

Dec. 10, 1963

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MICROWAVE PHASE SHIFTER

3,114,121

Filed Sept. 25, 1961

2 Sheets-Sheet 1

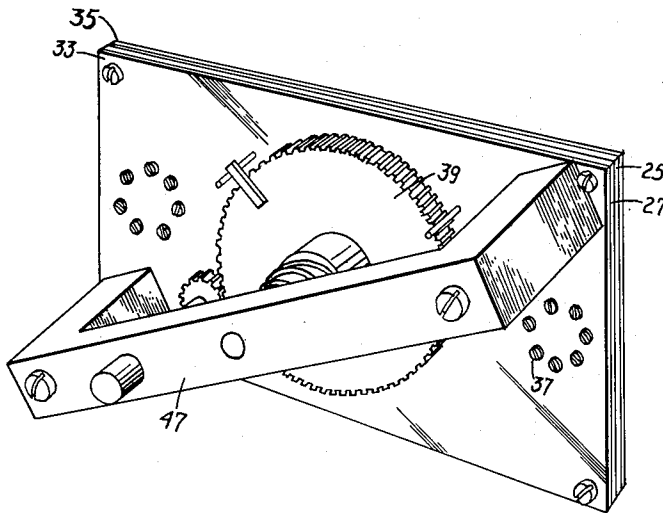


FIG. 1

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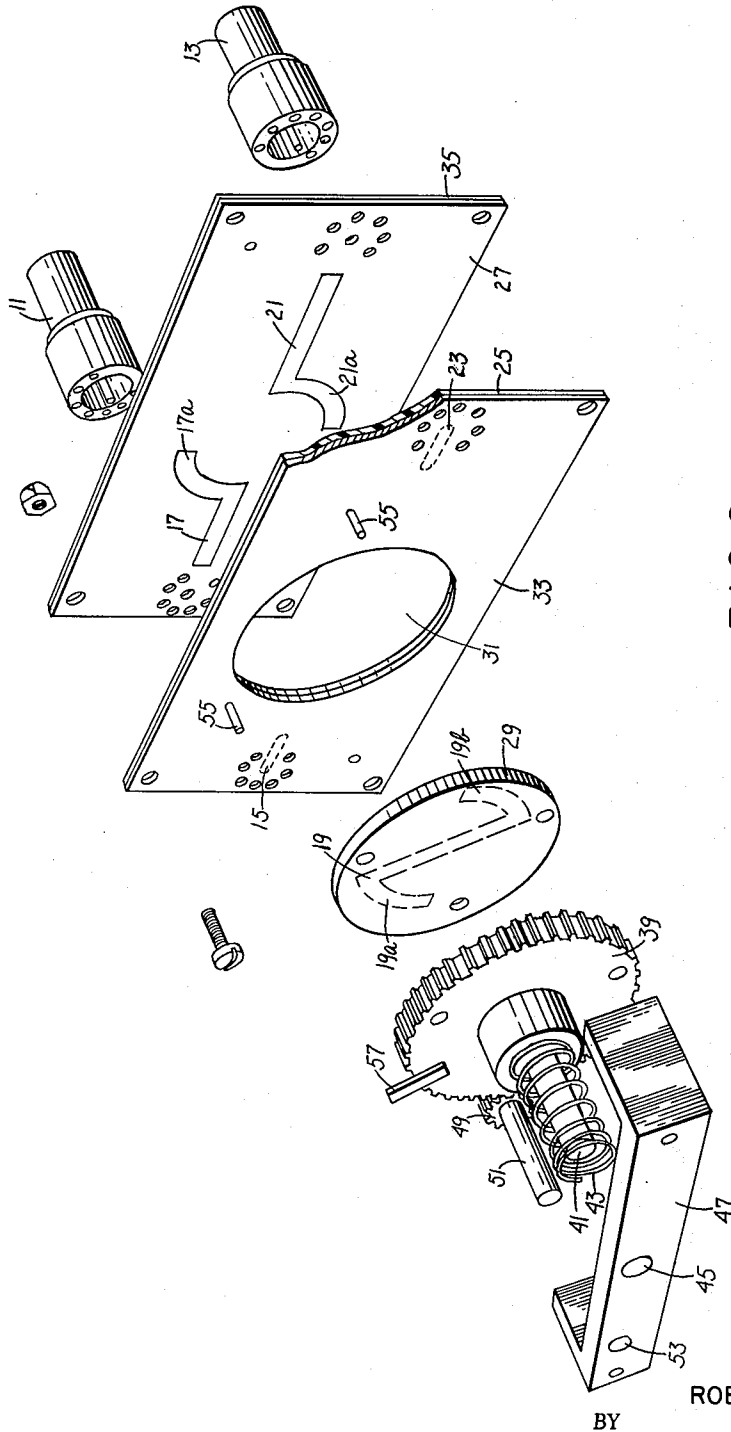


