

[54] **PHASED ARRAY ANTENNA
CONTROLLER**

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[58] Field of Search **343/5 R, 100 SA**

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[57] **ABSTRACT**

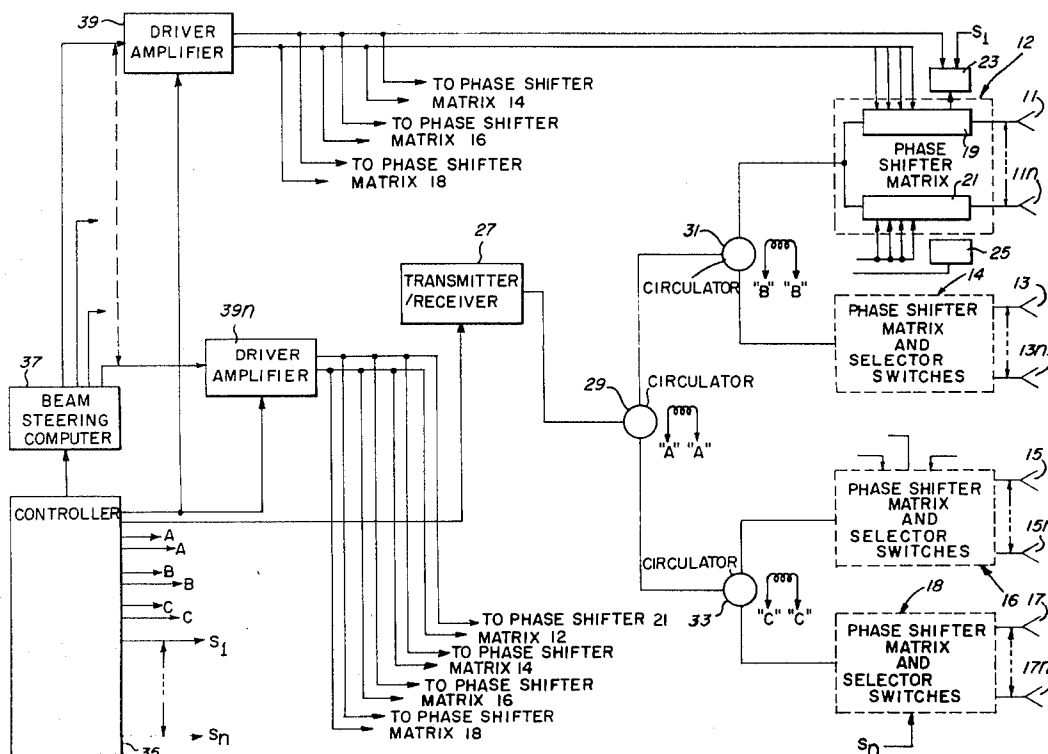
A phased array antenna arrangement which includes a plurality of independently operable phased arrays is disclosed. The phase shifters in each such array are connected to appropriate ones of a set of driver amplifiers through an electronic switching arrangement which is operable as desired to permit only the phase shifters in a selected one, or selected ones, of the phased arrays to be actuated.

