Nov. 23, 1948. J. R. BECKWITH 2,454,426

ELECTRICAL PHASE-SHIFTING SYSTEM

Filed April 21, 1944

FIG. 1

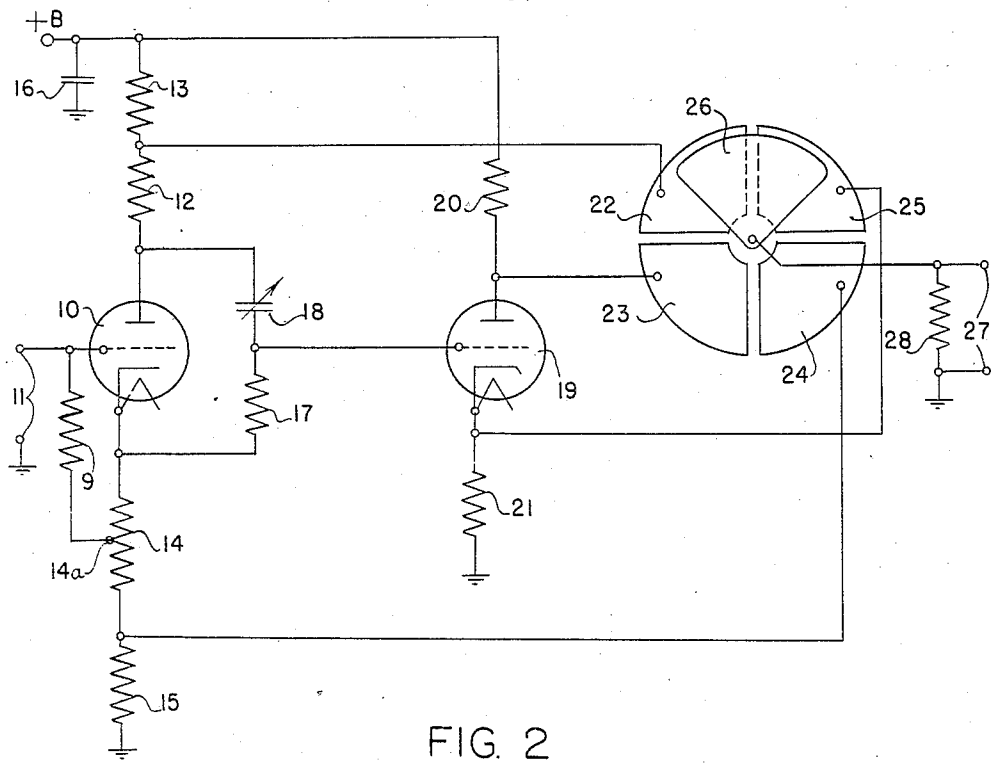
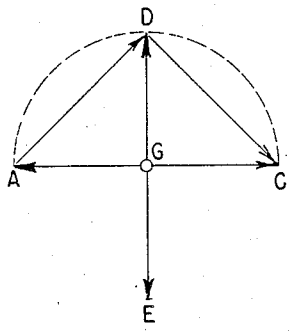


FIG. 2



INVENTOR
JOHN R. BECKWITH

Mueller, Dodds & Macon

ATTORNEYS

Patented Nov. 23, 1948 2,454,426

UNITED STATES PATENT OFFICE

2,454,426

ELECTRICAL PHASE-SHIFTING SYSTEM

John R. Beckwith, Chicago, Ill., assignor, by mesne assignments, to Belmont Radio Corporation, Chicago, Ill., a corporation of Illinois

Application April 21, 1944, Serial No. 532,192

8 Claims. (Cl. 178—44)

1

This invention relates to an electrical phase-shifting system and, while it is of general application, it is particularly suitable for deriving from a periodic input signal a plurality of quadrature-related periodic signals equal in amplitude. In a preferred embodiment of the invention the system is also effective to derive from the quadrature signals thus developed, a signal of substantially constant amplitude and rotatable in phase throughout a complete 360 electrical degrees.

It is frequently desirable or required in electrical control and communication systems to be able to derive from a periodic signal of a given phase, a second signal of constant amplitude but rotatable in phase with respect to the input signal throughout a complete 360 electrical degrees. At ordinary power frequencies there are a number of satisfactory arrangements for procuring this result, the most common of which is the well-known "Selsyn" type constructed like a conventional synchronous motor and comprising an armature for producing a uniform rotating magnetic field and a secondary rotatable inductor in which is induced a second electrical signal of constant amplitude and of a phase dependent upon the angular position of the inductor. However at higher frequencies such as are found in communication systems, the inductive type of phase shifting apparatus is difficult and expensive to design. Also, for the lower power requirements usually found in such systems, the inductive type of apparatus is unnecessarily complicated and costly in its electrical structure.

