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PHASE SHIFTER HAVING DIFFERENT LENGTH CONDUCTORS INSERTED INTO CIRCUIT BY REED RELAYS

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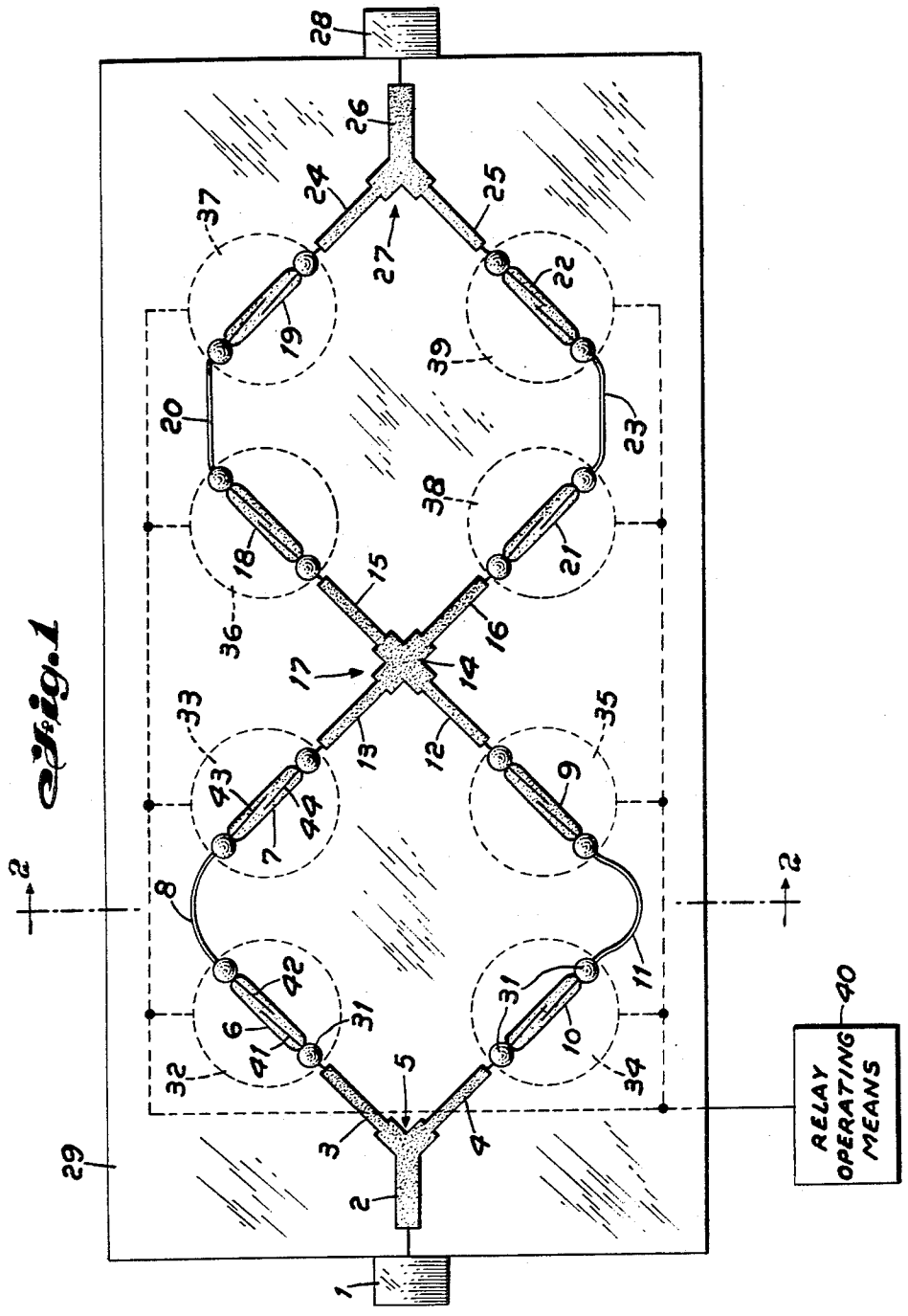


Fig. 1

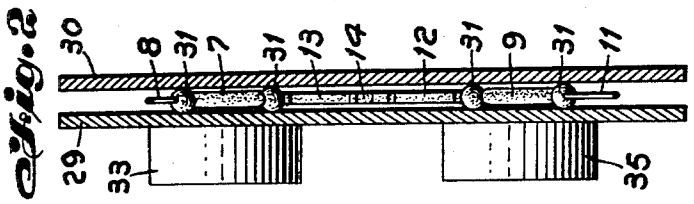


Fig. 2

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PHASE SHIFTER HAVING DIFFERENT LENGTH CONDUCTORS INSERTED INTO CIRCUIT BY REED RELAYS

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U.S. Cl. 333—31 1 Claim

ABSTRACT OF THE DISCLOSURE

A phase shifter circuit utilizing a plurality of conductors of various lengths serially connected in parallel pairs, one conductor of each pair switched into the circuit and the other switched out of the circuit so as to provide various degrees of phase shift. Reed relays are utilized, one relay being connected between either end of each of said conductors and associated circuitry, in such configuration as to provide a one half wavelength stub from said associated circuitry to said conductor when the relays associated with said conductor are in an open position.

