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QUANTIZED PHASE-SHIFTER USING COAXIAL LINE SHUNT-LOADED WITH DIODE-CAPACITOR GROUPS, EACH HAVING TUNED STUBS

Filed Jan. 31, 1968 3 Sheets-Sheet 1

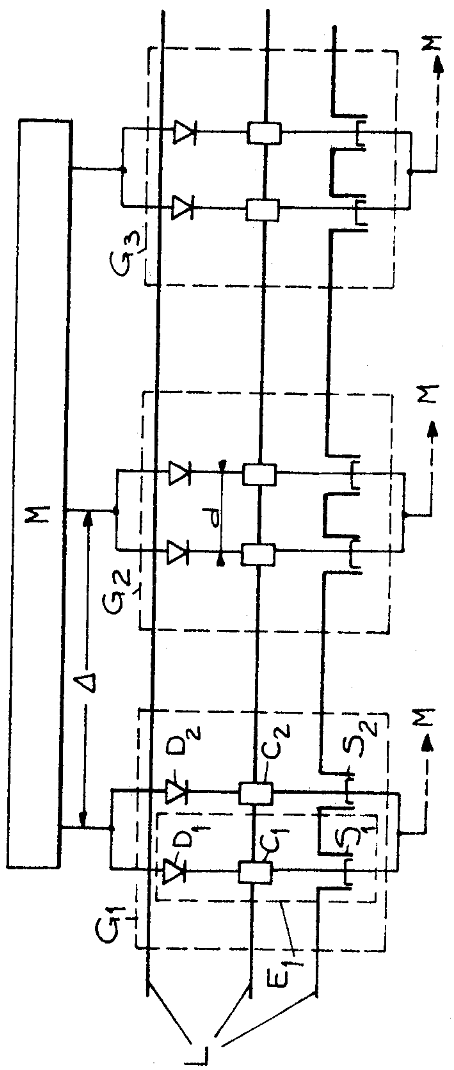

Fig.1

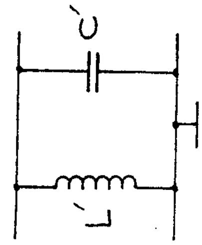

Fig.3b

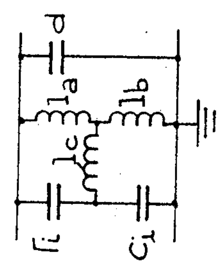

Fig.3a

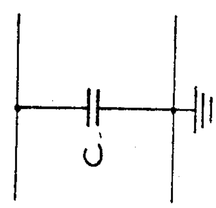

Fig.2b

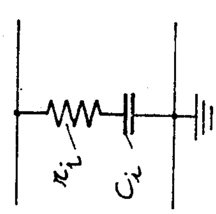

Fig.2a

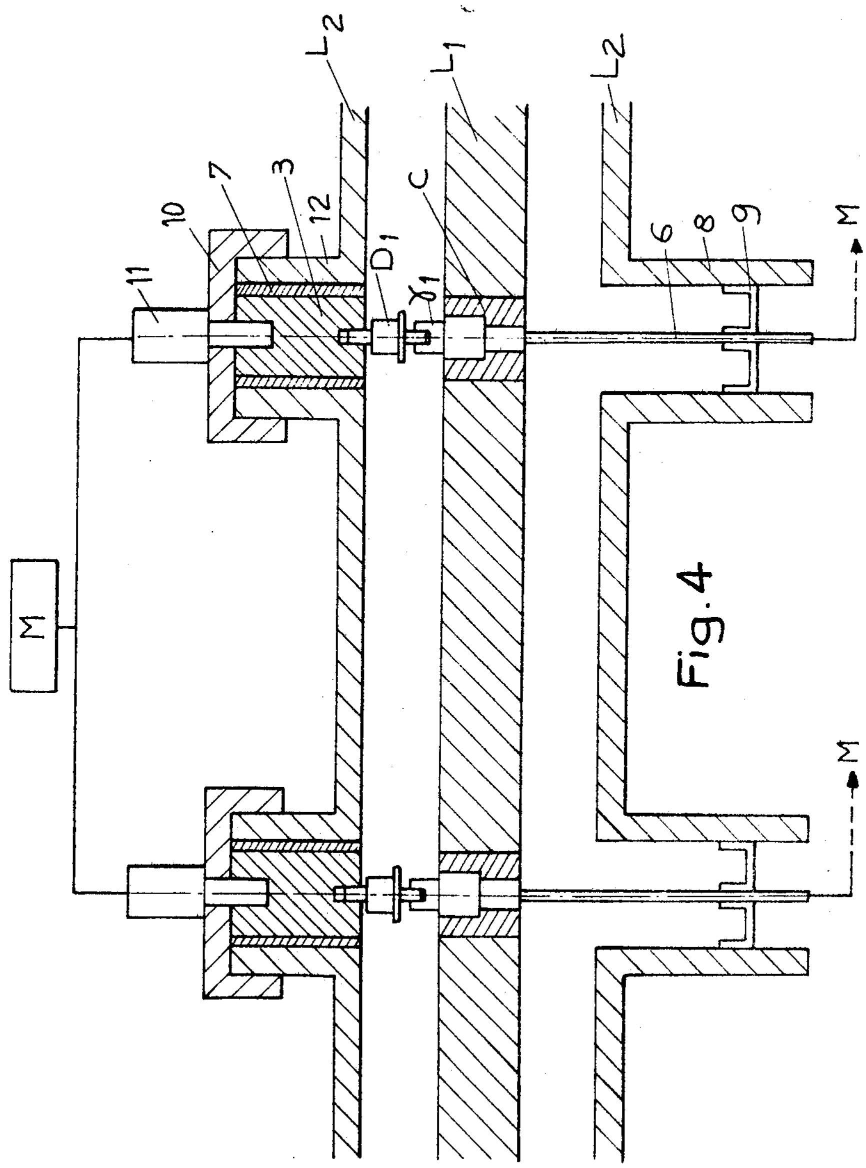

Fig. 4

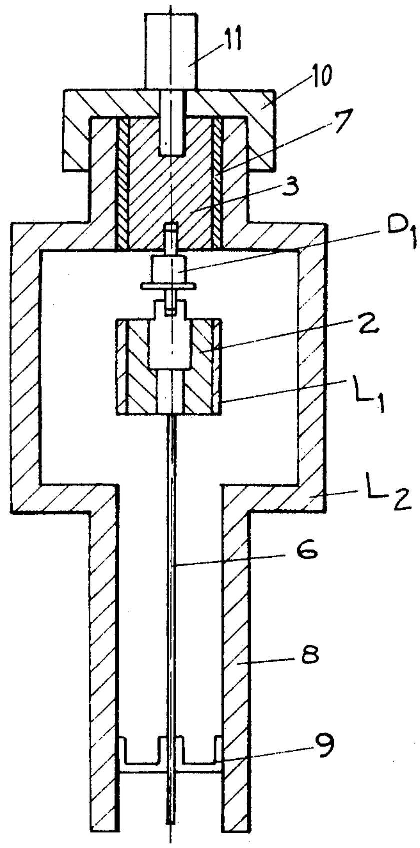

Fig.5

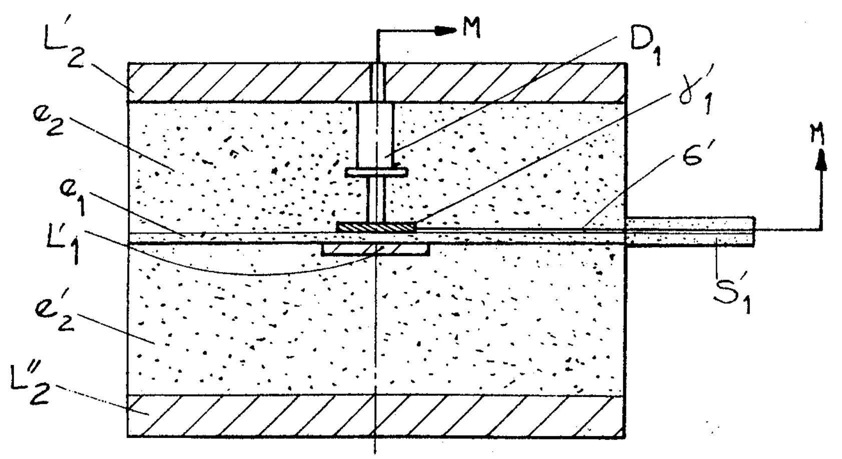

Fig.6

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QUANTIZED PHASE-SHIFTER USING COAXIAL LINE SHUNT-LOADED WITH DIODE-CAPACITOR GROUPS, EACH HAVING TUNED STUBS

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U.S. Cl. 333—31 3 Claims

ABSTRACT OF THE DISCLOSURE

A quantized phase-shifter for coaxial lines, of the type including diode-capacitor groups, each group comprising a short-circuited coaxial stub in parallel with the line and at least two identical diode-capacitor assemblies. This phase-shifter provides a constant phase-shift within a given ultra-high frequency band.

The present invention relates to a quantized phase-shifter.