It is an object of the invention, therefore, to provide a new and improved electrical phase-shifting system composed of simple and inexpensive electrical circuit elements of standard design.

It is another object of the invention to provide a new and improved high-frequency electrical phase-shifting system of the type which cannot readily be embodied in the "Selsyn" type of phase shifter at high frequencies, for example at radio frequencies.

In accordance with the invention, an electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprises a vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to the input electrode and an output circuit for the repeater including separate anode and cathode load impedances. The system also includes a phase-splitting impedance circuit connected between electrically spaced points on the load circuit, including the anode-cathode circuit of the repeater, and circuit connections for deriving a plurality of phase-displaced signals from at least one of the input and output circuits and from the phase-splitting circuit.

2

Also in accordance with the invention, an electrical phase-shifting system for deriving from a plurality of symmetrically phase-displaced signals of equal amplitudes a signal of constant amplitude and rotatable in phase comprises a plurality of primary conductive plates equal in number to, or to an integral multiple of, the number of the signals. The plates are symmetrically disposed about a common axis and there is provided a secondary conductive plate capacitively related to the primary plates, the primary and secondary plates being relatively rotatable. The system also includes circuits for individually applying the plurality of signals to the primary plates and a circuit connection to the secondary plate for deriving a signal of constant amplitude rotatable in phase.

Also in accordance with the invention the plurality of symmetrically phase-displaced signals of equal amplitudes utilized in the system described in the preceding paragraph are developed by an electrical phase-shifting system of the type described above, in which case the load impedances, the constants of the phase-splitting circuit, and the repeating ratio of the repeater are relatively so proportioned that the derived signals are symmetrically phase-displaced and of equal amplitudes.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connecetion with the accompanying drawings while its scope will be pointed out in the appended claims.

Referring now to the drawings, Fig. 1 is a circuit diagram, partially schematic, of an improved phase-shifting system for deriving from a periodic input signal a secondary signal of constant amplitude and rotatable in phase, while Fig. 2 is a vector diagram to aid in the explanation of the invention.

Referring now to Fig. 1 of the drawings, there is represented an electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals. This system comprises a vacuum tube repeater 10 having conventional input, anode and cathode electrodes and an input circuit connected to terminals 11, 11 for applying the input signal to the input electrode of the tube 10. The repeater 10 is pro-

vided with an output circuit including separate anode and cathode load impedances such as the anode load resistors 12 and 13 and the cathode load resistors 14 and 15, the values of the resistors 12 and 13 preferably being equal to those of the resistors 14 and 15, respectively.

The grid of tube 10 is connected through an input or grid-leak resistor to a tap 14a on resistor 14 in order to provide a suitable grid bias for the tube. Space current is provided for the repeater 10 from a suitable source +B, by-passed to ground for signal frequencies by means of a condenser 16. Thus the load circuit of the repeater 10 is balanced with respect to ground. A phase-splitting impedance circuit, such as a resistance-reactance circuit consisting of a resistor 17 and an adjustable condenser 18, is connected between electrically spaced points on the load circuit of the repeater 10 including the anode-cathode circuit of the repeater. In the preferred embodiment illustrated, the phase-splitting circuit is connected directly between the anode and the cathode of the repeater 10. As will be brought out hereinafter, connections may be made to the common terminal of resistors 12 and 13, to the common terminal of resistors 14 and 15, and to the common terminal of resistor 17 and condenser 18 for deriving a plurality of phase-displaced signals. The two signals derived from the resistors 13 and 15 are equal in amplitude and in phase opposition and, by proper adjustment of condenser 18, the signal derived from the midpoint of the phase-splitting circuit is in quadrature relation to such two signals.

However in the particular species of the invention illustrated, the phase-shifting system includes also a second vacuum tube repeater 19 having input, anode and cathode electrodes and an output circuit including separate anode and cathode impedances, such as resistors 20 and 21, respectively. Space current for the repeater 19 is similarly supplied from the source +B. The phase-displaced signal derived from the phase-splitting circuit 17, 18 is applied to the input electrode of the second repeater 19 and circuit connections are made to the common terminal of resistors 12 and 13, to the common terminal of the resistors 14 and 15, and to the high signal-potential terminals of resistors 20 and 21 for deriving from the anode and cathode load resistors or impedances four phase-displaced signals. Preferably the load impedances or resistors of the repeaters 10 and 19, the constants of the phase-splitting circuit 17, 18, and the repeating ratios of the repeaters 10 and 19 are relatively so proportioned that the four derived signals are symmetrical phase-displaced, that is in quadrature, and of equal amplitudes with respect to ground.

