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Goodrich

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[54] **SIGNAL PROCESSOR SYSTEM**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy,** Washington, D.C.

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[52] **U.S. Cl.** ..... **343/9;** 235/181; 340/173 LS; 343/17

[51] **Int. Cl.²** .. **G01S 7/06;** G01S 9/36; G06F 15/34; G11C 11/42

[58] **Field of Search** ..... 343/9, 17; 235/181; 340/173 LS

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Attorney, Agent, or Firm—R. S. Sciascia; R. E. O'Neill

[57] **ABSTRACT**

This application discloses an invention providing a device to improve the readout capabilities of signal return on doppler radars comprising the improvement of providing a cathode ray display in real time, an optical system for projecting tube face images on a photosensitive matrix. The matrix is also driven by the pseudo random code of the transmission subsequent to the elapsed time for the return trace while there is still persistence in the screen of the cathode ray tube. While the target and code coincide the photosensitive elements signals are summed in summing circuits and the target distance is obtained.

6 Claims, 5 Drawing Figures

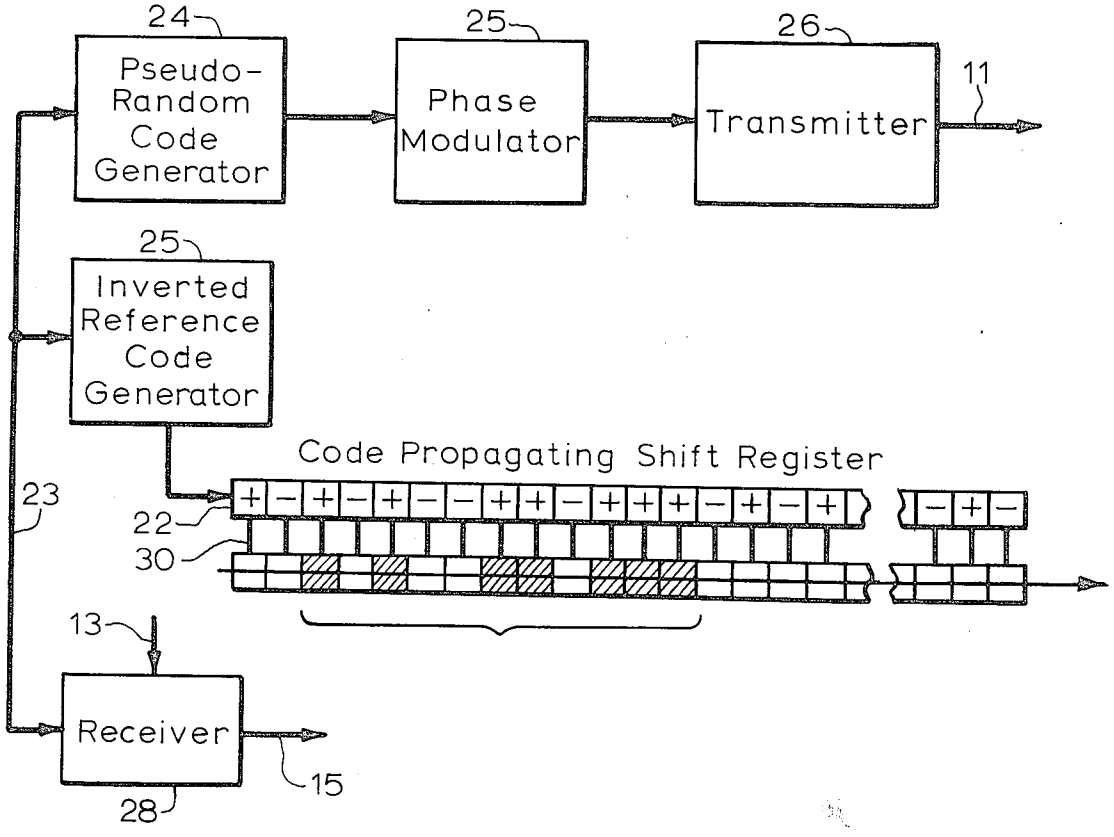


FIG. 1

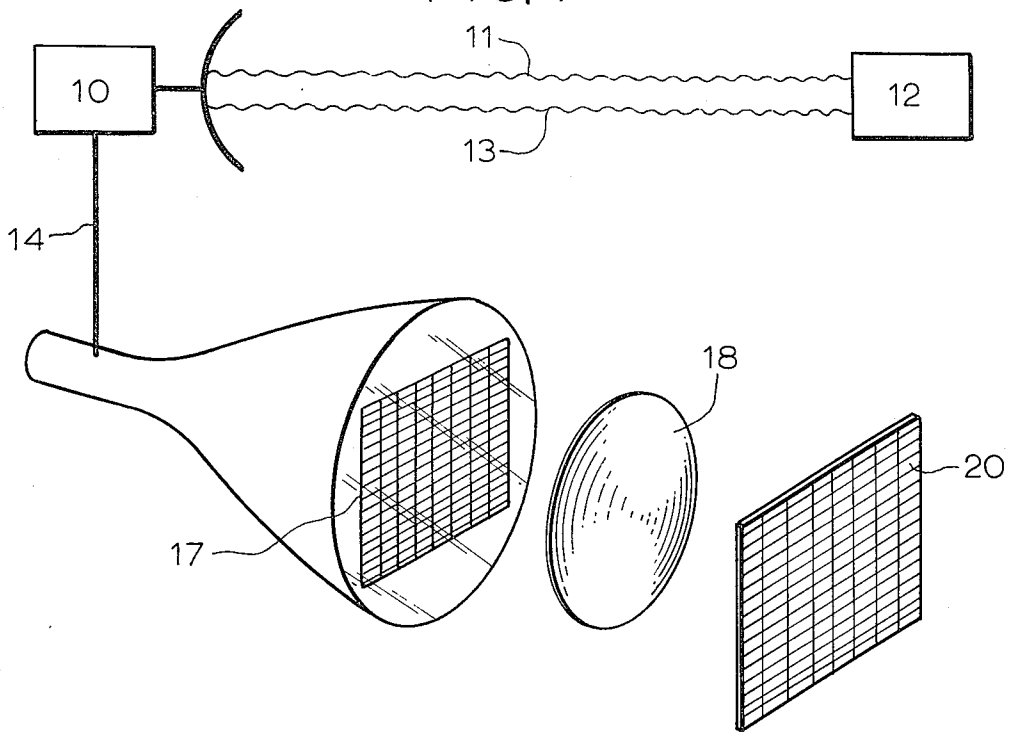

10
11
12
13
14
17
18
20

FIG. 2

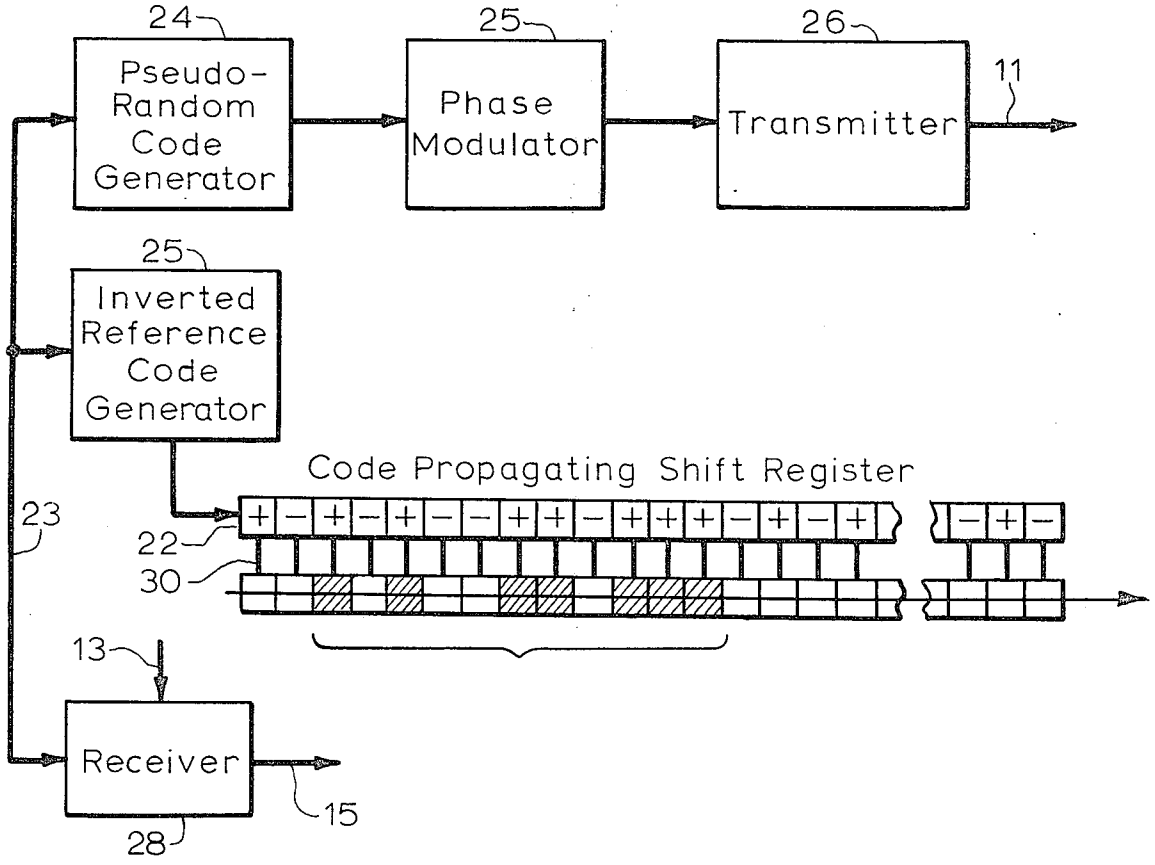

24
Pseudo-Random Code Generator
25
Phase Modulator
26
Transmitter
11
25
Inverted Reference Code Generator
Code Propagating Shift Register
23
22
30
13
Receiver
15
28

