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CONSTANT IMPEDANCE COAXIAL PHASE SHIFTER

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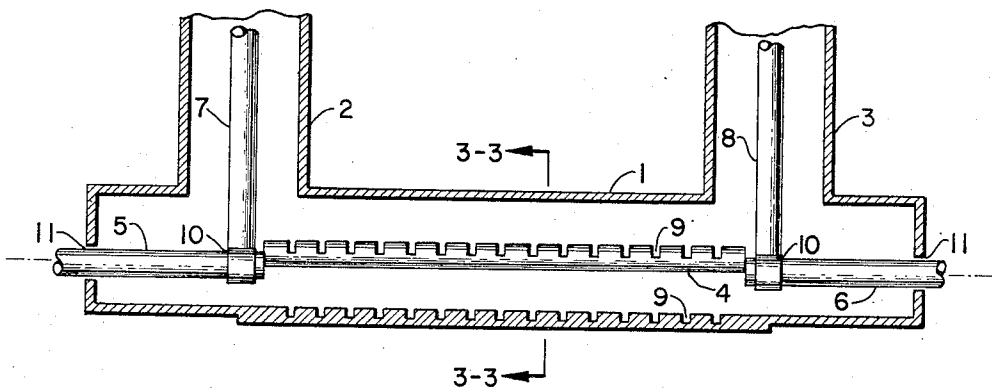


FIG. 1

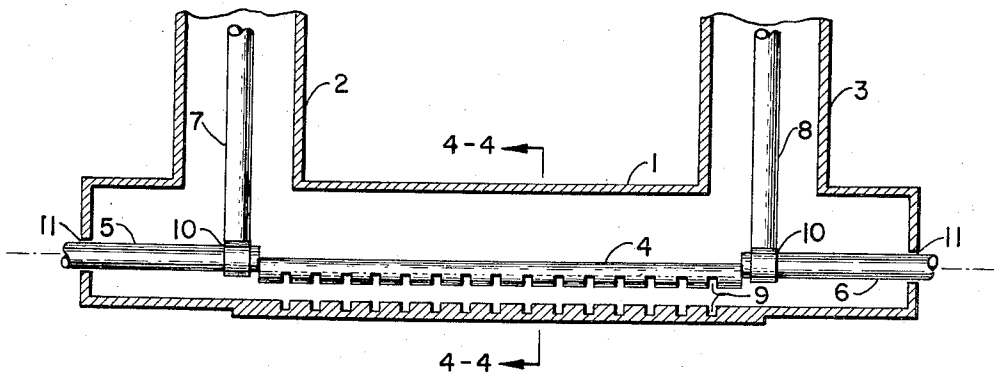


FIG. 2

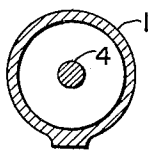


FIG. 3

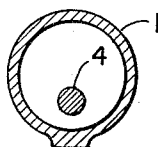


FIG. 4

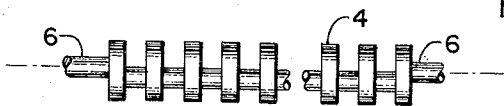


FIG. 5

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CONSTANT IMPEDANCE COAXIAL PHASE SHIFTER

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The present invention relates to phase shifters, and in particular to coaxial phase shifters.

It is sometimes necessary to compare two R.F. signals to determine their phase relationship with respect to one another. A method of performing this is to delay or shift one of the signals by an amount necessary to make a favorable comparison with the second signal. The degree of phase shifting necessary to provide this result is an indication of the phase relationship.

There are several methods for providing the necessary amount of phase shift. One method, which is commonly referred to as "line stretching," physically changes the length of the coaxial line through the use of telescoping conductors. A difficulty present in this method is the maintaining of good noise-free contacts in the telescoping parts.

Another method for providing various values of phase shift is to vary the dielectric in the line. This method presents several problems. One is that the dielectric which is used absorbs energy from the signal. As the dielectric is varied to provide different values of phase shift, the amounts of energy that are absorbed will also vary. These changes in absorption will produce varying signal amplitudes which will affect the comparing of the two signals. Another problem present in this method is that the characteristic impedance will vary as a function of the dielectric. This will cause standing waves to exist in one signal that are not present in the remaining signal. A favorable comparison is therefore impossible.

Still another method for providing various degrees of phase shift is through the use of a "butterfly" tuner. As the impedance of this device likewise changes with changes in phase shift adjustments, its use makes a favorable comparison impossible.

