Dec. 6, 1966 T. V. LINK ETAL 3,290,546

CATHODE RAY TUBE IMAGE MATCHING APPARATUS

Filed Oct. 25, 1962 2 Sheets-Sheet 1

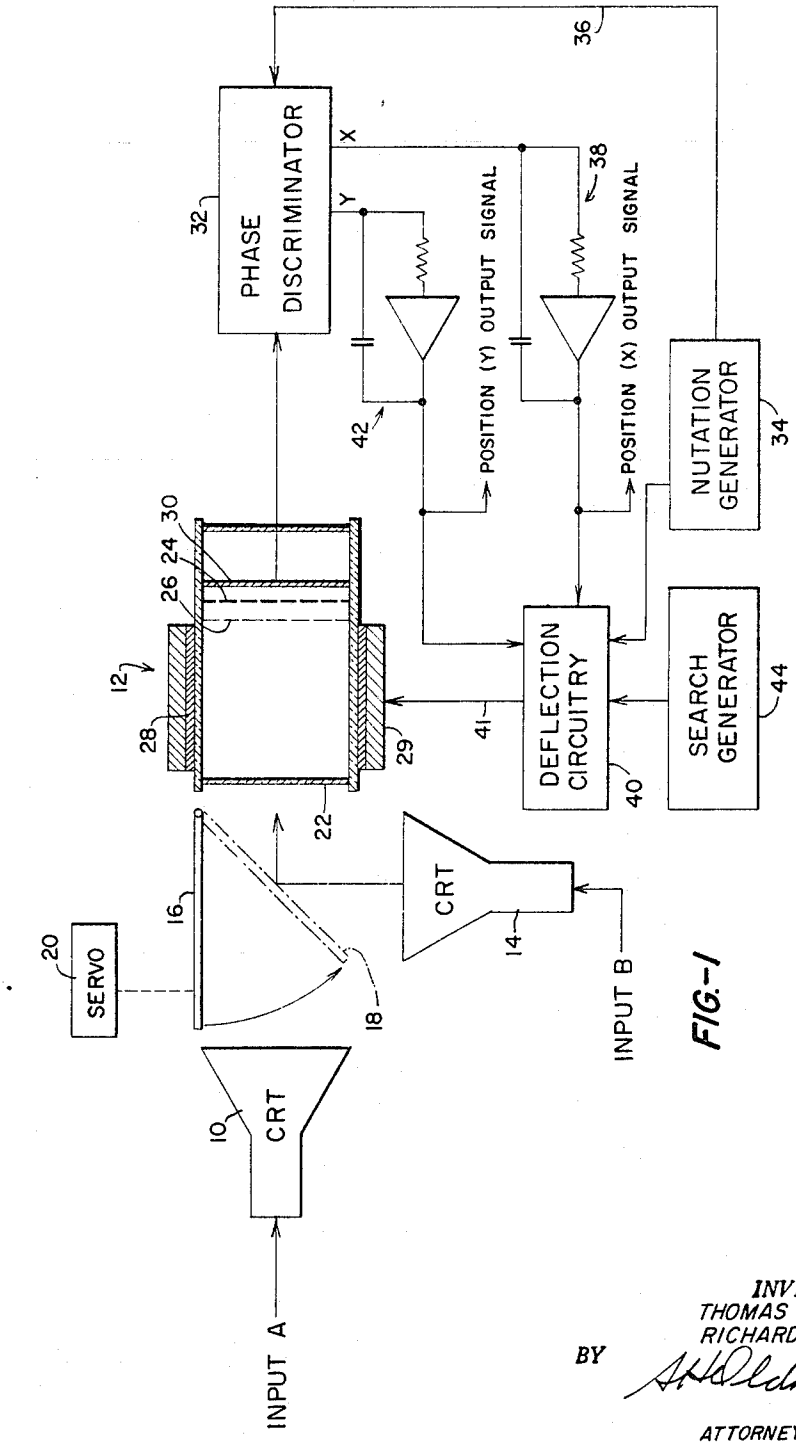

FIG-1

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CATHODE RAY TUBE IMAGE MATCHING APPARATUS

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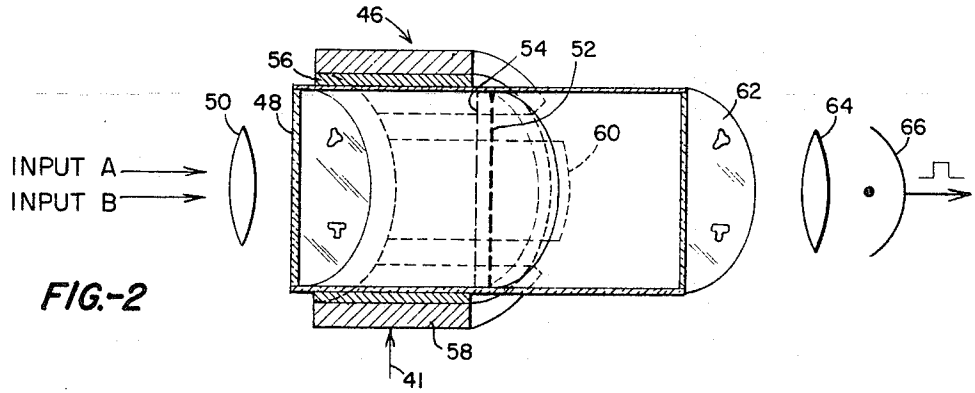

FIG.-2

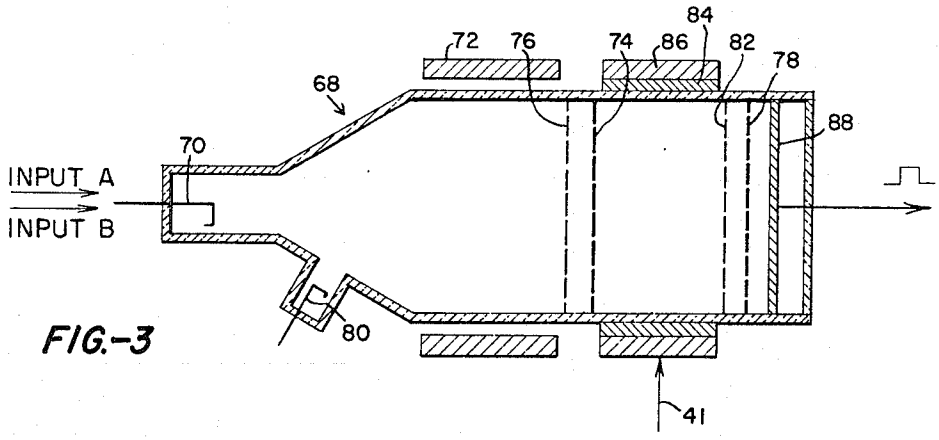

FIG.-3

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CATHODE RAY TUBE IMAGE MATCHING APPARATUS

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9 Claims. (Cl. 315—12)

This invention relates to an image matching system and more particularly to an image matching system having a single electronic tube which stores a reference electron pattern, correlates a second electron pattern with the reference electron pattern, and produces output information which is a function of the correlation between the patterns.

It is the general object of the invention to provide a simplified, improved, relatively inexpensive image matching system characterized by a minimum of parts, lightness of weight, and relatively small space requirements, but having high operating efficiency, and speed.

Another object of the invention is to provide a single electronic tube which stores and correlates electron patterns.

Another object of the invention is to provide a single electronic tube wherein a first electrical input signal is stored and correlated with a second electrical input signal to produce an electrical output signal which is a function of the degree of correlation.

Another object of the invention is to provide an image matching system wherein one electron pattern is moved relative to a second electron pattern in order to obtain best correlation and the displacement is measured to provide positional information relative to the reference electron pattern.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing an image matching system with an electronic tube which has read-in means for forming an electron charge pattern. The charge pattern is stored on a grid as reference information. A second electron charge pattern formed by the read-in means is focused on the grid and is moved or deflected electromagnetically or electrostatically in a predetermined path relative to the stored charge pattern. The number of electrons that pass through the storage grid is a function of the correlation between the charge patterns. Read-out means of the tube sense the number of electrons that pass through the grid and produce an output signal which is indicative of the correlation between the charge patterns. This output signal is fed into a phase discriminator which determines the direction of mismatch of the charge patterns and produces output error signals.