Quantized phase-shifters presently known generally present substantial phase variations as a function of the frequency. The only phase-shifter with a phase-shift which is constant within the whole of a given frequency band is a reciprocal phase-shifter operating by reflection and comprising transformers which makes it cumbersome and limits the pass band.

It is an object of the invention to avoid this drawback by providing a phase-shifter whose phase-shift is constant within the frequency bands used in electromagnetic detection.

According to the present invention, there is provided a quantized phase-shifter for coaxial lines having an inner conductor and an outer conductor, said phase-shifter comprising:

A plurality of groups, each of which comprises a short-circuited coaxial stub in parallel with said line and at least two identical assemblies, each including in series a diode and a capacitor mounted in parallel between said inner and outer conductors;

And voltage supply means for selectively blocking or making conductive simultaneously the diodes of each group.

For a better understanding of the invention, reference will be made to the drawings accompanying the following description and in which:

FIG. 1 is a basic diagram of a phase-shifter according to the invention;

FIGS. 2*a*, 2*b*, 3*a*, 3*b*, are explanatory diagrams;

FIGS. 4 and 5 show an embodiment of the invention; and

FIG. 6 shows another embodiment of the invention.

The phase-shifter according to the invention, which is shown in FIG. 1 as inserted in a coaxial transmission line L, comprises essentially n groups or cells $G_1, G_2 \ldots G_n$ (n being an integer), each cell comprising at least two identical assemblies, each including a diode D_i, with $i=1, 2 \ldots p$, where p is the number of assemblies in one group, which number may differ from one group to another, and a stub S_i. The diode D_i which may be of the PIN type, is placed in series with a capacitor C_i, in parallel between the inner and outer conductors L_1 and L_2 of the coaxial line L. The stub S_i is mounted in parallel. In addition, means M are provided for blocking or making conductive simultaneously the diodes of each group, the groups being independent of each other in this respect.

For the sake of clarity, only three groups G_1, G_2 and

G_3 have been shown, with only two diode-capacitor assemblies E_i in each group. In fact, it is essential that each group should consist of at least two such assemblies so that the standing wave ratios of the elementary phase-shifters may compensate each other within each group. In practice, p will vary between **2** and **4**. The means M, which do not form, as such, a part of the invention, being well known per se, comprise, for example, an electric energy source and a distributor with n outputs, connected respectively to the n groups, with automatic or manual control. Such means are also used for controlling quantized diode phase-shifters of known type and will therefore not be described in detail.

The components of the different groups are identical or not, according to whether one or more values of quantized phase-shifting steps are desired.

The operation of a phase-shifter group will be better understood by reference to FIGS. 2*a* and 2*b* on the one hand, and 3*a* and 3*b* on the other hand, showing, respectively, the equivalent diagrams of the phase-shifter in the conducting and blocked states.

In the former case, the diode is equivalent to a low resistance r_i and this diode is in series with the capacitor C_i (FIG. 2*a*). The stub is then equivalent to a high impedance in parallel with the capacitance, and the assembly is equivalent to the diagram in FIG. 2*b*, that is to say to a simple capacitance C.

In the second case, the diode is equivalent to a capacitance Γ_i and is in series with the capacitor C_i and the equivalent impedance of the stub, represented by the reactances **1***a*, **1***b*, **1***c* and the capacitance *d*, must be taken into consideration; the assembly is equivalent to an antiresonance circuit as in FIG. 3*b*, comprising in parallel a reactance L′ and a capacitance C′.

According to whether the diode is conductive or blocked, the assembly E_i is equivalent to different circuits and introduces therefore a different phase-shift.

The switching in and out of a diode, by changing the susceptance of the line, introduces therefore a differential phase-shift $\Delta\varphi_i$.

The equivalent diagrams may be complicated by parasitic elements. The circuits must be so defined that the latter are rendered negligible or are compensated. However, their presence does not change basically the operation.

In the case of a conductive diode the phase-shift ψ_1 introduced by the stub is defined simply by the capacitance C_i and the resistor r_i.

In the case of a blocked diode, the phase-shift φ_2 is that caused by an anti-resonance circuit loaded by the characteristic impedance of the line L. The function $\varphi_2(F)$, F being the frequency, is substantially of the form arc *tg*, whose characteristics are defined by those of the different elements, the electrical values and the geometrical arrangement. In particular by adjusting the latter, it can be obtained that near F_0, i.e., near the center frequency of the pass band, this characteristic is substantially of the same slope as that of the circuit with the diode open. It follows then that:

$$\frac{\Delta\varphi_1}{\Delta F} \# \frac{\Delta\varphi_2}{\Delta F}$$

and, for differential phase-shift:

$$\frac{\Delta\varphi_1 - \Delta\varphi_2}{\Delta F} \# 0$$

that is to say, a phase-shift which is independent of the frequency.

