

[54] PHASED ARRAY

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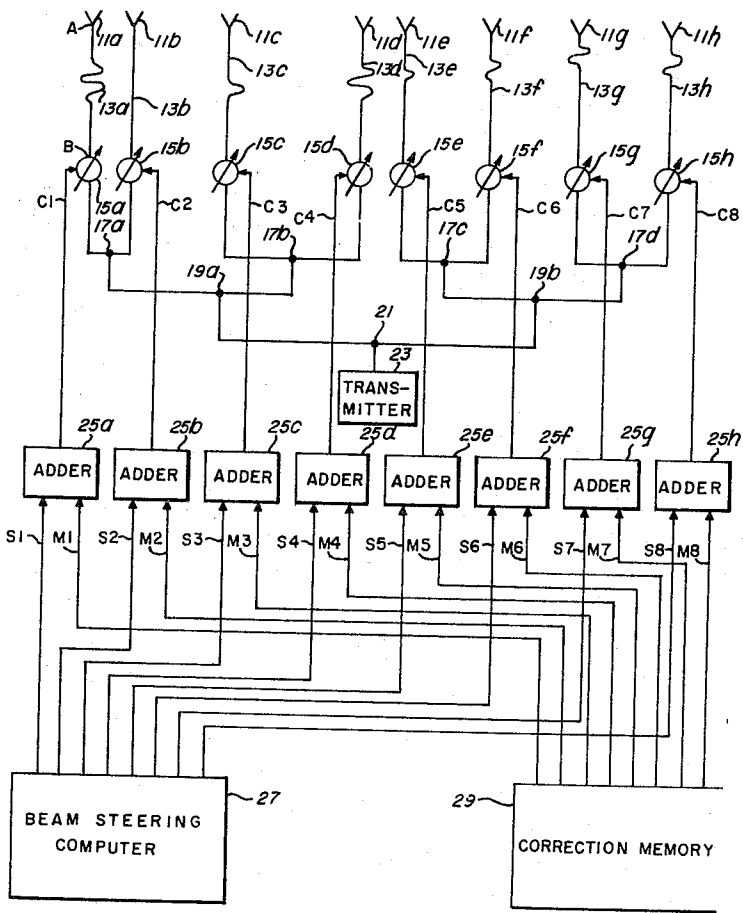
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[58] Field of Search 343/100 SA, 854