FIG. 2

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3,114,121

MICROWAVE PHASE SHIFTER

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Filed Sept. 25, 1961, Ser. No. 140,466

7 Claims. (Cl. 333-29)

This invention pertains generally to microwave transmission circuits and particularly to a phase shifter, or "line stretcher," useful in adjusting the electrical characteristics of microwave transmission circuits.

It is known that microwave transmission lines must either be specifically designed and carefully fabricated for each particular circuit application or must be adjustable if mismatch, and subsequent loss, are to be avoided. The latter expedient is almost always preferable in practice since it permits the use of standard components without exacting too high a price in terms of added weight, expense or complexity. For example, when transmission lines are to be used in complex circuits, as in feed systems for radar antenna arrays, adjustable microwave transmission lines are commonly used.

Adjustment of microwave transmission lines may be accomplished with many types of known apparatus which operate on the principal that a transmission line may be matched to associated electronic equipment by varying the electrical length of the line. For example, an adjustable stub, sometimes referred to as a "trombone" or a "line stretcher," have been developed and used for many years.

While such apparatus has been, and still is useful, a need exists for improved phase lifting, or line adjusting, apparatus which is adapted to recently developed printed circuit techniques. The problem is complicated, however, by the fact that a satisfactory phase shifter, in addition to being compact, must be efficient in that little, if any leakage of microwave energy may be tolerated. Further, a satisfactory phase shifter must present a substantially constant impedance to the circuit in which it is installed. This latter point is of particular importance in that, unless care is taken, variations in the impedance of a microwave phase shifter at best causes mismatch and at worst may cause unwanted oscillations.

Therefore, it is a primary object of this invention to provide an improved compact phase shifter for use in a microwave transmission circuit.

Another object of the invention is to provide a microwave phase shifter which may be fabricated using printed circuit techniques and which prevents leakage of any microwave energy.

Still another object of the invention is to provide a microwave phase shifter which, regardless of its effect on the phase of microwave energy, presents a substantially constant impedance to such energy.

These and other objects of the invention are attained generally in a photo-etched microwave phase shifter in which a center conductor is supported between two ground planes. Means are provided to connect the center conductor in circuit with the center conductor of a coaxial cable and the two ground planes to the shield of such cable. The center conductor in the microwave component is adjustable in length, such adjustment being accomplished by means operating through one of the ground planes in such a manner that the continuity of that ground plane is unaffected by operation of the adjusting means and there is no chance of creating any substantial change in the electrical characteristics of the center conductor, except the desired phase shift.

For a more complete understanding of a preferred embodiment of the invention, reference is now made to

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the following description of, and drawings illustrating, such an embodiment, in which:

FIG. 1 is a perspective view of the assembled preferred embodiment of the invention; and,

FIG. 2 is an exploded view of the assembly shown in FIG. 1 to illustrate in detail the shape and disposition of the various elements making up that assembly.

A microwave signal entering the device illustrated in the figures on, say coaxial cable 11, may have its phase shifted any desired amount from zero to 360°, or more, before leaving the device via a second coaxial cable 13. Obviously then, if the free end of coaxial cable 11 is connected to one of the output terminals of a microwave signal source (not shown), as, for example, a power divider, and if the free end of the coaxial cable 13 is connected to a circuit element (again not shown), as a driven element in an antenna array, the phase of the microwave signal at such a driven element with respect to the phase of the signal at the power divider may be adjusted as desired.

