fig. 4. The opposite or inner ends of the arcuate conductor portions 1*a*–1*d* are all connected by radially inward extending strips 6*a*–6*d* to the outer conductor *g*1 of the coaxial input line G. Only the upper and lower ones of these strips, 6*a*, 6*c* connected to conductor portions 1*a* and 1*c* are visible in Fig. 3 but it will be understood that the other two, lying horizontally, are similarly connected to conductor portions 1*b* and 1*d*.

The outer conductor of the variable length line which surrounds and is concentric with the inner conductor is composed of two completely cylindrical parts 2*a*′ and 2*b*′ arranged longitudinally of the axis *x*′—*x*′ of the line. Part 2*a*′ which has an inner periphery of uniform diameter is stationary and is electrically connected with the outer conductors *h*1–*h*4 of the four coaxial output lines H1–H4. Part 2*b*′ of the outer conductor which rotates partially telescopes over part 2*a*′ to form a rotatable coupling 3′. As in the embodiment of Figs. 1 and 2, the inner periphery of the outer conductor part 2*b*′ has equally peripherally spaced sections of radius R3 alternating with equally peripherally spaced sections of smaller radius R_2. Such construction establishes peripherally spaced arcuate recessed portions in which are set arcuate strips 4′ of insulating material having a dielectric constant greater than 1. Also, as in the embodiment of Figs. 1 and 2, the thickness of the inserts 4′ is such as to establish an inner radius for the latter intermediate R_1 and R_2. Consequently, the thickness and dielectric constant of the dielectric between the inner conductor parts 1*a*–1*d* and the outer conductor part 2*b*′ vary along the periphery of the outer conductor part 2*b*′. It will also be noted that the number of inserts 4′ is greater by one, in the example illustrated, than the number of output lines, there being five of the inserts 4′ and four output lines H1–H4. The input is distributed from the input line G to the four output line systems by means of a rotatable coupling 5 consisting of an inner, reduced diameter extension *g*3 of the inner conductor *g* of the coaxial input line G surrounded by a cylindrical sleeve portion 2*c* of the outer conductor 2*b*′. As in the embodiment of Figs. 1 and 2, means, not shown, are provided to rotate the outer conductor part 2*b*′ of the variable length line.

It will be evident from Fig. 4 that the electrical lengths of the four output lines H1–H4 are different from one another, such lengths changing cyclically with each one-fifth revolution of the outer conductor part 2*b*′. The mutual phase positions of the voltages which feed the antennae connected to the output lines H1–H4 undergo corresponding changes, so that with each one-fifth revolution of the outer conductor 2*b*′, the microwave beam produced by the antennae rotates five times about the aircraft guide line. Therefore a frequency of rotation of the beam of, for example, 100 periods per second, which may be expedient for guidance of aircraft, can be obtained with a moderately low speed of twenty revolutions per second of the outer conductor 2*b*′ of the variable length line. The advantage in the use of the arrangement according to the present invention over an antennae system moved with one hundred periods per second is therefore quite obvious.

In conclusion, it is to be understood that the foregoing described embodiments of the invention are to be considered exemplary rather than limitative and that hence various changes in the construction and arrangement of components of the variable length line can be made without, however, departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. A microwave line having a variable electrical length, said line comprising concentrically arranged inner and outer arcuate conductors arranged for relative rotation about their common central axis, said inner conductor being stationary and being constituted by only a part of a circular cylinder having a radius R_1, said outer conductor being rotatable and being a circular cylinder, the inner periphery of said outer conductor confronting the periphery of said inner conductor and having portions of radius R_2 greater than radius R_1 alternating with portions of radius R_3 greater than radius R_2 and inserts of insulating material having a dielectric constant greater than 1 arranged on said peripheral portions having the radius R_3.

2. A microwave line having a variable electrical length said line comprising concentrically arranged inner and outer arcuate conductors arranged for relative rotation about their common central axis, said inner conductor being stationary and being constituted by peripherally spaced parts of a circular cylinder having a radius R_1, said outer conductor being rotatable and being a circular cylinder, the inner periphery of said outer conductor confronting the periphery of said inner conductor and having portions of radius R_2 greater than radius R_1, alternating with portions of radius R_3 greater than radius R_2 and inserts of insulating material having a dielectric constant greater than 1 arranged on said peripheral portions having the radius R_3.

3. A microwave line as defined in claim 2 having a variable electrical length wherein the number of peripheral portions of said outer conductor having a radius R_3 and containing said inserts of insulating material differ from the number of peripherally spaced parts of a circular cylinder constituting said inner conductor.

4. A microwave line as defined in claim 2 having a variable electrical length wherein the number of peripheral portions of said outer conductor having a radius R_3 and containing said inserts of insulating material exceed by one the number of peripherally spaced parts of a circular cylinder constituting said inner conductor.

5. A microwave line having a variable electrical length, said line comprising concentrically arranged inner and outer arcuate conductors arranged for relative rotation about their common central axis, said inner conductor being constituted by only a portion of a circular cylinder having a radius R_1, said outer conductor being a circular cylinder, the inner periphery of said outer conductor confronting the periphery of said inner conductor and having portions of radius R_2 greater than radius R_1 alternating

with portions of radius R_3 greater than radius R_2, and inserts of insulating material having a dielectric constant greater than 1 arranged on said peripheral portions having the radius R_3.

6. A microwave line as defined in claim 5 wherein said inner conductor comprises a plurality of arcuate portions of radius R_1 equal in number to the arcuate portions R_3 of said outer conductor.

7. A microwave line as defined in claim 5 wherein said inner conductor comprises a plurality of arcuate portions of radius R_1 different in number to the arcuate portions R_3 of said outer conductor.

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