[56] References Cited
UNITED STATES PATENTS
3,500,412 3/1970 Trigon 343/100 SA

3,611,401 10/1971 Connolly.....343/100 SA
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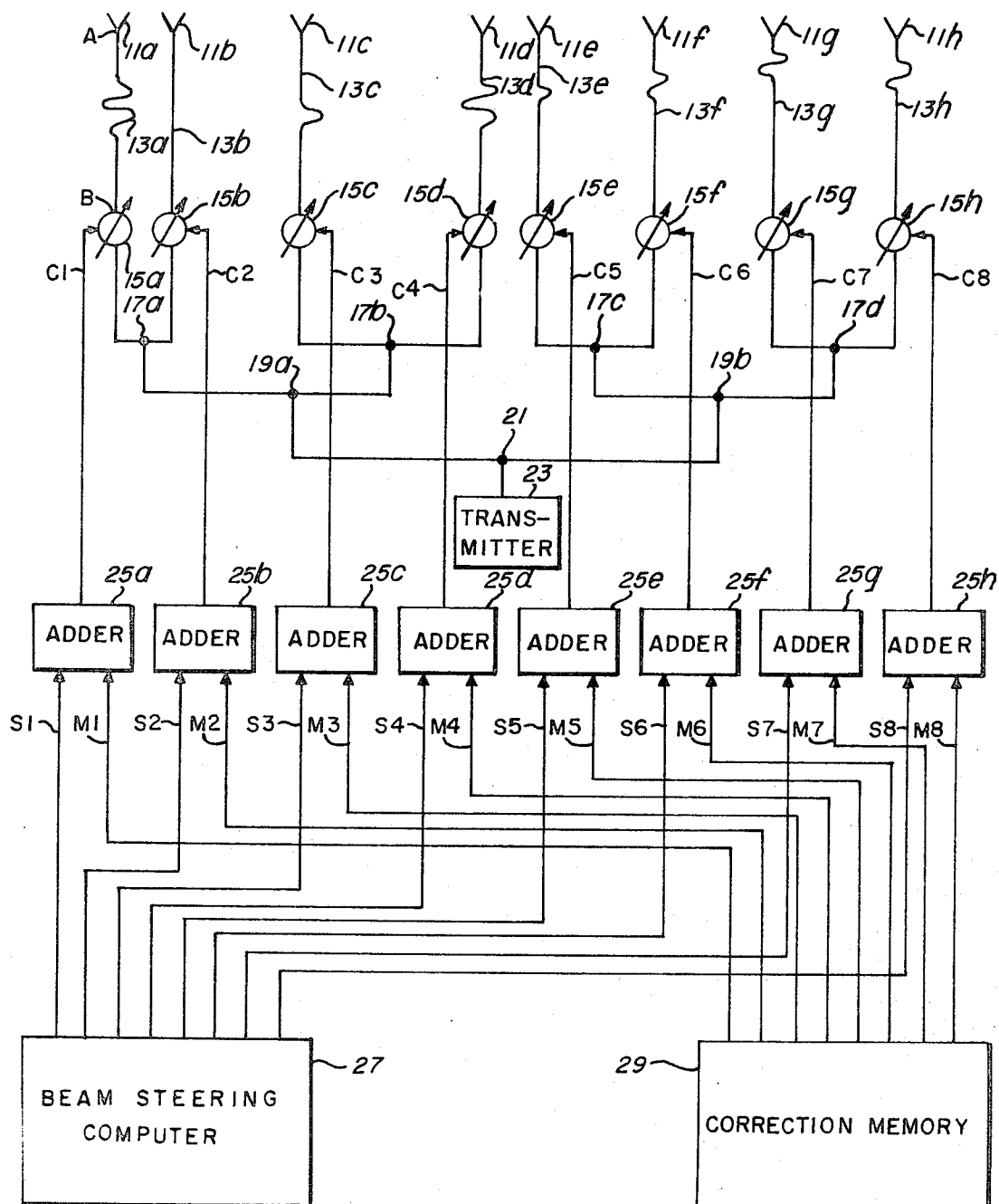
[57] ABSTRACT
A corporate feed phased array for radio frequency energy, such array being adapted to frequency angle phase shifter scanning. The electrical length of each transmission line leading to each radiating element is randomly selected to permit the digital phase shifter associated with each radiating element to be randomly actuated to produce a collimated and deflected beam.

3 Claims, 1 Drawing Figure



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PHASED ARRAY

The invention herein described was made in the course of or under a contract or subcontract thereunder, with the Department of Defense.

BACKGROUND OF THE INVENTION

This invention pertains generally to directional antennas and specifically to directional antennas made up of a plurality of antenna elements.

It is known in the radar art that phased array antennas are particularly well adapted to electronic scanning techniques which permit a directional beam of electromagnetic energy to be moved rapidly from one direction to another. While such arrays may be corrected for pointing errors and increased sidelobe levels which result from quantization arising from the use of digital phase shifters, see Skolnik, "Radar Handbook," published by McGraw-Hill, Inc., New York, 1970, known arrays of such type suffer from other error, specifically that caused by the frequency sensitivity of digital phase shifters. It is known that such error may be eliminated by providing an appropriate correction signal from the beam steering computer which produces the control signal for each digital phase shifter. While such a solution to the problem is satisfactory in many cases, the added complexity required of the beam steering computer entails added cost and difficulty.

Therefore, it is a primary object of this invention to provide, for a phased array using digital phase shifters, improved correction circuitry for decreasing the effect of the frequency sensitivity of such shifters.

Another object of this invention is to provide, for a phased array using digital phase shifters, phase correction circuitry which reduces the complexity of the beam steering computer.

Still another object of this invention is to provide, for a phased array using digital phase shifters, phase correction circuitry which decorrelates equally well over the usual narrow bandwidth of radar phased arrays.