Any desired phase shift is here accomplished by changing the path length of a microwave signal by shaping the various portions of the center conductor of the phase shifter as illustrated, and, at the same time, providing means for moving one such portion relative to another. Thus, the center conductor of the illustrated phase shifter is made up of a number of photoetched lengths of an electrical conductor, indicated by the numerals 15, 17, 19, 21, 23 and disposed, respectively, on plate 25, plate 27 and disk 29 (all of which last named parts are electrical insulators) and means, described hereinafter, for rotating disk 29 so as to move length 19 with respect to lengths 17, 21. It will be noted that while any known electrically insulating material may be used as the base material for plate 25, plate 27 and disk 29, it has been found that "Rexolite," a material manufactured by the Rex Corporation of Acton, Massachusetts, is suited for the purpose, since the mechanical and electrical characteristics of Rexolite are quite well adapted to their illustrated application. It will also be noted that the various lengths of electrical conductors (as well as the other electrically conductive portions of the phase shifter presently to be described) may be copper, silver, aluminum or any other electrical conductive material and that the dimensions of the various elements, as the width and thickness of the length of conductors 15, 17, 19, 21, 23 and the thickness of the plates 25, 27 are matters of design. That is, the particular dimensions of the various elements may be varied, as is well known, to adapt the illustrated phase shifter to use with transmission lines of differing characteristic impedances at differing frequencies. It is important only that length 17 and length 21 be shaped so as to have, respectively, concentric curved sections 17a, 21a (each of which preferably being equal to or slightly greater than one half wavelength of the longest microwave to be phase-shifted) and that length 19 be shaped so as to have curved sections 19a, 19b, matching, respectively, curved sections 17a, 21a when disk 29 is inserted in a complementary opening 31 in plate 25.

The electrical circuit through the phase shifter is completed by providing a ground plane 33 on the plate 25 and a ground plane 35 on the plate 27 and an opening (not numbered) formed through ground plane 35 and the plate 27 to allow the center conductors of coaxial cables 11, 13 to project into contact, respectively with lengths 15, 23. Ground plane 33 and ground plane 35 are, of course, metallic, preferably being deposited as a film on plates 25, 27 and photo-etched as indicated. The two planes further are electrically connected to each other and to the shields of coaxial cables 11, 13, as by a number of screws 37

(which also serve to hold the coaxial cables 11, 13 in place) in appropriately disposed openings through both plates 25, 27. It is clear from the foregoing, therefore, that a complete electrical circuit is formed between both the shields and the center conductors of the coaxial cables 11, 13 when the elements are assembled into the unitary structure shown in FIG. 1.

Turning now to description of the means for rotating disk 29 referred to hereinbefore, it may be seen that the disk 29 is attached, as by riveting to a metallic spur gear 39, the root diameter of which is greater than the diameter of opening 31. A shaft 41 is affixed in any known manner centrally of the spur gear 39 and a helical spring 43 is fitted over the shaft 41. Thus, when the shaft 41 is fitted into a journal bearing 45 in a bridle 47 and the bridle 47 is mounted, as with screws, to the plates 25, 27, the disk 29 is springly pressed into the opening 31, curved sections 19a, 19b being then forced into contact, respectively, with curved sections 17a, 21a. At the same time, the peripheral portion of the side of the spur gear 39 adjacent to the disk 29 is pressed into contact with the underlying portions of the ground plane 33. A driving gear 49, meshing with spur gear 39 and supported on a shaft 51 fitted into a journal bearing 53 in the bridle 47 permits a vernier adjustment of the spur gear 39, and the parts carried thereby, to be made.

In practice, it is highly desirable that positive means be provided to prevent rotation of the curved sections 19a, 19b so that the free ends thereof project beyond the lengths 17, 21. This is simply accomplished here by mounting stops 55 on the plate 25 and a cooperating arm 57 on the spur gear 39. Rotation of the spur gear, obviously, is then restricted to the sector between the stops 55 so that the curved sections 19a, 19b cannot move so far that their free ends override lengths 17, 21. Consequently, there is never any chance that open ended stubs are formed in the center conductor of the phase shifter, so the impedance of the phase shifter remains substantially constant.

In view of the foregoing description of a preferred embodiment of the invention and of the obvious modifications which may be made therein without departing from the inventive concepts so disclosed, it is felt that the invention should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A microwave phase shifter comprising a first, and a second arcuate section of line insulatingly disposed about a center between a first and a second ground plane, the length of each arcuate section being at least equal to one half a wavelength of the microwave energy whose phase is to be shifted, means operative through one ground plane to connect the first and second arcuate section of line in circuit with such microwave energy the just-mentioned means including, a phase adjusting section of line having arms complementary in shape to the first and second arcuate section and a central portion connecting one end of one such arm to one end of the other, and means operative through the second ground plane to press the phase adjusting section of line against the first and second section of line and to rotate the phase adjusting section to vary only the electrical length of line including the arcuate sections.