1 Claim, 2 Drawing Figures

[56] **References Cited**

UNITED STATES PATENTS

3,413,633 11/1968 Lehmann 343/100 SA X



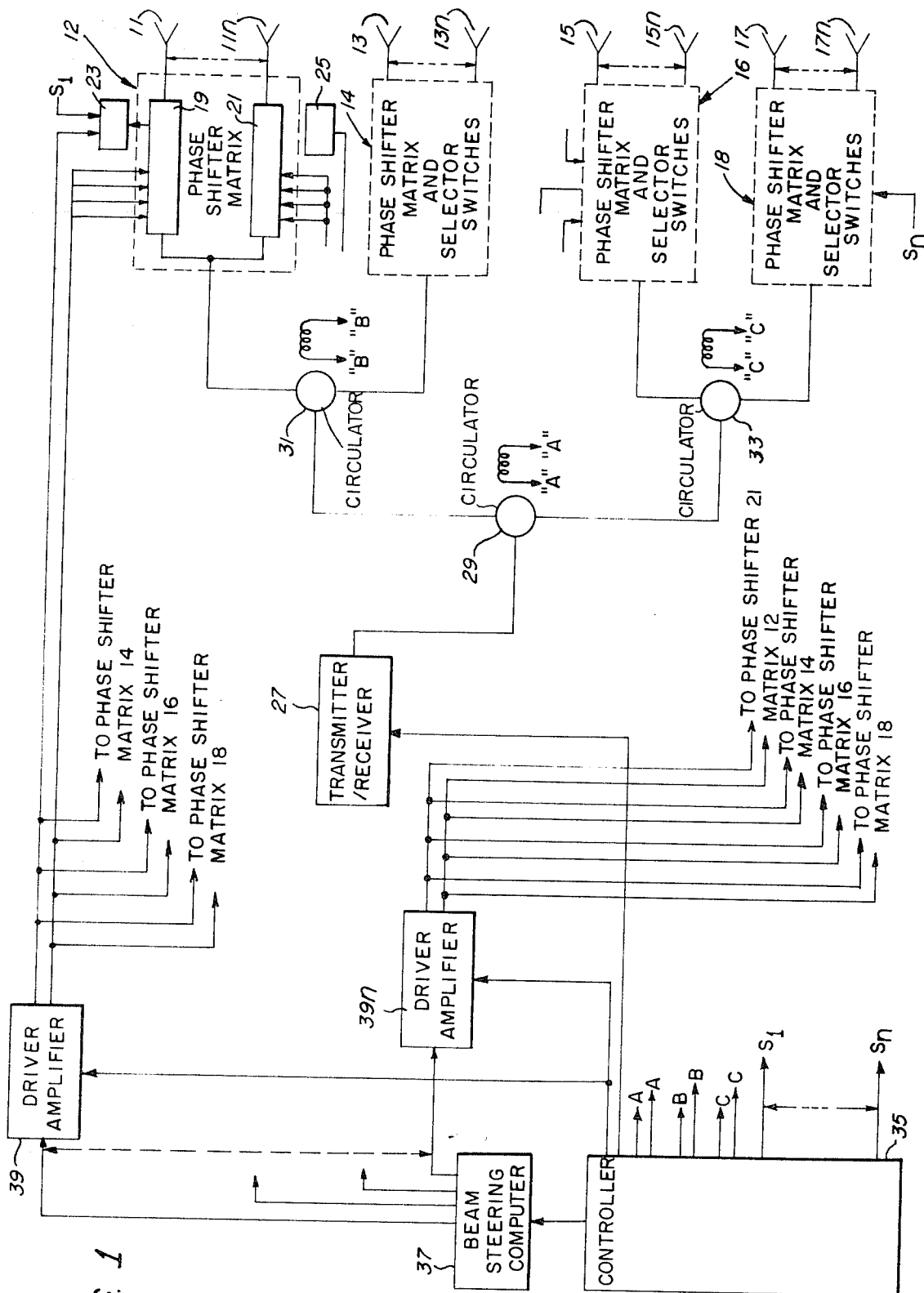


FIG. 1

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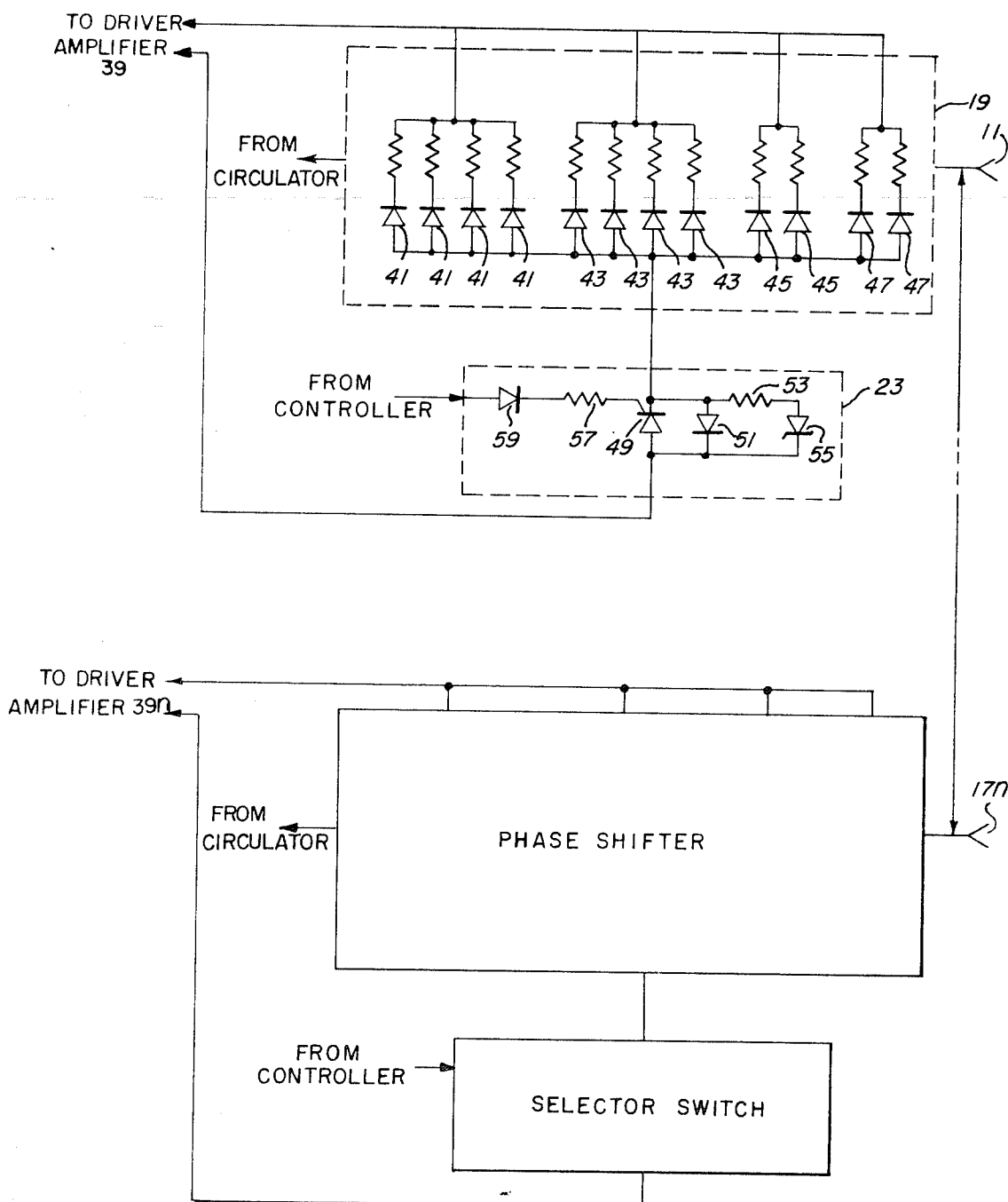


FIG. 2

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PHASED ARRAY ANTENNA CONTROLLER

BACKGROUND OF THE INVENTION

This invention pertains generally to microwave antennas and particularly to phased array antennas.

It is known in the art that phased array antennas may be combined so that each one of such arrays may cover a different sector within a field of view. In known systems using such an arrangement, it is conventional to provide independently operable phase shifters, and drive circuits therefor, for each one of the phased array antennas. Selection of which one, or ones, of the phased array antennas to be used is then effected by enabling only the drive circuits associated with the phased array antenna, or antennas, desired to be used at any particular time. Even though such an approach is relatively simple in theory, system complexity and cost are adversely affected by reason of the fact that a large number of driver circuits is required. The problem of system complexity and cost is particularly acute when semiconductor phase shifters incorporating p-i-n diodes as their switching devices are used. In such an arrangement, each one of the many driver circuits must be capable of producing relatively high-powered driver signals. Obviously, then, the use of separate driver circuits for each phased array antenna is inefficient.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of this invention to provide improved circuitry for operating one phased array antenna out of a number thereof, such circuitry being adapted to be switched from one such array to another.

