Oct. 17, 1961 D. L. FYE 3,005,168

MICROWAVE PHASE SHIFTER

Filed Oct. 8, 1959 3 Sheets-Sheet 1

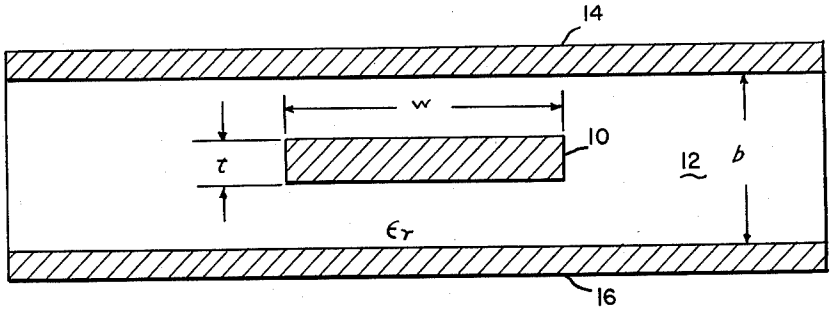


Fig-1

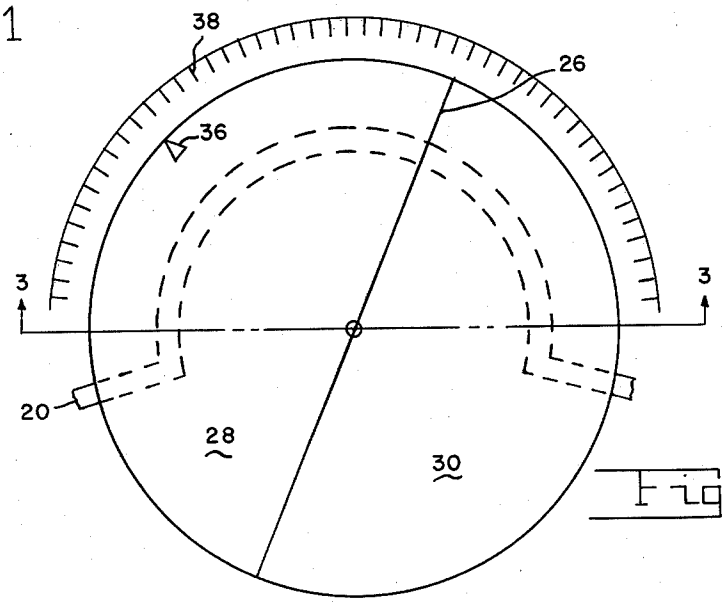


Fig-2

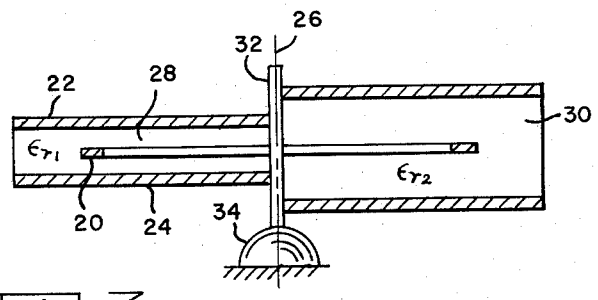


Fig-3

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MICROWAVE PHASE SHIFTER

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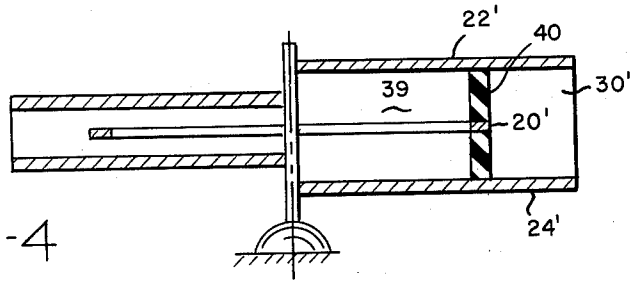


