July 19, 1949. B. M. OLIVER 2,476,946

PHASE SHIFTER CIRCUIT

Original Filed Feb. 24, 1944

FIG. 1

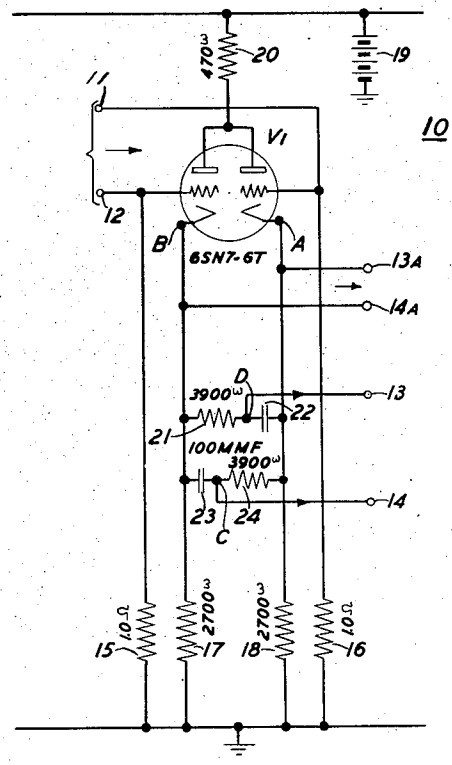


FIG. 2

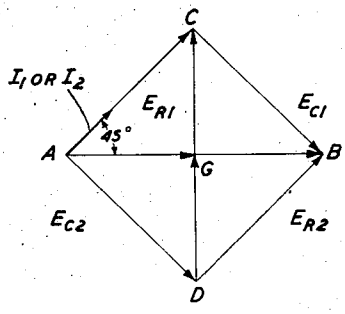
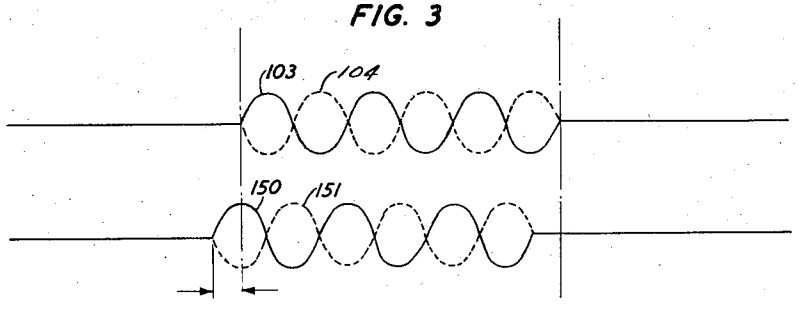


FIG. 3



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PHASE SHIFTER CIRCUIT

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4 Claims. (Cl. 178—44)

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This invention relates to phase shifting circuits and more specifically to such circuits for shifting the phase of input signals utilized in push-pull fashion. This application is a division of application Serial No. 523,721, filed February 24, 1944.

It is an object of this invention to provide an improved phase shifting circuit for balanced waves.

It is another object of this invention to provide an improved circuit arrangement for shifting the phase of push-pull input signals by an angle less than 180 degrees, as for example, 90 degrees.

It is still another object of this invention to provide a novel circuit arrangement involving space current devices connected in push-pull relationship.

In a specific embodiment of the invention, given by way of example for purposes of illustration, there is provided a phase shifting circuit comprising two space current devices each having an anode, a cathode and a control element and means for applying between the control element and cathode of one of the devices a voltage wave which is substantially 180 degrees displaced from a voltage wave applied between the control element and cathode of the other device. Between the two cathodes are connected two current paths each comprising a resistance and capacity in series, one path being arranged so that the condenser thereof is connected to one of the cathodes and the elements in the other path being positioned so that the condenser is connected to the other cathode. Connections to an output circuit are made to the two terminals of the condensers remote from the cathodes to which they are respectively connected. When proper circuit constants are chosen for the elements in the two current paths, a balanced output wave shifted by 90 degrees from the corresponding input wave is obtained. An output wave of substantially the same phase as the input wave can also be obtained across terminals connected respectively to the two cathodes.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which:

Fig. 1 is a schematic block diagram of a phase shifter in accordance with this invention for producing a 90-degree phase shift; and

Figs. 2 and 3 are diagrammatical and graphical representations to aid in understanding the invention.

Referring more particularly to the drawings,

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Fig. 1 is a diagram of a circuit 10 for shifting the phase of push-pull input signals 90 degrees. The circuit 10 comprises a double triode tube V1 having input terminals 11 and 12 and output terminals 13 and 14. The input signals, such as, for example, the two sine waves 103 and 104 (shown in Fig. 3) which are 180 degrees displaced from one another, are applied to the input terminals and two sine waves 150 and 151, respectively, displaced by 90 degrees from the waves 103 and 104, are taken from the output terminals 13 and 14. For a specific use in a radar system of sine waves having the phase displacements shown in Fig. 3, reference is made to the above-identified parent application.

