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CONSTANT IMPEDANCE HIGH RESOLUTION PHASE SHIFTER

Filed June 14, 1968

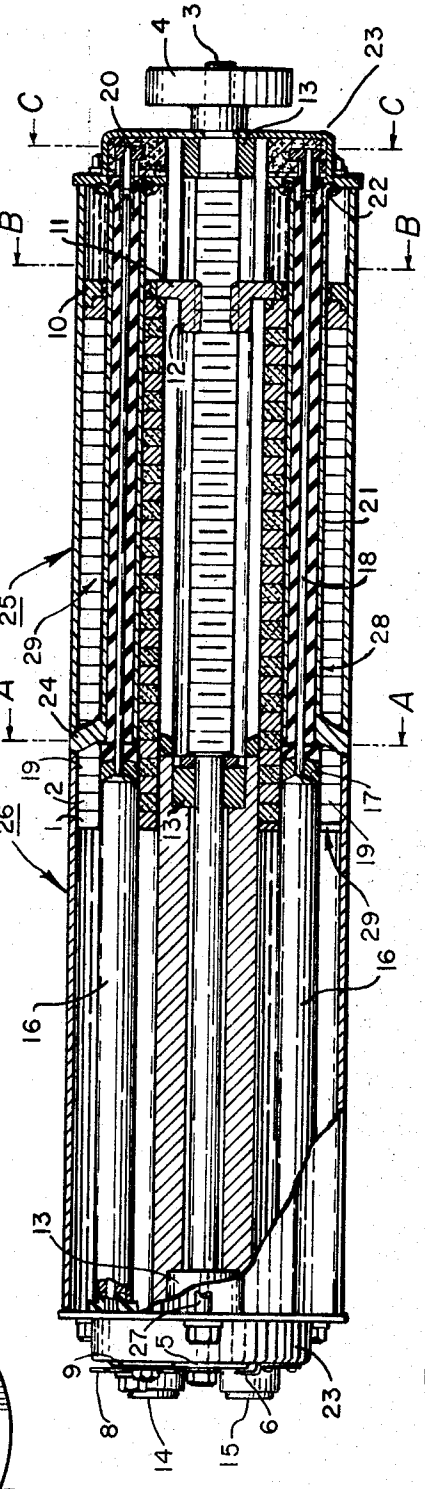


FIG. 1

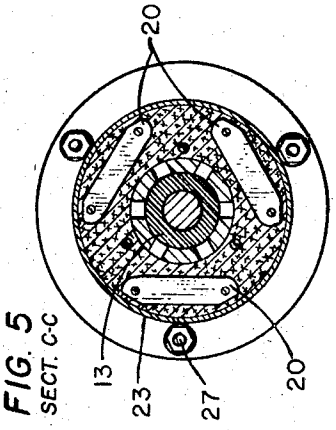


FIG. 5
SECT. C-C

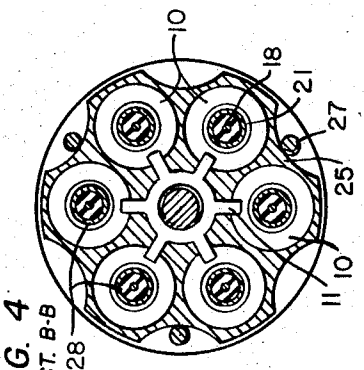


FIG. 4
SECT. B-B

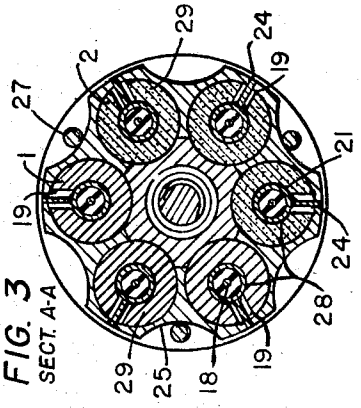


FIG. 3
SECT. A-A

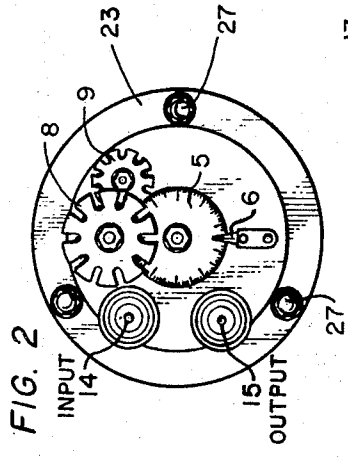


FIG. 2
INPUT
OUTPUT

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CONSTANT IMPEDANCE HIGH RESOLUTION PHASE SHIFTER

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U.S. Cl. 333—31 10 Claims

ABSTRACT OF THE DISCLOSURE

A continuously variable delay line is disclosed. The delay line features a plurality of sections of coaxial line electrically connected in series but physically arranged in parallel around a central adjusting mechanism. The delay time is varied by moving a plurality of ferrite tubes axially from a position where one tube is outside the outer conductor of each coax section to a position where one tube occupies the space between the inner and outer conductor of each coax section.