Fig-4

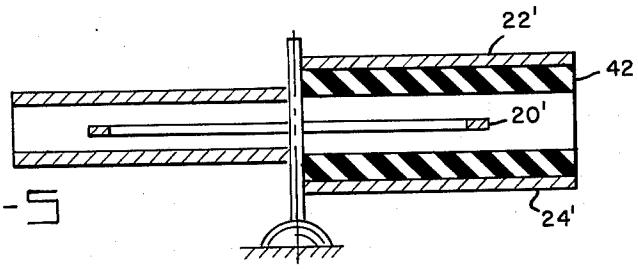


Fig-5

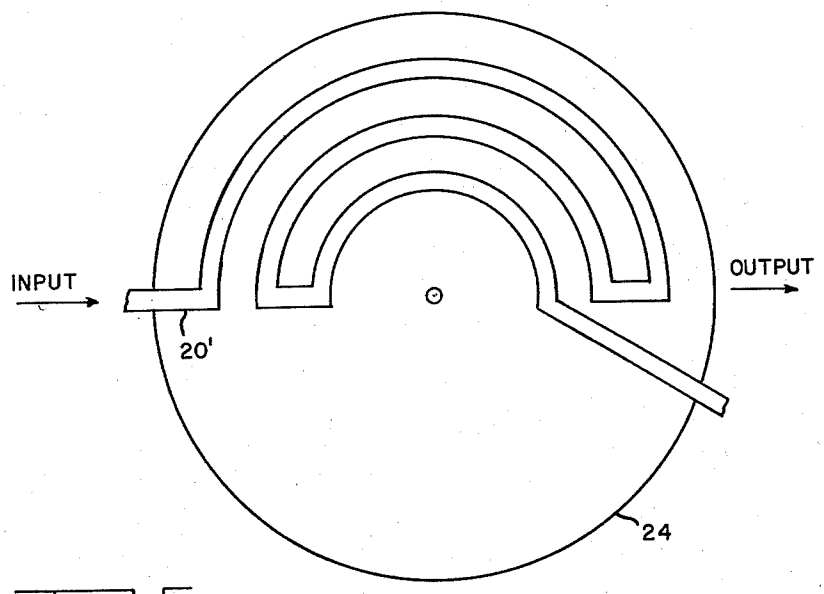


Fig-6

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MICROWAVE PHASE SHIFTER

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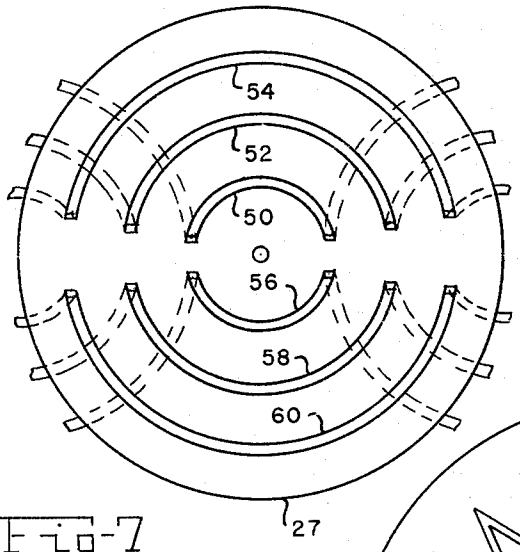


Fig-7

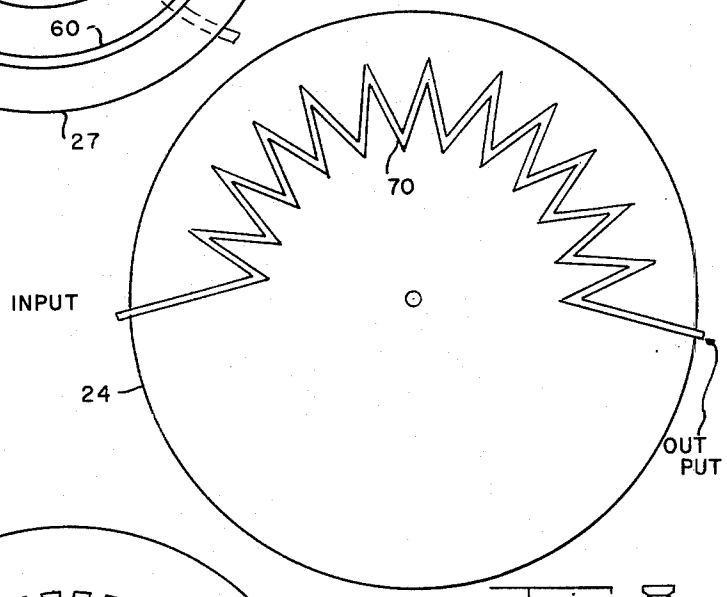
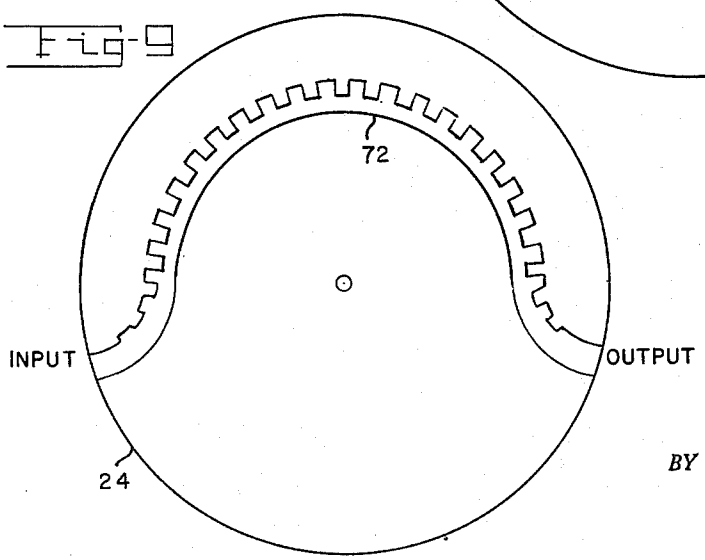