SUMMARY OF THE INVENTION

These and other objects of this invention are generally attained by providing, in a corporate feed phased array using digital phase shifters, a separate transmission line for the radio frequency energy passing each such shifter, each such line being chosen from a group of lines whose electrical length varies randomly and programming an associated beam steering computer so that each digital phase shifter causes a phase shift which, when combined with the phase shift of its associated line, produces the phase shift required for each array element to collimate the beam from such array. As a result, systematic phase shift errors due to the frequency-dependent characteristics of the digital phase shifters disappear. For a more complete understanding of this invention reference is now made to the detailed description of the drawing, in which the single figure is a block diagram showing the arrangement of a linear array according to this invention, the array being shown, for convenience, in a transmitting system, although it is equally useful in a receiving system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Thus, in the FIGURE, each one of a plurality of antenna elements 11a through 11h is connected, through a length of transmission line 13a through 13h and a digital phase shifter 15a through 15h, to a separate one of the output ports (not numbered) of hybrid junctions 17a through 17d. The length of each one of the transmission lines 13a through 13h is varied randomly to introduce a different phase shift, varying between 0° and 360°, in radio frequency signals passing therethrough. The hybrid junctions 17a through 17h are connected, as shown, through hybrid junctions 19a, 19b and hybrid junction 21 to a transmitter 23. It will be recognized that the arrangement just described constitutes a conventional reactive corporate feed wherein the power of the radio frequency signal out of the transmitter 23 may be divided (here equally) between the various antenna elements 11a through 11c and

the phase of the radio frequency signal entering each one of the digital phase shifters 15a through 15h is the same.

Each one of the digital phase shifters 15a through 15h is controlled by a signal c1 through c8 from a digital adder 25a through 25h. Each one of the latter elements, in turn, is actuated by a signal, s1 through s8, from a beam steering computer 27 and a signal, m1 through m8, from a correction memory 29.

Each signal, m1 through m8, out of the correction memory 29 is a digital number which, when applied to its associated digital phase shifter 15a through 15h, causes that element to shift the phase of radio frequency energy having a frequency at the center of the band of frequencies propagated by the array by an amount which causes the phase of such energy at each antenna element 11a through 11h to be the same within the accuracy of the least significant bit of the digital phase shifters 15a through 15h. It follows, from the fact previously noted that the length of each one of the transmission lines 13a through 13h is randomly chosen, that the signals m1 through m8 are also random with respect to each other. Consequently, the digital phase shifters 15a through 15h are also, with respect to each other, randomly actuated. It may be seen, however, that the beam (not shown) of electromagnetic energy from the array is directed along the boresight line.

The beam may be scanned in either one of two conventional ways. As illustrated, scanning may be accomplished by impressing an appropriate signal, s1 through s8, from the beam steering computer 27 on each adder, 25a through 25h. It will be noted that, even though there is an ordered sequence to the signals s1 through s8, the digital phase shifters 15a through 15h remain randomly actuated. It is clear, therefore, that regardless of the direction of the beam or the way in which the beam is scanned, periodicity of phase errors across the antenna elements 11a through 11h which could otherwise be present by reason of frequency sensitivity of the digital phase shifters 15a through 15h is not present in the illustrated embodiment of the invention. It follows, then, that peak sidelobes are "smeared" out and pointing error is reduced to the values predicted by statistical theory for random phase errors.

It will be evident to those of skill in the art that the concepts of this invention may be applied to arrays other than the array illustrated and described hereinbefore. For example, the linear array illustrated may be changed to a planar array in which the electrical length of the transmission line to each radiating element is randomly varied. Further, the type of feed may be changed from the particular type illustrated without departing from the concepts of this invention. 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 phased array for transmitting a collimated beam of electromagnetic energy from a source thereof, the combination comprising:
 - a. a plurality of array elements, each one of such elements including:
 - i. an antenna element;
 - ii. a digital phase shifter; and,
 - iii. a transmission line for coupling electromagnetic energy from the antenna element to the digital phase shifter, the electrical length of each such line differing randomly from the length of each other such line within the limit of a wavelength of the electromagnetic energy in such line;
 - b. a source of electromagnetic energy;
 - c. means for connecting each digital phase shifter to the source of electromagnetic energy; and,
 - d. shifter actuating means, cooperating with each digital phase shifter, for setting each such phase shifter to shift the phase of the electromagnetic energy passing through each such phase shifter as required to produce a systematic relationship in the phase of electromagnetic energy from each one of the antenna elements.

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2. In a phased array as in claim 1 the combination wherein the shifter actuating means includes a digital memory for producing digital numbers to set the digital phase shifters, the particular digital number applied to each digital phase shifter being the number required to result in a phase shift, within the limit of the phase shift due to the least significant bit of each digital phase shifter, which, when added to the phase shift

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caused by the associated transmission line, produces a systematic relationship in the phase of electromagnetic energy from each one of the antenna elements.

3. In a phased array as in claim 2, the combination wherein the means for connecting each digital phase shifter to the source of electromagnetic energy is a corporate feed.

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