The present invention makes available a means for phase shifting that is continuously adjustable, maintains a relatively constant impedance throughout its operating range, and absorbs very little energy from the signal.

An object of the present invention is to provide a coaxial type phase shifting means.

Another object is to provide a coaxial phase shifting means that may be adjusted in a continuous fashion while maintaining a relatively constant characteristic impedance.

A further object is to provide a relatively constant impedance phase shifting means that may be operated to provide, in a predetermined manner, a constantly varying phase shift in the signal.

A still further object is to provide all of the above objects in a means wherein the mechanical problems encompassing drive, balancing, and wear have been reduced.

These and other objects are present in a coaxial line arrangement wherein the outer and inner conductors are physically constructed and arranged to permit the inner conductor to be varied in position with respect to the outer conductor so that a relatively constant characteristic line impedance is maintained therethrough while

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the phase shifting characteristics thereof are varied as a function of the relative positions of the inner and outer conductors.

Referring to the drawings:

Fig. 1 depicts a coaxial line in which the invention is used;

Fig. 2 illustrates the same line as illustrated in Fig. 1 but with the inner conductor rotated 180°;

Fig. 3 is a sectional view through the line of Fig. 1;

Fig. 4 is a sectional view through the line of Fig. 2; and

Fig. 5 depicts a variation in the inner conductor illustrated in Figs. 1-4.

Referring in particular to Fig. 1, a coaxial line system comprising outer conductors 1, 2, and 3, and inner conductors 4, 5, 6, 7, and 8 is presented. Bearings are provided at points 10 and 11 to permit the inner conductors 5 and 6 to freely rotate while maintaining good R.F. connections. The R.F. signal may be inserted via one of the legs comprising either outer conductor 2 and inner conductor 7 or outer conductor 3 and inner conductor 8. The R.F. output signal may be obtained from the remaining leg.

The length of the inner conductors 5 and 6 is designed to be one-quarter of an electrical wave length of the frequency at substantially the center of the band of operating frequencies in order to present open-circuit conditions to the junctions of the conductors 5 and 4 and the conductors 6 and 4 respectively. Obviously any quantity of an odd integer of quarter wave lengths may be employed. The conductors 5 and 6 are below but parallel to the center line of the outer conductor 1. The inner conductor 4 is joined to the conductors 5 and 6 in such manner that the line through the center thereof does not coincide with the geometric axis of the conductors 5 and 6.

In Fig. 2 the conductors 5 and 6 have been rotated 180°. The conductor 4 has been rotated 180°, but in addition, it has revolved about the center line of the conductors 5 and 6 such that it is closer to the bottom of the conductor 1. This is further exemplified by the views in Fig. 3 and 4. Fig. 3 shows the position of conductor 4 illustrated in Fig. 1 and Fig. 4 shows the position of conductor 4 illustrated in Fig. 2.

A portion of the bottom side of the conductor 1 and a portion of the bottom side of the conductor 4 have corrugations 9 therein. When the conductors 4, 5, and 6 are in the position illustrated in Fig. 1, the impedance of the line is approximately that of a conventional line as the electromagnetic field is almost evenly distributed. When these conductors are in the position depicted in Fig. 2, the field distribution changes such that a heavy concentration thereof exists between the bottom side of the conducting surface of conductor 4 and the bottom side of the conducting surface of the conductor 1. This effect produces a change in the capacitance and the inductance along this section of the line in a manner such that as one increases in value, the other will also increase. By the proper control of these characteristics, a relatively constant impedance phase shifting means is produced. The conditions that must be met for a true constant impedance are expressed by the transmission line equations:

$$\text{Impedance} = \sqrt{\frac{\text{inductance}}{\text{capacitance}}}$$

and

$$\text{Phase shift} = \sqrt{\frac{1}{\text{inductance} \times \text{capacitance}}}$$

Therefore, if the ratio of the values of the inductance and the capacitance is maintained substantially constant, but the product thereof varies, a substantially constant

impedance will be maintained while the phase shift will vary.

The term "side" as used in the foregoing discussion is meant to connote that rounded surface of a portion of a conductor which is defined by a plane passing there-through so as to be substantially parallel to the center line thereof.