2. A phase shifter for use in a microwave transmission line including two coaxial cables, comprising: a first electrically insulating plate having a first electrically conductive coating deposited on its outside surface and a first and a second arcuate section of electrically conductive line deposited on its inside surface, the first and the second arcuate section covering opposing portions of the circumference of a circle; means operative through the first electrically conductive coating and the first electrically insulating plate to connect the center conductor of one coaxial cable to the first arcuate section and the center conductor of the other coaxial cable to the second arcuate section;

a second electrically insulating plate having a circular opening formed therethrough and an electrically conductive coating deposited on the outside surface thereof; an electrically insulating disk having a diameter less than the diameter of the circular opening and a section of electrically conductive line deposited on one surface thereof, such line being, generally Z-shaped but having a top and a bottom complementary to the first and the second arcuate section; an electrically conductive gear affixed to the second surface of the electrically insulating disk, the root diameter of such gear being greater than the diameter of the circular opening; and means for mounting the first and the second electrically insulating plate, the electrically insulating disk and the electrically conductive gear to establish a first movable electrical contact between the first and the second arcuate sections through the section of line deposited on the electrically insulating disk and a second movable electrical contact between the peripheral portion of the electrically conductive gear and the there underlying portions of the electrically conductive coating on the second electrically insulating plate.

3. In a microwave component for shifting the phase of microwave energy between two sections of coaxial transmission line, a variable length of line comprising a first and a second coplanar and circular section of line, a rotatable bridge, the bridge being generally in the shape of a Z but having a curved top similar in shape to the first circular section of line and a curved bottom similar in shape to the second circular section of line, means for pressing the top and the bottom of the bridge into contact, respectively, with the first and the second arcuate section of line whereby microwave energy passes only from the first section of coaxial line, through the first section of circular line, the bridge and the section of circular line to the second section of coaxial line, the length of such path being a function of the angular position of the bridge relative to the first and the second section of circular line and means for restricting the angular position of the bridge in such a manner that the free ends of the first and second circular section of line always underlie, respectively, the curved top and curved bottom of the bridge.

4. A phase shifter for insertion between a first and a second length of coaxial transmission line, comprising:

(a) means, including a pair of electrically conductive plates, for connecting the outer conductors of the two lengths of coaxial transmission line;

(b) means, disposed between the pair of electrically conductive plates, for adjusting the electrical distance between the center conductor of the first length of coaxial transmission line and the center conductor of the second length thereof, including:

(1) a first and a second arcuate section of line connected, respectively, to the center conductor of the first and the second length of coaxial transmission line, such sections lying on portions of the periphery of a circle and having their free ends diametrically opposite each other;

(2) A rotatable bridge disposed between the first and the second arcuate section of line and concentrically therewith, such bridge including a first arcuate arm complementary to the first arcuate section, a second arcuate arm complementary to the second arcuate section and a connecting portion joining such arms;

(c) means for frictionally engaging the first arcuate arm with the first arcuate section and the second arcuate arm with the second arcuate section so that the free ends of each so engaged arcuate arm and section are overlapped; and,

(d) means for rotating the bridge about the center of the circle to change the amount of overlap of the first and second arcuate arm with, respectively, the first and second arcuate section, thereby to adjust

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the electrical distance between the center conductors of the first and the second coaxial transmission lines.

5. A phase shifter as in claim 4 having, in addition, mechanical stop means coacting with the means for rotating the bridge to limit the possible angular positions of the bridge to those angular positions in which the free ends of the first and second arcuate sections and the first and second arcuate arms remain overlapped.

6. A phase shifter as in claim 4 wherein:

(a) the first of the parallel plates and the arcuate sections of line are electrically conductive films deposited on opposite sides of a first sheet of electrically insulating material;

(b) the second of the parallel plates is an electrically conductive film deposited on a second sheet of electrically insulating material having a circular opening formed therethrough;

(c) the rotatable bridge is an electrically conductive

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film deposited on an electrically insulating disk rotatably mounted in the circular opening; and,

(d) the means for rotating the bridge includes a metallic gear overlying the outside surface of such disk and in contact with the second of the parallel plates.

7. A phase shifter as in claim 6 wherein the length of the first and the second arcuate section, and the length of the first and the second arcuate arm, are each at least equal to one half the wavelength of the microwave whose phase is to be shifted.

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