Fig-8

Fig-9



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3,005,168

MICROWAVE PHASE SHIFTER

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Filed Oct. 8, 1959, Ser. No. 845,291
1 Claim. (Cl. 333—31)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Goverment for governmental purposes without payment to me of any royalty thereon.

This invention relates to a microwave phase shifter and particularly to a phase shifter having a single mechanical movement and no moveable electric connections for changing or adjusting the phase between the elements of a fixed antenna array.

In order to control the position of a pencil beam from a large fixed antenna array, it is frequently necessary to adjust the phase between the elements of the array. This is a particularly difficult task at the lower end of the microwave region (100 mc. p.s. to 1000 mc. p.s.) because the distributed constant transmission line elements are necessarily large. Heretofore many types of phase shifters have been used, such as; coupled helices, transmission line elements utilizing ferromagnetic effects, delay lines, etc. Each of the known tuning elements has its own advantages and its disadvantages. The most common disadvantages are: complexity, fluctuations in impedance and insertion loss, reliability and size.

It is a well known fact that the velocity factor of electromagnetic waves in the TEM mode on ordinary transmission lines (e.g. not spiral delay lines) with the field totally immersed in a uniform dielectric of dielectric constant ϵ_r (relative to air) is $1/\sqrt{\epsilon_r}$. Therefore, the relative phase between the input and output of a fixed length of transmission line may be varied by changing either the effective dielectric constant of the surrounding material, or the ratio of the amounts of the line surrounded by dielectrics with more than one value of ϵ_r.

This invention consists of a device for varying the ratio of the amount of line surrounded by dissimilar effective dielectrics (or velocity factor) between two fixed points without varying the input and output impedances of the line. Mechanically varying the above ratio results in a continuously variable phase shift that is insensitive to frequency and a constant impedance.

In a practical construction according to the invention, a fixed dimension center conductor is received between outer conducting plates, which are mounted for movement to inclose the inner conductor in various portions of the outer plate and providing different spacing between different portions of the plates and providing the wider spaced positions of the plate with a dielectric having a higher dielectric constant than the dielectric between the closely spaced portions of the plates and providing means for shifting the plates so that the center conductor extends through the narrow and wider positioned portions of the plate in adjustable ratio.

It is accordingly an object of the invention to provide an improved microwave phase shifter.

It is a further object of the invention to provide a phase shifter which maintains constant impedance while the phase is shifted.

It is another object of the invention to provide a microwave phase shifter having a continuously variable phase shift with a simple mechanical motion.

It is a further object of the invention to provide a phase shifter with negligible insertion loss and with very small change in this loss as the phase is shifted.

It is still another object of the invention to provide a phase shifter with a simple low cost construction.

It is a further object of the invention to provide a phase shifter having no variable electrical contacts.

It is still another object of the invention to provide a microwave phase shifter having high reliability.

It is a further object of the invention to provide a phase shifter having all characteristics independent of frequency except for the amount of phase shift vs. mechanical motion.

Other objects and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a cross section of a flat-strip transmission line;

FIG. 2 is a top plan view of a constant impedance phase shifter;

FIG. 3 is a sectional elevation of the phase shifter taken on the plane indicated by section line 3—3 of FIG. 2;

FIGS. 4 and 5 are views similar to FIG. 3 showing modifications;

FIG. 6 is a top plan view similar to FIG. 2 with top ground plane removed to show design of strip conductor to obtain a compact phase shifter;

FIG. 7 is a view similar to FIG. 6 showing arrangement to obtain synchronous phase shift in multiple lines; and

FIGS. 8 and 9 are views similar to FIG. 6 showing further arrangements of the center conductor to reduce the overall physical size of the phase shifter.