FIG. 3

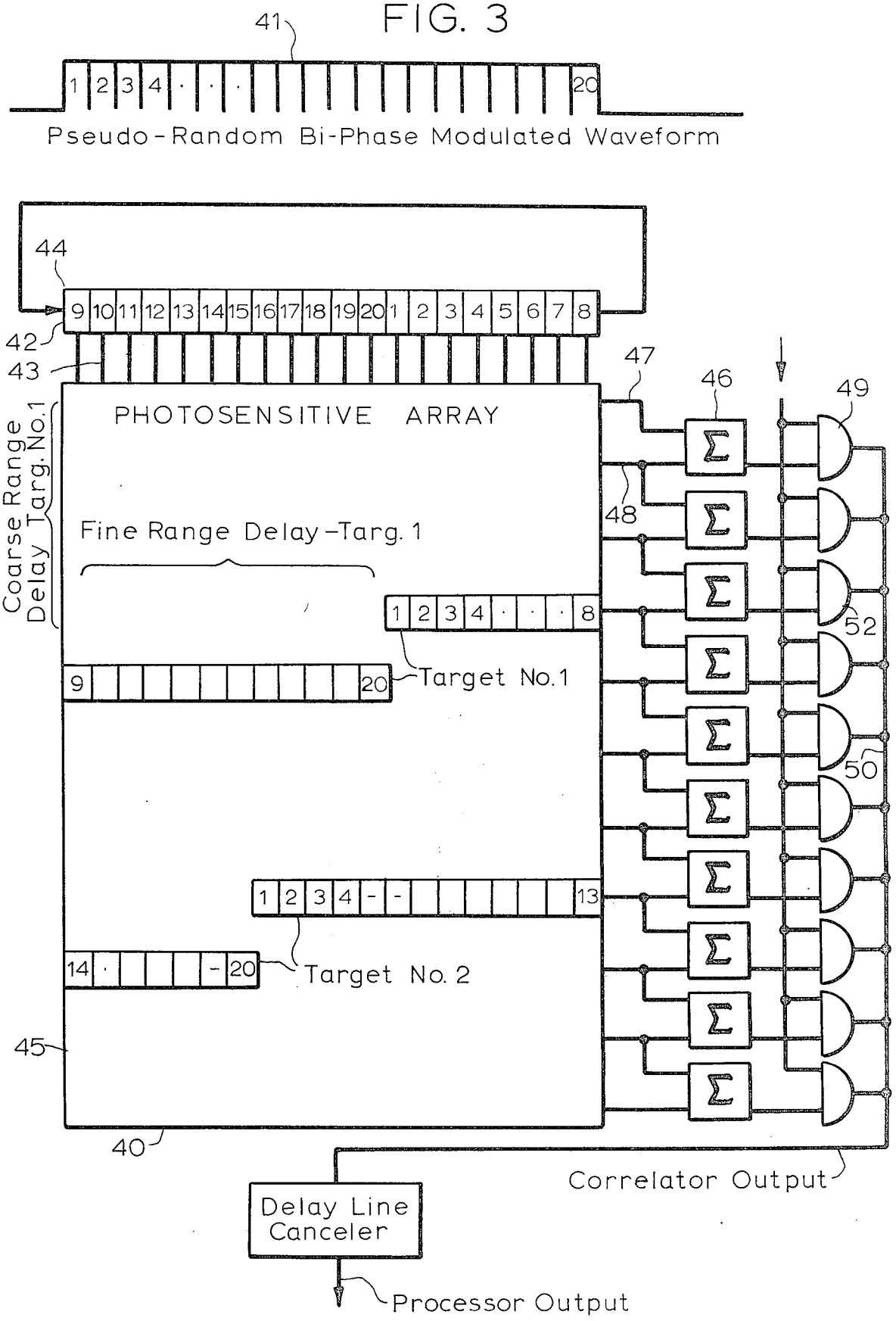
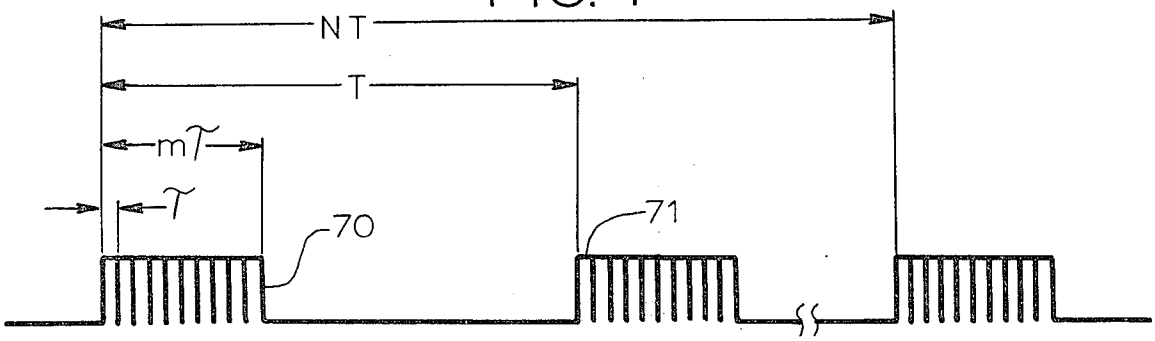

41
1 2 3 4 · · · 20
Pseudo-Random Bi-Phase Modulated Waveform
44
9 10 11 12 13 14 15 16 17 18 19 20 1 2 3 4 5 6 7 8
42
43
47
46
49
PHOTOSENSITIVE ARRAY
Coarse Range Delay Targ. No. 1
Fine Range Delay – Targ. 1
48
1 2 3 4 · · · 8
Target No. 1
9 20
52
50
1 2 3 4 - - 13
Target No. 2
14 · - 20
45
40
Correlator Output
Delay Line Canceler
Processor Output