Another object of this invention is to provide an improved driver circuit arrangement for a plurality of phased array antennas, each of which uses semiconductor phase shifters, such arrangement being adapted to time-share driver amplifiers between phase shifters in different ones of such arrays.

These and other objects of this invention are attained generally by providing a single driver amplifier for corresponding phase shifters in all of a number of phased arrays to be controlled, switching means in circuit with each one of such corresponding phase shifters, and switch control means for operating, at any given time, only the switching means associated with the phase shifters of the phased array to be controlled.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of this invention reference is now made to the following description of a preferred embodiment thereof and to the accompanying drawings in which:

FIG. 1 is a block diagram, greatly simplified for expository purposes, of a radar system using four different phased array antennas, the figure showing the manner in which driver amplifiers may be time-shared between matrices of phase shifters in each one of such antennas; and

FIG. 2 is a schematic diagram showing in particular the arrangement of a preferred form of switching means for semiconductor phase shifters.

Referring now to FIG. 1 it may be seen that an exemplary radar system incorporating this invention includes four independently operable phased array antennas (not numbered), each such array including a number of antenna elements arranged in rows and col-

umns, as antenna elements 11, 11n, 13, 13n, 15, 15n, 17, 17n, four phase shifter matrices 12, 14, 16, 18, each one of such matrices including a semiconductor phase shifter, as p-i-n diode phase shifters 19, 21 (shown associated with antenna elements 11, 11n), and a phase shifter selector switch, as phase shifter selector switches 23, 25, for each row and each column of p-i-n diode phase shifters in each phased array.

A path for microwave energy between the antenna elements of each phased array antenna and a transmitter/receiver 27 is provided to include circulators 29, 31, 33. The latter elements, in turn, are selectively operated by signals from a controller 35 (which signals are designated "A"—"A", "B"—"B" and "C"—"C"). It is evident, therefore, that, depending on the combination of signals from the controller 35 to the circulators 29, 31, 33, microwave energy may be caused to pass between the transmitter/receiver 27 and only a selected one of the phased array antennas. In passing, it should be noted that the arrangement and number of circulators could be changed if it is desired to permit, during any given period of time, microwave energy to pass to more than one of the phased array antennas. The controller 35 is arranged also to produce, as indicated, synchronizing and trigger pulses for the transmitter/receiver 27, phase shifter selector switch actuating signals $S_1 \dots S_n$, beam steering computer program signals for a beam steering computer 37 and a drive amplifier back-bias signal for each one of a plurality of drive amplifiers 39 ... 39n. (The number of drive amplifiers equals the product of the number of p-i-n diode phase shifters in one of the phased array antennas and the number of bits in each such phase shifter). Thus, as indicated, corresponding bits of corresponding p-i-n diode phase shifters in all of the phase shifter matrices 12, 14, 16, 18 are connected in parallel to a single one of the drive amplifiers 39 ... 39n.

The controller 35 is conventional in construction, consisting here of well known components to produce periodic system trigger pulses, beam steering computer program signals, and back-bias signals for the drive amplifiers 39 ... 39n, as well as the D.C. control signals for the circulators 29, 31, 33 and the switch actuating signals for the phase shifter selector switches associated with the phase shifter selector switches in the phased array antenna selected to be used. In this connection, however, it should be noted that, for most efficient operation of a system incorporating this invention, the controller 35 should include interlocking, or rather, inhibiting means so as to prevent system trigger pulses from passing to the transmitter/receiver 27 whenever switching from one phased array antenna to another is being accomplished and to disable the driver amplifier back-bias line except when such switching is being accomplished. Such inhibiting means are desirable, as will be pointed out hereinafter, to permit switching from one phased array antenna to another under optimum conditions.