In the particular embodiment of the invention illustrated, the four quadrature signals of equal amplitudes are utilized to derive a signal of constant amplitude rotatable in phase. To this end, the four quadrature signals are individually applied to a plurality of primary conductive plates 22, 23, 24 and 25 equal in number to, or to an integral multiple of, the number of the signals. As illustrated, there are provided four plates, one for each of the quadrature signals. These plates may be sector-shaped, as illustrated, and are symmetrically disposed about a common axis. There is provided also a secondary conductive plate 26, also approximately sector-shaped, and capacitively related to the primary plates 22 to 25, inclusive. For example, the plates 22 to 25, inclusive, may be disposed in a common plane while

the secondary plate 26 is in a parallel plane adjacent to the plane of the primary plates. The secondary plate 26 is rotatable about the common axis of the plates 22 to 25, inclusive, and the output terminals 27 are connected across a load resistor 28 connected between the secondary plate 26 and ground.

The operation of the system described above will be apparent to those skilled in the art. Referring to Fig. 2, since the output circuit of the repeater 10 is balanced with respect to ground, the electrical midpoint in the space-current path of the repeater 10 is at ground potential and the signals appearing between this neutral point and the anode and cathode of the repeater are represented by the vectors GA and GC respectively. The signals appearing across resistor 17 and condenser 18 of the phase-splitting circuit are then represented by the vectors AD and DC respectively, the signal between the neutral point of the repeater 10, that is ground, and the midpoint of the phase-splitting circuit being represented by the vector GD, this being the well-known semi-circular vector diagram.

The signals appearing across the load resistors 13 and 15 are in phase with the vectors GA and GC, respectively, and thus are both in quadrature with the signal potential at the midpoint of the phase-splitting circuit 17 and 18, vector GD. This quadrature signal is applied to the input electrode of the second repeater 19 which develops across its cathode resistor 21 at signal in phase with that represented by the vector GD and across its anode resistor 20 a signal represented by the vector GE, in phase opposition to that represented by the vector GD.

Thus by making circuit connections to the points described there are provided four quadrature signals. By properly adjusting the values of the load resistors of repeaters 10 and 19, the constants of the phase-splitting circuit 17, 18, and the repeating ratios of the repeaters 10 and 19, these four quadrature signals may be given amplitudes of equal values.

The four quadrature signals of equal amplitudes being individually applied to the four primary conductive plates 22 to 25, inclusive, these plates are effective to develop a rotating electrostatic field of substantially constant amplitude by analogy to the development of a rotating magnetic field of constant amplitude by polyphase armature winding. The secondary conductive plate 26 therefore has induced upon it electrostatically a signal of constant amplitude but of a phase dependent upon its angular position and this signal appears across the load resistor 28 and is applied to the output terminals 27. By rotating the secondary plate 26, the derived signal of constant amplitude can be rotated in phase throughout a complete 360 electrical degrees.

While in the preferred embodiment of the invention illustrated and described above the signals derived from the load circuits of the repeaters 10 and 19 are symmetrical and of equal amplitudes, that is, they comprise a balanced polyphase signal with respect to ground, in certain applications these signals may be unbalanced to derive any particular output signals of predetermined relative amplitudes and phases. Also rather than employing a single set of primary conductive plates 22 to 25, inclusive, and a single secondary plate 26, the device comprising these plates may be made up of stacks of interleaved primary and secondary plates in a form of construction similar to the usual tuning condenser.