FIG. 4



Pseudo-Random Bi-Phase Modulated Waveform

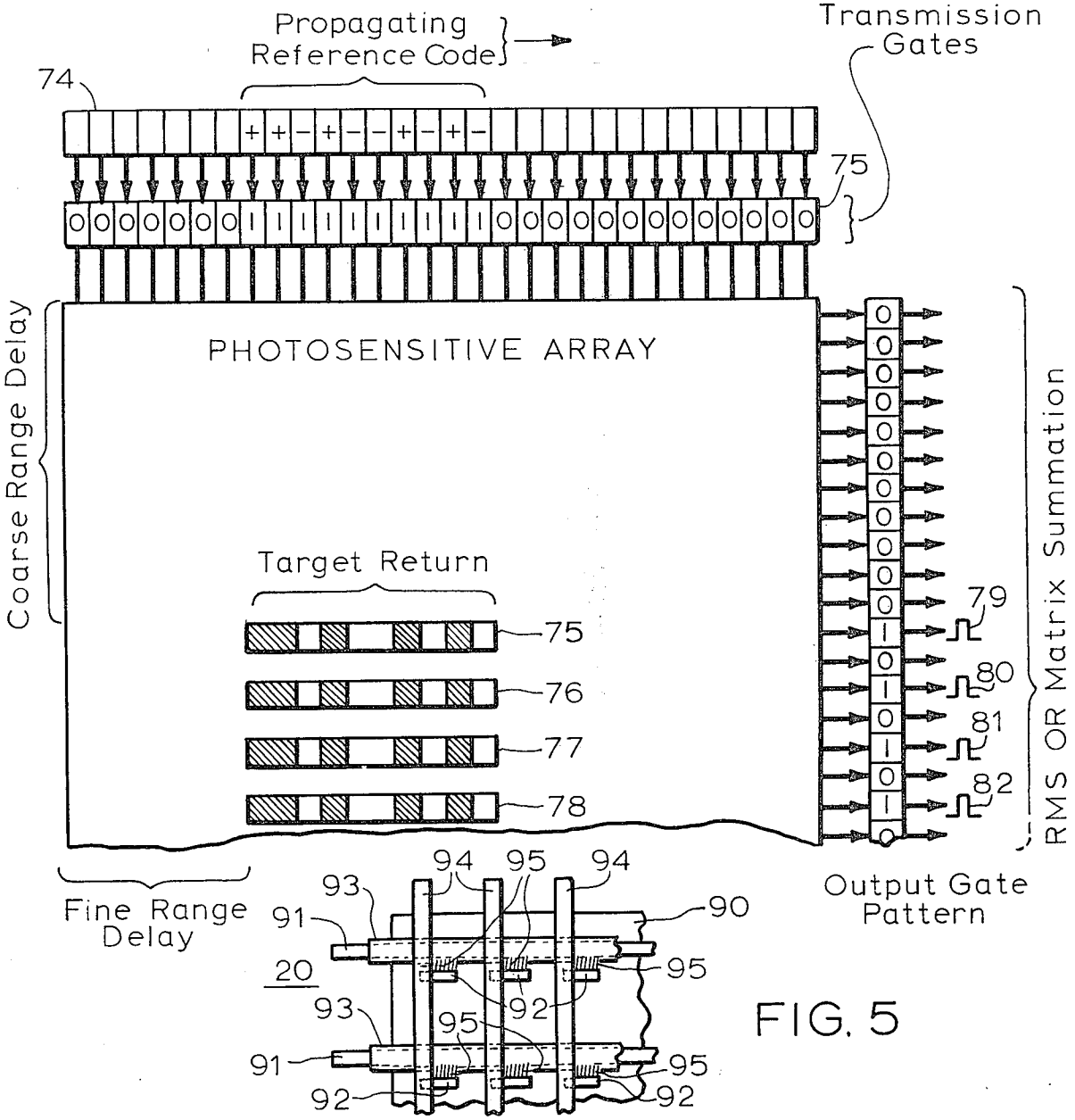


FIG. 5

SIGNAL PROCESSOR SYSTEM

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Modern radars use coded large time-bandwidth signal waveforms to achieve high range and velocity resolution with limited peak transmitted power. Providing an optimum or matched filter for returns from targets to unknown range and velocity normally requires a very large amount of hardware. The subject photosensitive array correlator processes returns from a very large number of range-velocity resolution cells essentially in parallel in real time with a relatively simple integrated device.