Referring again to Fig. 1, the input waves 103 and 104 are applied to the two control grids of the double triode tube V1 which with its associated circuits acts to shift the phase of these two waves by 90 degrees. The two control grids are connected to ground through resistors 15 and 16, respectively, and the two cathodes are connected to ground through resistors 17 and 18 respectively. The two plates are connected to the positive terminal of the direct current source 19 through resistor 20. Connected in parallel between the two cathodes of the tube V1 are two series-connected circuits, one comprising the resistor 21 and the condenser 22 and the other comprising the condenser 23 and the resistor 24. The tube V1 serves as a double cathode-follower tube to drive the phase shifter, and the outputs of this phase shifter are taken from the points C and D which are the respective common terminals of the two series-connected circuits just described. If desired, the output signals can be taken (without phase shift) from the terminals 13A and 14A connected to the two cathodes.

The voltages applied to the tube V1 result in alternating voltages from points A and B to ground which are equal and 180 degrees out of phase with each other. Since this is true, the voltage between points A and B will be twice that of the voltage between either of these points to ground. These voltages are shown in the vector diagram of Fig. 2 by vectors AG and GB and the voltage AB is the sum of these two vectors. In this diagram the point A is used as a reference point and, therefore, the arrows for vectors AG and BG are not shown 180 degrees apart as would be the case if point G or ground were used as a point of reference. The currents I_1 and I_2 flowing between points A and B by way of parallel paths ACB and ADB will lead the voltage AB by 45 degrees as shown on the vector dia-

gram, since each of these paths has a resistance (21 or 24) in series with a capactive reactance of the same magnitude. For example, at 410 kilocycles this reactance is 3900 ohms. The voltage drop E_{R1} across resistor 24 will be in phase with the current I_1 as represented by vector AC. The voltage drop E_{C1} across condenser 23 lags behind current I_1 by 90 degrees and is represented by the vector CB. The voltage drop E_{C2} across the condenser 22 lags behind current I_2 by 90 degrees and is represented by the vector AD. The voltage drop E_{R2} across the resistor 21 is in phase with the current I_2 and corresponds to vector DB.

The resulting voltage between C and D is 90 degrees ahead of the voltage AB. On the vector diagram of Fig. 2 the voltage from point C to ground adds to that from point D to ground so that vectors CG and DG are represented by arrows pointing upwards. However, if point G had been used as the reference point instead of point A, the vector GD would have been shown with the direction of the arrow reversed since the voltage from point C to ground is 180 degrees out of phase with that from point D to ground. The vector voltage at points C and D are then 90 degrees of the voltage AB at the cathodes of the tube V1 and the voltage to ground at point C is 180 degrees out of phase with the voltage to ground at point D. The voltages from the points C and D are connected to any suitable push-pull amplifier.

Circuit constants of a phase shifting arrangement in accordance with the invention which has been actually constructed and satisfactorily operated in a radar system have been indicated on the drawings. It is to be understood, however, that the invention is not limited to the use of elements having these particular circuit constants nor is the invention limited to use in radar systems.

Although the present invention has been described in terms of a preferred illustrative embodiment, it should be realized that the invention and its several features are susceptible of embodiment in a wide variety of other forms and hence the invention is to be understood as comprehending such other forms as may fairly come within the spirit and letter of the claims.

What is claimed is:

1. In combination, two space current devices each comprising an anode, a cathode and a control element, means for applying to each of said control elements a signal wave, the two waves being substantially identical except that they are displaced by 180 degrees, two series circuits connected in parallel between said two cathodes, each series circuit comprising a resistance and a condenser, all portions of each series circuit between said two cathodes being free to vary in potential and one circuit being arranged so that the condenser thereof is directly connected to one of said cathodes and the other circuit being arranged so that the condenser thereof is directly connected to the other of said cathodes, and means for connecting an output circuit to the two terminals of said condensers remote from said cathodes to which they are respectively connected, whereby the output waves are shifted in phase from the corresponding input waves.

2. In combination, two space current devices each comprising an anode, a cathode and a control element, means for applying to each of said control elements a signal wave, the two waves being substantially identical except that they are displaced by 180 degrees, two series circuits connected in parallel between said two cathodes, each series circuit comprising a resistance and a condenser, all portions of each series circuit between said two cathodes being free to vary in potential and one circuit being arranged so that the condenser thereof is directly connected to one of said cathodes and the other circuit being arranged so that the condenser thereof is directly connected to the other of said cathodes, means for connecting an output circuit to the two terminals of said condensers remote from said cathode to which they are respectively connected, whereby the output waves are shifted in phase from the corresponding input waves, and means for connecting the terminals of a second output circuit to the two cathodes, respectively.

3. The combination of elements as in claim 1 in which the two resistances are equal and the two condensers are also equal.

4. The combination of elements as in claim 1 in which the two resistances are equal and the two condensers are of equal capacitance and have the same impedance at a predetermined frequency as the resistance, whereby the phase shift is 90 degrees.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,135,051	Plebanski	Nov. 1, 1938
2,201,345	Percival	May 21, 1940
2,228,869	Chireix	Jan. 14, 1941
2,256,085	Goodale	Sept. 16, 1941
2,376,392	Shepherd	May 22, 1945