This invention relates to phase shifters and the main object is to provide a novel, economical phase shifter operable over a wide band of frequencies utilizing switching means for inserting selected lengths of conductors in the transmission path of a signal to provide a phase shift.

According to the invention a phase shifter is provided which comprises a plurality of conductors, at least some of which are of different lengths, each of said conductors being coupled to a source of signals and to means for receiving signals via switches and means for controlling the switches, the distance between said source of signals and each inoperative switch associated therewith, and the distance between said means for receiving signals and each inoperative switch associated therewith being multiples of a half wavelength at the frequency of operation, so that an unselected conductor appears substantially as a true open circuit.

The above mentioned and other objects of this invention will become apparent by reference to the following description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is an illustration of a preferred embodiment of this invention; and

FIGURE 2 is a section view of the configuration illustrated in FIGURE 1.

Referring to FIGURE 1, a preferred embodiment of a phase shifter according to this invention comprises input connector 1 coupled to a high frequency impedance matching device 5 which comprises member 2 and arms 3 and 4. This type of impedance matching device is well known in the art and therefore, no further discussion of the operation thereof is deemed necessary for a proper understanding of the invention herein described. Coupled to arm 3 of matching device 5 is the series combination of reed relay 6, conductor 8 and reed relay 7. Conductor 8 provides a predetermined phase shift at a particular frequency, which phase shift is determined by the physical length of conductor 8. The free end of relay 7 is coupled to arm 13 of coupling means 17, which in this embodiment is also an impedance matching device. Impedance matching device 17 comprises member 14 and arms 12, 13, 15 and 16 and operates in the same well known manner as matching device 5. Coupled to arm 4 of matching device 5 is the series combination of reed relay 10, conductor 11 and reed relay 9, the free end of reed relay 9 being coupled to arm 12 of impedance matching device 17. Coupled to arm 15 of matching device 17 is the series combination of reed relay 18, conductor 20 and reed relay 19, the free end of reed relay 19 being coupled to arm 24 of impedance matching device 27. Coupled to arm 16 of matching device 17 is the series combination of reed relay 21, conductor 23 and reed relay 22, the free end of reed relay 22 being coupled to arm 25 of matching device 27. Coupled to member 26 of matching device 27 is an output connector 28.

The above described configuration is mounted on a metallic surface 29, which surface provides a ground plane for the phase shifter. Mounted on the other side of the delay line configuration is metallic surface 30, as shown in FIGURE 2. This surface 30 is not shown in FIGURE 1 for ease of illustration. Electromagnets 32, 33, 34, 35, 36, 37, 38 and 39 are mounted behind the reed relays and preferably behind surface 29 for selectively actuating the reed relays, thereby closing a transmission path from the input to the output. Relay operating means 40 is coupled to the electromagnets for selectively operating same in accordance with the desired phase shift. Means 40 may be any well known actuating device for electromagnets, a limitation being that only one of the parallel connected conductors may be inserted in the signal path at any one time.

Members 31 are provided in the structure illustrated in FIGURE 1 as spacers for preventing the ground plane surfaces 29 and 30 from electrically shorting out the transmission sections of the phase shifter. These spacers 31 may be made from any suitable low loss insulating material at the operating frequencies of the phase shifter.

The lengths of conductors 8, 11, 20 and 23 are all different and each will provide a different phase shift to a signal being transmitted therethrough. Therefore, in order to provide a desired phase shift, one of the two parallel paths in each section of the phase shifter shown in FIGURE 1 is closed by relay operating means 40 turning on the proper electromagnets which in turn operate the corresponding reed relays. For example, if reed relays 6, 7, 18 and 19 are closed by energizing electromagnets 32, 33, 36 and 37 a predetermined phase shift determined by the length of the signal path via conductors 8 and 20 will be provided. Alternatively a path comprising reed relays 6, 7, 21 and 22 may be provided by energizing electromagnets 32, 33, 38 and 39, thereby providing a phase shift which is determined by the physical length of the signal path via conductors 8 and 23. Since all of the paths are substantially identical except for the conductors of different length, various different combinations of relative phase shifts may be provided by selecting various combinations of signal paths. Note that only one of the parallel coupled paths may be closed at a time. If more than one path in each group of parallel paths is closed, then distortion of the signal will result. This is because each path provides a different phase shift and if the signals from the two paths are combined at a junction point (i.e. at the matching device 17) phase distortion of the signal will result. Furthermore, a mismatch will be produced by the closing of two parallel paths, thereby providing additional distortion in amplitude and phase.