BACKGROUND OF INVENTION

The present invention relates generally to delay lines; and more particularly to low-loss, continuously variable, phase shifters for use at high power RF frequencies. Until the invention of a low-loss continuously variable delay line by Helmut Brueckmann, Pat. No. 3,219,950, assigned to the assignee of this invention, low-loss delay lines tended to be heavy and bulky and many of the prior art delay lines, due to particular design features, were not entirely satisfactory for applications involving high RF power. This invention is an improvement of the basic variable delay line disclosed in the above cited patent to Helmut Brueckmann.

SUMMARY

It is therefore, an object of this invention to provide a continuously variable phase shifter.

Another object of this invention is to provide a relatively small and compact low-loss delay line for use at high power RF frequencies.

A still further object of this invention is to provide a variable delay line constructed in a compact structural unit with an indicator for reading the time delay introduced for a given setting of the delay adjustment means.

DESCRIPTION OF DRAWINGS

Other objects and advantages of the invention will hereinafter become more readily apparent from the following detailed description when considered with the annexed drawing in which:

FIG. 1 shows in section a preferred embodiment of the invention.

FIG. 2 is an end view of the invention.

FIG. 3 is a cross-section view of the invention taken along the line A—A of FIG. 1.

FIG. 4 is a cross-section view of the invention taken along the line B—B of FIG. 1.

FIG. 5 is a cross-section view taken along the line C—C of FIG. 1.

DESCRIPTION OF PREFERRED EMBODIMENT

The phase shifter shown in the drawing utilizes six sections of flexible coax line. The coax sections **28** are arranged physically in a circular fashion around a common center. While the coax sections are physically arranged in parallel, they are connected electrically in series by means of the straps **20** shown in FIG. 5. Straps **20** or any

suitable connectors are used at both ends of the device to complete the series circuit. These electrical connections are protected by means of the end caps **23**. End caps **23** also provide shielding. The body or main housing of the phase shifter consists of the two sections **25** and **26**. Both sections **25** and **26** are solid aluminum blocks that have been machined out to accommodate coaxial lines **28** and other parts to be described in detail later. Body sections **25** and **26** are held together by long bolts **27**. The main housing is fabricated in two sections in the manner just described to facilitate assembly of the phase shifter.

Each of the six coax sections **28** can be considered to be separated into two pieces. The first piece comprises an outer conductor **21** and an inner conductor **18**. The second piece of each coax section **28** has an inner conductor labelled **16** in FIG. 1. Inner conductor **16** has the same diameter as outer conductor **21** of the first piece. Outer conductors **21** are connected to the main body or housing by means of the rings **22** and the ribs **24**. Ribs **24** provide short connections to each outer conductor **21** to the main housing sections **25** and **26**. Outer conductor **21** and inner conductor **18** are discontinuous at this point. The outer conductor of the second piece of each coax is section **26** of the main housing.

The inner conductor **18** of each of the six coax sections is electrically connected, by any suitable means such as solder, to the inner conductor **16**. Inner conductor **16** is supported by outer conductor **21** by means of the insulating ring **17**.

From the foregoing description it is apparent that each coax section **28** can be considered as consisting of two parts, one part having a larger diameter than the other part. The small diameter part having an outer conductor **21**. The larger diameter part consists of piece **16** and housing section **26**.

As shown in the drawing the smaller diameter part of each coax section **28** is surrounded by a tubular member **29**. Tubular member **29** is a hollow ferrite cylinder constructed of alternate hollow cylindrical discs of a ferrite material **1** and a ceramic material **2** bonded together by any suitable means. Of course, ceramic discs **2** can be replaced by ferrite discs or tubular member **29** could be made from a solid piece of ferrite that has been machined out to form a hollow cylinder. Each tubular member **29** has a longitudinal slot **19** to allow it to slide past rib **24**. Another function of slot **19** is to reduce the effective relative permeability of the ferrite to match it to the effective relative dielectric constant of the ferrite for the purpose of making the characteristic impedance a constant, whether the ferrite is inserted or withdrawn.

The six tubular members **29** are connected by means of the rings **10** and the ribs **11** to a micrometric lead screw **3** having 10 threads to an inch. Lead screw **3** rotates in the bearings **13** and is turned by means of a knob **4**.