The exemplary embodiment according to the invention has been illustrated as applied to a stripped transmission line including a center conductor **10** having a width w, thickness t and immersed in a dielectric **12** having a dielectric constant ϵ_r relative to air between outer conductor plates **14** and **16** having a spacing b, as indicated in FIG. 1. However, the principles are applicable to coaxial and other types of transmission lines that support TEM modes. In stripline (sandwich type) transmission lines, the impedance is a function of the center conductor width w, thickness t, ground plane spacing b, and the effective dielectric constant ϵ_r, between the ground planes. See FIG. 1. The velocity of propagation along the line is a function of ϵ_r only. In order to maintain a constant impedance while changing ϵ_r, adjustments must be made in one or all of the variables w, t and b. For example: an increase in ϵ_r requires one of the following: (a) Increase in b keeping w and t constant. (b) Decrease in w keeping b and t constant. (c) Decrease in t keeping b and w constant. (d) Any equivalent combination of the above in which the net result is essentially one of maintaining a constant capacitance between the center conductor and the ground planes.

Obviously the maximum phase change would be one of maximum change in ϵ_r or from air to some medium with a higher effective dielectric constant. A study of the above conditions for constant impedance reveals that the most practical method is: increasing b in the region of increased ϵ_r keeping w and t constant.

FIG. 2 is an illustration of a practical construction by which this may be accomplished. The center conductor **20** is arranged in arcuate position between an outer plate **22** and an opposite outer plate **24**, which are spaced from the conductor **20** so that the conductor **20** is immersed in a dielectric material between the plates **22** and **24**. The plates **22** and **24** are offset as along a medium line **26** so that the plates **22** and **24** have a sector **28** of narrow spacing and a sector **30** of wider spacing. The sectors **28** and **30** are filled with a suitable dielectric with the dielectric in the sector **28** having a preselected value ϵ_{r1} and the sector **30** has a dielectric having higher dielectric constant ϵ_{r2}. The plates **22** and **24** are mounted on a shaft **32**, which is in turn mounted in bearing **34** so that

the plates may be rotated as a unit about the shaft 32 as an axis. The portion of the conductor 20 received in the sectors 28 and 30 can then be readily varied by rotating the plates about the axis 32. Any suitable means (not shown) may be provided for adjusting the position of the plates 22 and 24 and suitable indicating means, such as pointer 26, may be affixed to, or operated by, one of the plates such as 22 to cooperate with a suitable dial 38.

Obviously, rotation of the plates 22 and 24 will result in a change of phase relation and proper choice of dimensions and the constant of the dielectric contained in the various sectors will result in a constant impedance.

The dielectric medium in the sectors 28 and 30 need not be uniform, but may be composed of portions of different dielectric constants, for example, in FIG. 4 the main portion of the sector 30' is filled with a dielectric 39 of one constant while an arcuate portion 40 of another dielectric having a different dielectric constant is placed in direct position between the central conductor 20 and the outer conductors 22' and 24'. As indicated in FIG. 5, the entire sectors may be filled with layers 42 of dielectric of different characteristics.

In order to reduce the physical size of the phase shifter, the conductor 20' may be arranged in labyrinth type convolutions, as shown in FIG. 6, so that a relatively small plate 24 will cover a large extent of the conductor 20'.

A plurality of multiple lines 50, 52, 54, 56, 58 and 60, may be arranged as shown in FIG. 7 to provide synchronous phase shifters in each of the multiple lines.

Instead of the labyrinth type construction of FIG. 6 a wave type construction 70, as shown in FIG. 8, may be utilized to increase the effective length of the center conductor to reduce the size of the outer or ground plates 22 and 24.

A slow wave type conductor 72 may be utilized between the plates as shown in FIG. 9 to further assist in reducing the size of the phase shifter to produce the desired phase shift.

In the operation of the phase shifter no electrical contacts are changed and the phase may be smoothly shifted for the full range for the device with practically no disturbances of the impedance or losses of the transmission lines.

For purposes of exemplification particular embodiments of the invention have been shown and described according to the best present understanding thereof. However, it will be apparent to those skilled in the art that various changes and modifications in the construction and arrangements of the parts thereof may be readily resorted to without departing from the true spirit of the invention.

I claim:

An adjustable microwave phase shifter comprising an arcuate conductor, a pair of conductive plates located on either side of said conductor and parallel thereto, means for pivoting said plates about an axis normal to the plates and passing through the center of the arc of said conductor, means dividing said plates into two sectors along a plane containing said axis, said sectors being of substantially the same angular extent as said arcuate conductor, dielectrics of different dielectric constants between the plates of the two sectors, the spacing of the plates in the sector having the dielectric of higher dielectric constant being greater than the spacing in the other sector by the amount required to produce equality between the characteristic impedances of the sections of transmission line formed by the arcuate conductor and the plates in each sector.

References Cited in the file of this patent

UNITED STATES PATENTS

2,527,608	Willoughby	Oct. 31, 1950
2,816,273	Peck	Dec. 10, 1957
2,831,169	Casal	Apr. 15, 1958

FOREIGN PATENTS

313,688	Switzerland	June 15, 1956

OTHER REFERENCES

Electronics, vol. 27, No. 9, September 1954, pp. 148–150.