Impedance matching devices 5 and 27 are for properly matching the impedance of the phase shifter to the impedance of the input and output utilization devices. For example, assume that the input and output devices interfacing the phase shifter each have an impedance of 50 ohms and that a delay path comprising two reed relays and a length of conductor have a characteristic impedance of 126 ohms. Then with reference to matching device 5, the combination of member 2 and arm 3 is designed to comprise a 50 ohm to 126 ohm transformer in a manner well known in the art. Likewise, member 2 and arm 4 are designed to comprise a 50 ohm to 126 ohm transformer.

The same impedance matching transformation is provided by matching device **27**.

Matching device **17** provides a 126 ohm to 126 ohm impedance match between any two of its arms **12, 13, 15** or **16**. Actually, the impedance match between two arms of device **17** is 126 ohm to 50 ohms (at member **14**) and back to 126 ohms. Matching device **17** may be omitted from the design, but including it greatly facilitates initial calibration of the phase shifter. For example, the exact delay provided by each delay path may be easily measured by replacing an intermediate coupling point (such as matching device **17**) with another matching device such as device **27** coupled to an output means. After these paths (between the input **1** and the newly inserted matching device) have been calibrated the intermediate matching device **17** is placed back into the phase shifter configuration without upsetting the calibration. This is because device **17** "looks" the same electrically as device **27** when it is coupled to a delay path. In a similar manner each delay path may be independently measured and calibrated. This enables one to use as many sections as desired in order to provide the desired magnitude of phase shift while providing a fairly simple and very accurate method of calibrating the phase shifter.

In the particular design described herein two reed relays (e.g. relays **6** and **7**) are connected in series with each length of conductor (e.g., conductor **8**) in order to provide a delay path having a higher impedance when the relays are inoperative, thereby providing better isolation between the various selectiable signal paths. In order to provide a high isolation between selected paths and non-selected paths, the system is designed such that each unselected path "looks" like a one-half wavelength stub (or a multiple thereof) at the operating frequency of the phase shifter. For example, referring to the path comprising arm **3**, relay **6**, conductor **8**, relay **7** and arm **13** (illustrated in FIGURE 1), the distance from the electrical center of element **2** to the end of contact **41** of relay **6** is designed to "look" like a one-half wavelength stub (or a multiple thereof) at the operating frequency when relay **6** is inoperative. Likewise, the distance from the electrical center of element **14** to the end of contact **44** of relay **7** is also designed to look like a one-half wavelength stub or a multiple thereof. In order to maximize the isolation, the length of the path between the free end of contact **42** of relay **6** and the free end of contact **43** of relay **7** is designed so as not to be a multiple of one-half wavelengths at the frequency of operation. Preferably the length of the path between free ends of contacts **42** and **43** should be as close as possible to multiples of one-quarter wavelength. Ordinary telephone-type reed relays are utilized in order to keep the cost of the system as low as possible while providing a system capable of operating at powers greatly exceeding those realizable with diode switches as shown in the prior art.

The phase shifter herein described has an advantage in that it is operable over a relatively large band of frequencies without necessitating a redesign. The limiting factor is the impedance matching devices **5, 17** and **27** which can be designed to provide proper impedance matching over a relatively large band of frequencies.

It should be clear that the above-described embodiment of this invention may be expanded by adding more

parallel paths per section and/or by coupling more of the parallel coupled paths in series. Modifications along these lines are dictated by the values of phase shift that one wishes to provide, and such modifications may be easily carried out within the spirit of this invention by one ordinarily skilled in the art. It is obvious that the more alternate signal paths via different length conductors that are provided, the more flexible will be the range of possible phase shifts.

It should also be pointed out at this point that reed relays were used in this embodiment merely by way of example and that any other types of switching devices may be utilized with comparable results.

While we have described above the principles of our invention in connection with specific apparatus it is to be clearly understood that this description is made by way of example and not as a limitation to the scope of our invention as set forth in the accompanying claim.

We claim:

1. A phase shifter circuit comprising:

a plurality of conductors, at least some of said conductors being of different lengths, for providing a predetermined phase shift at a predetermined frequency;

a source of signals including impedance matching means;

a signal receiving means including impedance matching means;

a plurality of pairs of normally inoperative reed relays, one relay of each pair connected between one end of each of said conductors and said source of signals, and the second relay of each pair connected between the opposite end of each of said conductors and said signal receiving means; and

a control means for energizing a selected pair of said plurality of relays so as to insert a selected one of said plurality of conductors into said circuit, the balance of the relays remaining inoperative,

wherein the distance between said signal source and each of the inoperative relays directly coupled thereto, and the distance between the signal receiving means and each of the inoperative switches directly coupled thereto, are multiples of a half wavelength at the frequency of operation, so that an unselected conductor appears substantially as a true open circuit, and

wherein the distance between any pair of switches coupled via one of said plurality of conductors is a multiple of a quarter wavelength so as to maximize the isolation between the selected and unselected conductors.

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