The correlation process has been shown theoretically to provide an optimum detector, i.e., the best attainable signal/noise ratio. Correlation basically requires multiplying each element of a return signal by the element of a sequence-reversed replica or reference of the transmitted waveform and summing or integrating the products of all these elemental multiplications. For search radar this process must be duplicated with references for each possible range delay and each possible velocity-induced doppler carrier shift. For those delays and doppler shifts where the correlation function is a maximum, the return and reference are said to match or correlate. In the subject correlator, each photoconductive cell is an elemental multiplier, since its output current is the product of the signal elemental light intensity and the applied elemental shift register reference voltage. Summing, with weighting for carrier doppler shift, is done in the doppler resistor matrix. These comments will aid in understanding the following description of the subject correlator.

It is therefore an object of this invention to provide an improved signal processor for a doppler radar.

It is a further object of the invention to provide an improved signal processor for a doppler radar utilizing a pseudo random coded transmission signal.

A further object of this invention is to provide an improved signal processor for a doppler radar including, means for generating a pseudo random code coupled thru a phase modulator to a transmitter for projecting a radar signal echo returns of which are received back at the transmitter and processed thru a receiver to its modulator, an electrical gun of a cathode ray tube which has a time sweep placed upon its horizontal and vertical deflection plate to produce a sweep on the face of the tube which is a series of horizontal lines vertically displaced from each other; means for projecting the illumination on the face of the cathode ray tube on a matrix of photosensitive devices causing said individual devices to generate electrical signals relating to the light projected thereon, the distance to the target being coarsely displayed in the vertical direction and finally displayed in the horizontal direction.

And still a further object of this invention is to provide an improved signal processor signal for coupling to a doppler radar system that includes elements for generating a phase modulated pseudo random coded radar signal, said signal being re-radiated by a target and being received back at said radar system with frequency shifts due to the motion of the target, said signal having the randon coding of the transmitted signal. The received signal is coupled to the electron gun of a cathode ray tube to intensity modulate the electron beam

to produce on the face of the tube the random coded return echo. Circuitry is coupled to the deflection system of said cathode ray tube to provide a raster on the face thereon where the electron beam moves linearly from one side to the other in a time related sweep in a series of lines on the face of said tube. The return signal appearing on the face of the tube as a series of pulses corresponding to the coding of the transmitted signal, their placement on the face giving an indication of distance to the target. A photosensitive array in a rectangular form is positioned adjacent to the face of said tube. An optical system is provided for transmitting the image on the face of the tube to the photosensitive devices. A series of summing circuits coupled to receive signals from the photosensitive devices and a circuitry coupling a signal from the pseudo random code generator to the photo-sensitive array whereby vertical columns of said photosensitive array are energized consecutively by said code. A net signal generated by the photosensitive device being the sum of the return signal and the code signal thereby identifying the target.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. 1, schematically shows one embodiment of the invention.

FIG. 2, shows a simplified diagram without doppler matching of a linear photosensitive array correlator.

FIG. 3, is a simplified two dimensional photosensitive array correlator.

FIG. 4, is a two dimensional photosensitive array correlator with multiple pulse train.

FIG. 5, shows the details of one photosensitive array.

As set forth above, the invention concerns itself with providing processing means including a two dimensional photosensitive array correlator usable with a doppler shift radar that is set forth in the figures.

A doppler radar system is a coded signal system using a pseudo random code to aid in the processing of the return or echo signal. Fundamentally the coded signal consists of a carrier frequency, superimposed upon this is a code of a pre-selected manner which can be varied in a pre-determined way. A moving target receiving the radar transmission causes the signal to be re-broadcast and there may be a doppler shift in the frequency depending upon the direction of motion of the target with regard to the transmitting antenna.

It is necessary to provide a processing means for separating the coded signal from all other signals and at the same time to determine the range to the target.

FIG. 1, a block diagram of the invention shows a transmitter **10** sending out a pseudo random code generator coded signal **11** to a target **12** which in turn rebroadcasts the coded signal **13** back to the transmitter **10.** That signal is coupled via **14** to a cathode ray tube **15** and the electron beam **16** is intensity modulated by the code. The raster of the cathode ray tube is such that it draws a rectangular diagram **17** which is a series of lines of varying intensity depended upon the signal distance.

An optical system **18** is set to project this raster on a plurality of photosensitive elements **20.** In the discussion ensuing, the photo system element includes a 100 × 100 grid giving 10,000 individual photo system items.