The amount of phase shift that will be achieved for a given wave length will depend on the corrugations 9, the diameter and length of the conductor 4, and the eccentricity of the inner conductor 4. Although the corrugations 9 have been shown in both the inner conductor 4 and the outer conductor 1, it is to be understood that the invention is not limited to this particular combination, as it is possible to provide a workable device with the corrugations 9 limited to one conductor. Likewise, it is possible to provide other types of rugose surfaces that will operate to assist in providing the conditions set out in the two previously stated equations. The rugosities must have a longitudinal directional component that is perpendicular to the center line of the conductor in order to provide the capacitive and inductive variations.

In a particular model of the invention similar to that depicted in Figs. 1 and 2 that was constructed for operation at a frequency of 2,000 mc., the following dimensions produced a unit capable of providing a shift of approximately one wave length:

I.D. of the outer conductor 1=0.785 in.;
O.D. of the inner conductors 4, 5 and 6=0.341 in.;
Offset of the inner conductors 5 and 6 in the extremities of the outer conductor 1=0.090 in.;
Offset between the inner conductors 4, 5, and 6 to provide the crank action=0.090 in.;
Distance between the legs comprising the conductors 2, 3, 7, and 8=10 in.;
Distance between the legs comprising the conductors 2, 3, 7, 8, and the extremities of the conductor 1=1.5 in.;
Width of the slots 9 in both inner and outer conductors 1 and 4= $\frac{1}{64}$ in.;
Distance between the slots 9= $\frac{1}{64}$ in.;
Depth of slots 9 in the inner conductor 4=0.170; and
Depth of slots 9 in the outer conductor 1=0.045 in.

Fig. 5 illustrates a modification of the inner conductor 4. Various combinations of undercuts may be provided to secure the rugosity to meet the necessary conditions as set out in the above equations.

It is not meant to restrict the invention to an adjustable phase shifting means as it is sometimes desirable to provide an additional but fixed value of shift in a given length of coaxial line. Therefore, the invention may take the form of a device of the same general description as heretofore presented, without utilizing the rotatable feature of the conductors 4, 5, and 6.

A particular coaxial arrangement has been utilized to demonstrate the invention. For example, the use of the one-quarter wave length sections comprising conductors 5 and 6 provides a convenient means for supporting the conductor 4. Other methods for supporting the conductor 4 are obvious to those skilled in the art.

Although the invention has been described in its preferred embodiment, it will be obvious to those skilled in the art after understanding the invention, that various changes, alterations, modifications, and substitutions can be made therein without departing from the spirit and scope of the claims.

What is claimed is:

1. A substantially constant impedance adjustable phase shifting means comprising: a coaxial line comprising an inner conductor and an outer conductor; means for moving said inner conductor laterally through a circular path within the said outer conductor, the geometric center of the said circular path being offset from the axis of the said outer conductor, at least one of said conductors being rugose in the surface area that attains the

closest proximity to the other said conductor as a result of the lateral movement of said inner conductor, said inner conductor being maintained in spaced relation to said outer conductor without overlapping during all operative movements thereof, last said means and said rugose surface being arranged to maintain substantially constant the ratio between the values of the inductance and capacitance of the said line while permitting the product thereof to vary.

2. A substantially constant impedance adjustable phase shifting means comprising: a coaxial line comprising an inner conductor and an outer conductor; means in the extremities of the said line that mounts one of said conductors for movement with respect to the other; a second coaxial line; means joining the said second line to the first said line at a point located at a distance from one of the said means in the said extremities that is equal to a quantity of an odd integer of one-quarter electrical wave lengths of a frequency at substantially the center of the band of operating frequencies of the first said means; a third coaxial line; and means joining the said third line to the said first line at a point located at a distance from the remaining one of the said means in the said extremities that is equal to a quantity of an odd integer of the said one-quarter electrical wave lengths; and rugosities located in the surface of at least one of said conductors between the said second and the said third lines; said rugosities being more pronounced on one side of the conductor than the other and arranged to produce, when one of said conductors is moved laterally with respect to the other, a plurality of sets of values of inductance and capacitance between the said inner conductor and the said outer conductor such that the ratio of the said values of the said sets remains substantially constant throughout the operating range of the said phase shifting means.