The position of lead screw **3** is determined by an indicator as shown in FIGS. 1 and 2. The indicator consists of a dial **5** with engraved markings corresponding to .001 inch movement of members **29**, an index **6** and Geneva drive type counting dials **8** and **9**. If desired, the indicator can be calibrated to read time delay directly. The input and output connections, **14** and **15** respectively, are located next to the indicator.

The phase shifter constructed in the manner shown in the drawing provides a continuously variable time delay of up to 30 nanoseconds, from 7 nanoseconds to 37 nanoseconds. When tubular members **29** are in the position shown in the drawing no time delay, other than the basic time delay of the device, is introduced. In this position the members **29** are outside of the outer conductors **21** of coax sections **28**. When members **29** are moved by means of screw **3** and knob **4** to a position to the left of the position shown, the time delay is varied. In this position, mem-

bers **29** occupy the space between the inner and outer conductors of coax sections **28**. The outer conductor for all six coax sections being housing section **26** in this area. The time delay increases as the members **29** are moved from right to left. The time delay introduced is a maximum when members **29** occupy all the space between housing section **26** and parts **16** of coax sections **28**. In other words, the time delay is a maximum when members **29** are moved completely to the left of the position shown in the drawing.

What has been described above is a preferred embodiment of the invention. Various changes and modifications can be made to the preferred embodiment without departing from the spirit and scope of the invention as defined in the claims. For example, rigid coax sections having tubular conductors can be used for coax sections **28** instead of the flexible type coax. If rigid coax is used the housing can be a hollow cylinder of brass or aluminum instead of the machined out aluminum block shown; because no extra support is needed for the coax. Also, more than six coax sections can be used.

What is claimed is:

1. A constant impedance high resolution phase shifter comprising:

a plurality of coaxial sections each having an inner and outer conductor, each of said coax sections being discontinuous at its mid-point along the length of the section thereby forming a first half and a second half, the diameter of the inner conductor of said second half of each coax section being the same size as the diameter of the outer conductor of said first half of each coax section;

a plurality of hollow ferrite cylinders being equal in number to said plurality of coax sections and being approximately one-half as long as said coax sections, one of said coax sections being inserted into each of said ferrite cylinders;

a generally cylindrical shaped housing;

means to secure said coax sections inside said housing in such a manner that said coax section-ferrite cylinder combinations form a ring having a diameter slightly smaller than the diameter of said housing;

means inserted inside said housing and secured to said ferrite cylinders for axially moving said ferrite cylinders along said coax sections;

means positioned at said mid-point for connecting said inner conductor of said first half of each coax section to its associated inner conductor of said second half;

means for connecting the outer conductor of said first half of all of said coax sections to said housing;

means for electrically connecting said coax sections in series;

means for applying an input signal to said coax sections; and,

means for obtaining an output signal from said coax sections.

2. A constant impedance high resolution phase shifter as defined in claim **1** wherein said plurality of coax sections is six in number.

3. A constant impedance high resolution phase shifter as defined in claim **2** wherein said housing comprises two sections, each section being a solid block of aluminum that has been machined out to accommodate the coax sections, the ferrite cylinders and said means for moving said ferrite cylinders.

4. A constant impedance high resolution phase shifter as defined in claim **3** wherein said means to axially move said ferrite cylinder comprises a micrometric screw having a knob at one end to facilitate the turning of said screw.

5. A constant impedance high resolution phase shifter as defined in claim **1** wherein said coax sections are rigid.

6. A constant impedance high resolution phase shifter as defined in claim **1** wherein said coax sections are flexible.

7. A constant impedance high resolution phase shifter as defined in claim **5** wherein said housing is a hollow cylinder of electrically conductive material.

8. A constant impedance high resolution phase shifter as defined in claim **1** wherein indicator means for indicating the position of said ferrite cylinders along the length of said coax sections is mounted on said housing.

9. A constant impedance high resolution phase shifter as defined in claim **1** wherein said ferrite cylinders are made of alternate hollow discs of a ferrite material and a ceramic material.

10. A constant impedance high resolution phase shifter comprising a plurality of coax sections so designed that the effective diameter of each of said coax sections is greater for one half of its length than it is for the other half;

a plurality of ferrite cylinders; and

means connected to said cylinders for selectively moving said cylinders to a position where one of said cylinders is outside the outer conductor of each of said coax sections to a position where one said cylinder is between the inner and outer conductor of each of said coax sections.

References Cited

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M. NUSSBAUM, Assistant Examiner

U.S. Cl. X.R.

333—97