FIG. 2, shows a single row of photosensitive items coupled to a coded processing shift register **22.** A tim-

ing circuit **23** actuates a pseudo random code generator **24** and an inverted reference code generator **25.** A phase modulator **25** is coupled between the random code generator **24** and a transmitter **26.** The return echo **13** is received at a receiver **28** which, via **15,** would intensively modulate the electron beam in the cathode ray tube. Array **20,** has projected upon it illumination via the optical system **18,** which gives light on the face of the cathode ray tube. Subsequently, the shift register has a code passing thru it which is generated in response to timing device **23** that has a time-inverted light-dark pattern to the pattern of a return echo.

The pattern of the target is displaced from the left in proportion to the target range. The optical signal produces a conductivity pattern in the photosensitive array which persists temporarily because of phosphorus persistance and the storage characteristic of the photoconductive material. During the persistance interval the reference code is propagated through the shift register driving the array. Correlation occurs when the propagating reference code and the static signal pattern instantaneously match as shown in FIG. **2.** For this case, the register stages containing the plus **1** bits fall on highly conductive cells and the minus 1 bits fall on cells on low conductance. The summed currents will thus produce a positive output pulse. The time of occurrance of the output pulse indicates the range of the target. For non-correlating positions of the reference code the positive and negative currents substantially change. The photoconductive cells provide the function of temporary storage, multiplication and summation in an extremely simple structure.

The present invention relates to a two-dimensional photosensitive array correlator for signal processing. This array is scanned in the manner of a TV raster, for example, FIG. **3** shows a two-dimensional array **40** having a 100 × 100 photosensitive element array. The pseudo random bi-phase modulated waveform broadcast by the transmitter is shown as **41** which includes a series of positive and negative pulses. There is provided a circulating shift register **42,** shown coupled by a series of lines **43,** to the photosensitive arrays individually. That is, the first one on the left **44,** is connected to all of the photosensitive elements in the perpendicular column **45.** The individual summing circuit **46,** is coupled to a plurality of adding circuits **49,** and the output is derived via line **50,** as the correlator output.

The photosensitive array used in the correlator is the type in which the individual photosensitive cells are electrically interrogated or read out on a rapid repetitive basis. This is necessary because a given cell is pulsed or interrogated by each "1" in the propagating reference code. The required code shift period is determined by the desired array line readout time divided by the number of array columns. In one successful test array, a 3 μs shift period was used, so that a given element was interrogated at a 333 kHz rate by successive "1's" in the reference code. The array to be described was operated at this rate and is capable of being scanned at rates of at least 5 MHz.

The array structure is shown in FIG. **5.** It contains an activated (cadmium sulfide) photosensitive layer **90** which is deposited on a ceramic substrate (not shown). A first metalization consisting of horizontal row conductors **91** and cell electrode pads **92** is next evaporated onto the photosensitive layer **90.** The row conductors are next covered with SiO crossover insulation stripes **93** which are also evaporated. Finally, the second metalization, consisting of vertical column conductors **91** is laid down in position so that each conductor **94** connects with all the cell electrode pads **92** in its respective column. The active area of each cell **95** consists primarily of the photoconductive area laying between its cell electrode **92** and the adjacent row conductor **91.** Ideally, the photoconductive film not lying within these gaps is either eliminated or covered with an opaque film to render it non-conductive. However, acceptable performance is achievable without this feature by virtue of the fact that the leakage paths are longer and hence of higher resistance than the direct path across the cell electrode to row conductor gap. In this embodiment the array cells were on 12 mil centers.

In the structure of FIG. **5,** it is evident that the current delivered into the load on each horizontal row conductor **91** is the sum of the individual cell currents for that row. Each cell current is the product of the cell voltage (applied from the connecting vertical column conductor) and the cell conductivity (determined by the impinging light from the CRT). In one embodiment, the correlator light pattern generated on the CRT phosper was imaged on the array by using a fiber optics CRT faceplate (not shown) but was composed of transverse optical fibers or "light pipes" and was placed in optical contact with this faceplate.