3. A substantially constant impedance adjustable phase shifting means comprising: a coaxial line comprising an inner conductor and an outer conductor; means in the extremities of the said line that rotatably mount the said inner conductor in the said outer conductor; a second coaxial line; means joining the said second line to the first said line at a point located at a distance from one of the said means in the said extremities that is equal to a quantity of an odd integer of one-quarter electrical wave lengths of a frequency at substantially the center of the band of operating frequencies of the first said means; a third coaxial line; means joining the said third line to the said first line at a point located at a distance from the remaining one of the said means in the said extremities that is equal to a quantity of an odd integer of the said one-quarter electrical wave lengths; and rugosities located in the surface of at least one of said conductors between the said second and the said third lines; said rugosities comprising corrugations arranged such that one longitudinal directional component thereof lies in a direction perpendicular to the center line of the said inner conductor to produce, when the said inner conductor is rotated and moved eccentrically with respect to said outer conductor, a plurality of sets of values of inductance and capacitance between the said inner conductor and the said outer conductor such that the ratio of the said values of the said sets remains substantially constant throughout the operating range of the said phase shifting means.

4. A substantially constant impedance adjustable phase shifting means comprising: a coaxial line comprising an inner conductor and an outer conductor; means in the extremities of the said line that rotatably mount the said inner conductor in the said outer conductor; a second coaxial line; means joining the said second line to the first said line at a point located at a distance from one of the said means in the said extremities that is equal to a quantity of an odd integer of one-quarter electrical wave lengths of a frequency at substantially the center of the band of operating frequencies of the first said means; a third coaxial line; means joining the said third line to

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the said first line at a point located at a distance from the remaining one of the said means in the said extremities that is equal to a quantity of an odd integer of the said one-quarter electrical wave lengths; and the surface of one side of at least one of the said conductors between the said second and the said third lines being rugose; said rugose surface comprising corrugations arranged such that one longitudinal directional component thereof lies in a direction perpendicular to the center line of the said inner conductor to produce, when the said inner conductor is rotated and moved in a lateral direction with respect to said outer conductor, a plurality of sets of values of inductance and capacitance between the said inner conductor and the said outer conductor such that the ratio of the said values of the said sets remains substantially constant throughout the operating range of the said phase shifting means.

5. A substantially constant impedance adjustable phase shifting means comprising: a coaxial line comprising an inner conductor and an outer conductor; means in the extremities of the said line that rotatably mount the said inner conductor in the said outer conductor; a second coaxial line; means joining the said second line to the first said line at a point located at a distance from one of the said means in the said extremities that is equal to a quantity of an odd integer of one-quarter electrical wave lengths of a frequency at substantially the center of the band of operating frequencies of the first said means; a third coaxial line; means joining the said third line to the said first line at a point located at a distance from the remaining one of the said means in the said extremities that is equal to a quantity of an odd integer of the said one-quarter electrical wave lengths; and the surface of at least one of the said conductors between the said second and the said third lines being more rugose at one side than the other; said rugose surface comprising corrugations arranged such that one longitudinal directional component thereof lies in a direction perpendicular to the center line of the said inner conductor to produce, when the said inner conductor is moved in a lateral manner within said outer conductor, a plurality of sets of values of inductance and capacitance between the said inner conductor and the said outer conductor such that the ratio of the said values of the said sets remains substantially constant throughout the operating range of the said phase shifting means.

6. A phase shifting device of substantially constant

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impedance comprising a coaxial line having inner and outer conductors, said inner conductor being substantially enclosed by said outer conductor, and means for moving one of said conductors in a lateral manner with respect to the other conductor, at least one of said conductors being rugose in the surface area that attains the closest proximity to the other said conductor as a result of said lateral movement, said conductors being spaced apart without overlapping throughout all operative positions of said device, said means for moving and said rugose surface being arranged to maintain the ratio between the values of the inductance and capacitance between said conductors substantially constant while permitting the product thereof to vary.

7. A substantially constant impedance adjustable phase shifting means in accordance with claim 1 in which the rugose surface area is the inner surface of said outer conductor.

8. A substantially constant impedance adjustable phase shifting means in accordance with claim 1 in which the rugose surface area is the outer surface of said inner conductor.

9. A substantially constant impedance adjustable phase shifting means in accordance with claim 1 in which the inner surface of said outer conductor and the outer surface of said inner conductor are rugose.

10. A phase shifting device of substantially constant impedance in accordance with claim 6 in which the said rugose surface area is the inner surface of said outer conductor.

11. A phase shifting device of substantially constant impedance in accordance with claim 6 in which the said rugose surface area is the outer surface of said inner conductor.

12. A phase shifting device of substantially constant impedance in accordance with claim 6 in which the inner surface of said outer conductor and the outer surface of said inner conductor are rugose.

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