The drive amplifiers 39 ... 39n are identical one to the other, each one being conventional to provide forward bias or back bias current for its associated p-i-n diodes as required to carry out any given beam steering command.

Referring now to FIG. 2, it may be seen that each p-i-n diode phase shifter in the illustrated example is a four bit digital phase shifter. Thus, the cathode electrodes of the p-i-n diodes 41, 43, 45, 47 for each bit are

connected, each through a current limiting resistor (not numbered) and a cable (not numbered) to a selected one of the drive amplifiers 39 . . . 39n of FIG. 1. The anode electrodes of all the p-i-n diodes 41, 43, 45, 47 are connected together to the cathode electrode of a silicon controlled rectifier (SCR) 49, the anode electrode of a diode 51 and one end of a resistor 53. The second end of the resistor 53 is connected, through a zener diode 55, to the cathode electrode of the diode 51 and the anode electrode of the SCR 49. The resulting common point is then connected to ground. Ground here is taken to be the same as the ground of the drive amplifiers 39 . . . 39n (FIG. 1). The control electrode of the SCR 49 is connected, via a resistor 57 and a diode 59, to the controller 35 (FIG. 1) so that a selected one of the phase shifter selector switch actuating signals, say S1, may be applied thereto.

The illustrated circuit operates in the following manner. When it is desired to switch from one phased array antenna to another, the transmitter/receiver 27 (FIG. 1) is inhibited and a back-bias signal is applied to the p-i-n diodes 41, 43, 45, 47 of all phase shifters. As a result of these two preparatory operations, microwave energy from the transmitter portion of the transmitter/receiver 27 is prevented from passing through any one of the phase shifters. In addition, all p-i-n diodes 41, 43, 45, 47 are driven, if necessary, (depending on their previous state) to their back-bias condition, i.e., to a low current state. (In this connection diode 51 completes the circuit between the p-i-n diodes 41, 43, 45, 47 and the drive amplifiers 39 . . . 39n. The SCR 49, as is well known, cannot become conductive in the absence of a signal to its control electrode. The SCR 49, therefore, cannot conduct during the preparatory operations. When, however, a control signal is applied to the control electrode of each SCR 49 in a selected one of the phased array antennas, i.e., when a control signal is applied via diode 59 and resistor 57, each SCR 49 becomes conductive. The SCR 49 turns off during a back-bias command due to reverse current in the p-i-n diodes. It should be noted, however, that due to the con-

tinuous application of the control signal, the SCR turns on at every forward-bias command. The diode 51 bypasses any current surges to the ground.

Having described a preferred embodiment of this invention, it will now be apparent to one of skill in the art that changes may be made without departing from my inventive concepts. Thus, it is obvious that the disclosed selection circuitry may be used with phased arrays using either analog or digital ferrite phase shifters. It is felt, therefore, that this invention should not be restricted to its disclosed embodiment, but rather should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. In a radar system utilizing a plurality of like phased array antenna assemblies, each one thereof including a matrix of antenna elements and associated semiconductor phase shifters adapted to form and direct a beam of radio frequency energy, each one of such phase shifters incorporating p-i-n diodes actuatable by a different one of a plurality of driver amplifiers, the improvement comprising:

- a. means for selectively enabling the p-i-n diodes incorporated in each different matrix of semiconductor diode phase shifters to be actuated, such means including at least one different silicon controlled rectifier disposed in circuit between all of the driver amplifiers and a first electrode of all of the p-i-n diodes in each different matrix of semiconductor phase shifters;
- b. means for connecting a second electrode of corresponding p-i-n diodes in each different matrix of semiconductor phase shifters to each different one of the driver amplifiers; and
- c. control signal generating means for providing a control signal to the at least one different silicon control rectifier in circuit with the p-i-n diodes in the matrix of semiconductor phase shifters to be actuated.

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