A cathode ray tube in the optical system would be arranged so that the raster on the cathode ray tube would be 100 horizontal lines and these would coincide with the 100 rows of the optical system (it should be noted for the sake of clarity the array is not shown as 10,000 individual segments but rather as 400). Two targets optically imaged are shown on the face of the photosensitive array, this means return echoes utilizing the random code are projected. The circulating reference code shift register **44,** in effect positively senses individual vertical rows within the code. When the code is received as discussed above in the simple linear arrangement of FIG. **2,** a signal is produced as shown at **52.**

A timing circuit actuated by the beginning sweep of the cathode ray tube raster keeps the time from transmitting of the signal to the receipt of the signal and the number of horizontal rows in a descending order determines the coarse range direction of the target. The signal is retained in the sweep rate to the distance to the target and a count is kept by the summing circuit **46,** as to the number of rows that have been swept. For example, an effective range of 200,000 yards might have 2,000 yards of horizontal rows of time delay. Thus, a count down of 25 rows before any signal was encountered would represent 50,000 yards on a coarse range. Since there are 100 photosensitive elements in each horizontal row each element represents the 20 yard distance. Therefore, counting over in a horizontal direction to the beginning of a coded signal gives the final distance by counting the numbers.

FIG. **4,** shows the two-dimensional array and is particularly well suited for processing a train of coded pulses. The pseudo random bi-phase modulated waveform is shown as **70** having a plurality of coded elements **71.** The propagated reference code is shown in the register **74** coupling signals thru a transmission gate **75** to the rows of the array. The target is designated as a series of times as shown **75, 76, 77, 78.** These four target returns designated within the random codes en-

counter them for pulses **79, 80, 81** and **82.** The advantage of this system is that the bi-polar video output can be applied simultaneously to a resistor coded doppler matrix. This will intergrate the full return, raising the signal noise and signal clutter ratios and indicating the velocity of each target. The instantaneous doppler resolution of targets is made possible by the storage capability of the array. To improve the range ambiguity characteristics of the waveform as shown in FIG. **4,** the spacing between pulses can be made slightly irregular. These irregularities can be compensated, i.e., the outputs time-aligned by placing a set of time aligning delay devices at the inputs to the doppler matrix.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. An improved signal processor system usable with a doppler shift radar system comprising:

a. a radar system capable of generating a signal and receiving back signals from stationary and moving targets, said radar system having a pseudo random code generator to modulate the transmitted signal and inverted reference code generator, and a receiver;

b. a cathode ray tube;

c. electrical circuitry for generating a rectangular raster on the face of said tube, said receiver coupled by intensity modulate the raster on said cathode ray tube, the phosphorus in said cathode ray having a small but finite persistance;

d. a photo sensitive array consisting of a plurality of photo sensitive elements arranged in a two dimensional array capable of receiving light and generating electrical signals;

e. an optical system for projecting the raster of said cathode ray tube face on said photosensitive array;

f. an echo signal appearing on the raster of the cathode ray tube as coded signal, said echo signal on said face being projected on said photosensitive array;

g. said code generator coupled to said cathode ray tube to sweep the raster and intensity modulate the raster, said raster projected on said photosensitive array elements and causing the generation of electrical signals;

h. a series of summing circuits coupled to said photosensitive elements to add the electrical signals generated by target echoes and the random signals identify the said return signals, placement on said raster giving indication of distance to the target.

2. The improved signal processor of claim **1** wherein there is provided circuitry coupled to said cathode ray to cause the electron beam of said tube to traverse the face of said tube in a predetermined linear sweep with respect to time, said sweep commencing at a point on the face of said tube and being divided into a plurality of equal length lines displaced vertically, successive lines indicating greater time lapse.

3. The improved signal processor of claim **2** wherein there is provided phase modulation of said generated radar signal.

4. The improved signal processor of claim **3** wherein said photosensitive array consists of a plurality of photosensitive devices arranged in a rectangular array.

5. The improved signal processor of claim **4** wherein said pseudo random code generator is coupled to said photosensitive array so that the photosensitive devices can be energized by said pseudo random signal to provide correlation of the return echo signal in its coded form with the generated coding signal.

6. The improved signal processor of claim **5** wherein circuitry is provided coupled to said random code generator to provide non-uniform time spacing between transmitted signals and said non-uniform coding signals and is transmitted to said photosensitive devices.

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