Thus in the system described, it is seen that there is derived from a periodic input signal an output signal of constant amplitude rotatable in phase and that this system comprises primarily an assembly of simple and inexpensive electric circuit components and elements.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What is claimed is:

1. An electrical phase-shifting system for deriving from a periodic input signal a signal of constant ampiltude and rotatable in phase comprising a vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load impedances, a phase-splitting impedance circuit connected between electrically spaced points on said load circuit including the anode-cathode circuit of said repeater, circuit connections for deriving at least three phase-displaced signals from at least one of said input and output circuits and from said phase-splitting circuit, said load impedances, the constants of said phase-splitting circuit, and the repeating ratio of said repeater being relatively so proportioned that vectors representative of said derived signals are of equal magnitudes and said vectors representative of said first and second derived signals are symmetrically displaced with respect to said vector representative of said third derived signal, a plurality of primary conductive plates equal in number to an integral multiple of the number of said signals, said plates being symmetrically disposed about a common axis, a secondary conductive plate capacitively related to said plates, said primary and secondary plates being relatively rotatable, circuits for individually applying the said phase-displaced signals to said primary plates, and a circuit connection to said secondary plate for deriving a signal of constant amplitude rotatable in phase.

2. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a vacuum tube repeater having input anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load impedances of like type for developing output signals of opposite polarity, a phase-splitting impedance circuit connected between said anode and cathode electrodes, and circuit connections for deriving two signals of opposite polarity from said anode and cathode load impedances and a signal of intermediate phase from said phase-splitting circuit.

3. An electrical phase-shifting system for deriving from a periodic input signal at least three phase-displaced signals comprising, a vacuum tube repeater having input, anode, and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load impedances, a phase-splitting impedance circuit connected between electrically spaced points on said load circuit including the anode-cathode circuit of said repeater, and circuit connections for deriving at least three phase-displaced signals from at least one of said input and output circuits and from said phase-splitting

circuit, said load impedances, the constants of said phase-splitting circuit, and the repeating ratio of said repeater being relatively so proportioned that vectors representative of said derived signals are of equal magnitudes and said vectors representative of said first and second derived signals are symmetrically displaced with respect to said vector representative of said third derived signal.

4. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load resistors of equal values, a phase-splitting impedance circuit connected between electrically spaced points on said load circuit including the anode-cathode circuit of said repeater, and circuit connections for deriving from said resistors two signals of equal values but opposite in phase and for deriving from said phase-splitting circuit a third signal displaced in phase with respect to said two signals.

5. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load resistors of equal values, a phase-splitting resistance-reactance phase-splitting circuit connected between said anode and said cathode of said repeater, and circuit connections for deriving from said resistors two signals of equal values but opposite in phase and for deriving from said phase-splitting circuit a third signal in quadrature with said two signals.

6. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a first vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load impedances, a phase-splitting impedance circuit connected between electrically spaced points on said load circuit including the anode-cathode circuit of said repeater, a second repeater having input, anode, and cathode electrodes, an output circuit for said second vacuum tube repeater including separate anode and cathode load impedances, a circuit for deriving a phase-displaced signal from said phase-splitting circuit and applying it to said input electrode of said second repeater, and circuit connections for deriving from the anode and cathode impedances of said repeaters four phase-displaced signals.

7. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a first vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load impedances, a phase-splitting impedance circuit connected between electrically spaced points on said load circuit including the anode-cathode circuit of said repeater, a second repeater having input, anode, and cathode electrodes, an output circuit for said second vacuum tube repeater including separate anode and cathode load impedances, a circuit for deriv-

ing a phase-displaced signal from said phase-splitting circuit and applying it to said input electrode of said second repeater, circuit connections for deriving from the anode and cathode impedances of said repeaters four phase-displaced signals, said load impedances, the constants of said phase-splitting circuit, and the repeating ratios of said repeaters being relatively so proportioned that said four signals are in quadrature with respect to each other and of equal amplitudes.

8. An electrical phase-shifting system for deriving from a periodic input signal a plurality of phase-displaced signals comprising, a first vacuum tube repeater having input, anode and cathode electrodes, an input circuit for applying the input signal to said input electrode, an output circuit for said repeater including separate anode and cathode load resistors of equal values, a resistance-reactance phase-splitting circuit connected between said anode and said cathode, a second repeater having input, anode and cathode electrodes, an output circuit for said second repeater including separate anode and cathode resistors of equal values, a circuit for deriving from said phase-splitting circuit a signal in quadrature with the input signal and for applying it to the input electrode of said second repeater, and circuit connections for deriving from the anode and cathode resistors of said repeaters four quadrature signals of equal amplitudes.

JOHN R. BECKWITH.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,147,728	Wintringham	Feb. 21, 1939
2,178,012	White	Oct. 31, 1939
2,231,955	Schrader	Feb. 18, 1941
2,332,253	Peterson	Oct. 19, 1943
2,371,905	Mathes	Mar. 20, 1945
2,384,263	Schlesinger	Sept. 4, 1945