FIGS. 4 and 5 show, respectively, a longitudinal section and a transverse cross-section of an embodiment of a phase-shifter according to the invention comprising a coaxial line with an inner conductor L_1 and an outer conductor L_2. The figures show only a single cell with two elements, and all cells have the same construction except for the number p of assemblies and the characteristics of the elements.

The fixed capacitance is formed by a dielectric element and a first armature γ_1, connected directly to the diode D_1, a second armature formed by the inner conductor L_1. The armature γ_1 is connected to the inner conductor of the stub **6** which forms, with the short-circuit **9**, the conductor **3**, and the conductor **11**, which may be equipped with cooling ribs, the supply circuit of the diode, connected to the means M.

The stub is closed by the short-circuit **9** whose position is adjustable which connects its inner conductor **6** to its outer conductor **8**. The stub is equivalent to a short-circuited coaxial line whose length varies with the elements used and the application domain, and may reach $\lambda/4$.

At **10** and **7** are shown an insulating plug and an insulating cylinder, ensuring the insulation of the diode from ground represented by the outer conductor L_2.

The supply conductor **3**, the insulator **7** and the outer conductor **12**, form an open coaxial line, which line, with low impedance and an electrical length equivalent to $\lambda/4$, short circuits high frequency currents.

Of course other arrangements, for example including wave traps, can be used.

FIG. 6 shows in cross-section another embodiment, wherein a three-plate line L′, is used. In this embodiment, the end of the diode located adjacent to the outer body of the line L′ is grounded.

L'_1, D'_1, γ'_1, S'_1 designate, in a similar manner, the center strip of the transmission line, the diode, the armature of the capacitor on the diode side, and the stub. However, here the diode tip is connected to one of the outer conductors L'_2 of the three-plate line, the other outer conductor being represented at L''_2, and e_1, e_2 and e'_2 represent, respectively, the dielectric layer on which the core L'_1 is photoengraved and the two other layers of the dielectric of the line, the layer e_1 forming also the insulators of the capacitor.

The second connection of the diode is formed by a conductor **6**, also photoengraved, connected to the armature γ'_1, and forming the center strip of a stub, S'_1.

At the end of the stub S'_1, a wave trap may be provided.

When the diode is in inverse polarization, the mounting is matched.

The spacing d between the two assemblies forming one group is adjusted so as to prevent the formation of standing waves in direct polarization. It depends on the number of assemblies and on their characteristics.

For example, for $p=2$ and a phase-shift of $\pi/4$ per group, it is $3\lambda/8$. For $p=3$ and a phase-shift of 1.5 radians, it is $\lambda/4$.

The spacing between two groups (distance Δ in FIG. 1) is independent of the spacing of the assemblies. It is essentially dependent on the selected embodiment and it is even possible, in order to reduce the bulk, to place the first assembly of a group in the same transverse plane as the last assembly of the preceding group.

Of course, the invention is not limited to the embodiments shown and described merely by way of example.

It should be noted in particular that the principle of the invention can be applied to any T.E.M. lines, whether coaxial with circular, square, rectangular, concentrical or excentric cross-section, in the form of three-plate elements with constant distribution or not, or even with lines with mixed propagation or so-called "microstrip," the essence of the invention being in the use of a stub placed in shunt and with at least two assemblies per group.

What is claimed is:

1. A quantized phase-shifter for coaxial lines having an inner conductor and an outer conductor, said phase-shifter comprising:

a plurality of groups, each of which comprises a short-circuited coaxial stub in parallel with said line and at least two identical assemblies, each including in series a diode and a capacitor mounted in parallel between said inner and outer conductors; and

voltage supply means for selectively blocking or making conductive simultaneously the diodes of each group.

2. A phase-shifter as claimed in claim **1**, wherein the inner conductor and the short-circuit of said stub form one of the supply connexions of said diodes.

3. A phase-shifter as claimed in claim **2**, wherein the inner conductor of said coaxial line forms one of the armatures of said capacitors.

References Cited

UNITED STATES PATENTS

2,414,541	1/1947	Madsen	333—31 X
3,246,265	4/1966	Smith-Vaniz	333—31
3,290,624	12/1966	Hines	333—31
3,436,691	4/1969	Hoffman et al.	333—31
3,454,906	7/1969	Hyltin et al.	333—31

FOREIGN PATENTS

156,688	5/1954	Australia.

OTHER REFERENCES

Gardner et al., High Speed Microwave Phase Shifters Using Varactor Diodes, the Review of Scientific Intsruments, vol. 37, No. 1, January 1966, pp. 19–22.

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U.S. Cl. X.R.

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