The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing in which:

FIGURE 1 is a schematic illustration of one embodiment of the image matching system of the invention.

FIGURE 2 is a schematic illustration, partially in perspective, of an electron image correlating tube adapted to be used in the image matching system of FIGURE 1.

FIGURE 3 is a schematic illustration of a modified electron image correlating tube adapted to be used in the image matching system of FIGURE 1.

Referring to the drawing, there is shown in FIGURE 1, an image matching system which produces a pair of position output signals X and Y which are a function of the correlation between the images being matched. A CRT **10** adapted to receive input A information converts the A information into an A image. The A information is reference information and may be stored radar signals

indicative of terrain or target characteristics. The A image is projected on a light sensitive portion of an electron correlator tube **12** and is electrically stored therein. A second CRT **14** adapted to receive input B information converts the B information into a B image. After the A image is stored in tube **12**, the B image is reflected by a mirror **16** on the light sensitive portion of tube **12**. The mirror is rotated into the position indicated by the broken line **18** by a programmed servo **20** so that it reflects the B image toward the tube. The B information is active information such as actual radar signals. The light images A and B may be produced by known methods such as optical systems and projecting light through a film-like picture of the image.

It should be understood that CRT **10** could be used for both A image and B image by using CRT **10** to give a proportionate time to each image.

The tube **12** converts the images into A and B electron patterns and functions to correlate the A and B electron patterns by moving the active electron pattern relative to the stored electron pattern. The output signal of the tube is a function of the correlation between the two patterns. The best match between the patterns results in a maximum output signal.

The tube **12** contains a light sensitive portion or photoemissive cathode **22** which emits electrons proportional to the amount of light projected thereon. The electrons emitted from the cathode are accelerated toward and focused on an electron storage grid **24** by means of proper biasing and a magnetic focusing field produced by a cylindrical permanent or electromagnet **28**. A collector element **26** is positioned adjacent the forward surface of the grid **24** and collects the electrons that are emitted from the grid **24** as a result of secondary emission. The magnet **28** surrounds the tube and extends between the cathode **22** and grid **24**. A positive charge pattern which corresponds to the optical image A is written onto the storage surface. This charge pattern represents stored reference information.

An active charge pattern is subsequently projected on the grid by exposing the cathode **22** to light image B from CRT **14**. The electrons that paint the B charge pattern are deflected electromagnetically by means of two pair of magnetic coils or yokes **29** to effect a nutating or scanning movement of the B electron pattern relative to the A charge pattern. The particular deflection path of the electrons is controlled by the alternating current voltage feed to the yokes. The B electron pattern is moved relative to the A charge pattern to determine the best match position.

During the matching operation the electrons projected on grid **24** as a result of the B image on cathode **22** are transmission modulated, without loss of charge, by the charged storage grid **24**. The electrons pass through the charged portions of grid and are collected by a signal electrode **30** positioned adjacent the rear surface of the grid. The greater the correlation between the charge patterns the greater the number of electrons that will be sensed by the signal electrode **30**.

The output signal from the signal electrode is fed to a phase discriminator **32**. The discriminator **32** also receives reference input signals from a nutation generator **34** via conductor **36**. The discriminator determines the direction of mismatch in any given rotary quadrant of the deflection yoke **29**. The quadrant in which the match is effected breaks down into a left-right X error voltage and an updown Y error voltage.

The X error voltage is fed to an integrator **38** shown as a resistor in series with an amplifier shunted by a capacitor. The output signal from integrator **38** is the X position signal. This signal is fed to deflection circuitry **40**.

The Y error voltage is fed to an integrator 42 shown as a resistor in series with an amplifier shunted by a capacitor. The output signal from integrator 42 is the Y position signal. This signal is fed to deflection circuitry 40. The X and Y position signals may be used to control the guidance of a vehicle.

A search generator 44 and the nutation generator 34 sends preselected search and nutating signals to the deflection circuitry. The deflection circuitry in response to the X and Y position signals adjusts the search and nutating signals in accordance with the value of the position signals. The output signal from the deflective circuitry 40 is sent to the yokes 29 via conductor 41.

The nutation generator 34, search generator 44 and circuitry 40 are known components and can be provided by the average man skilled in the art. It is noted that typical circuits suitable for this purpose is shown and described in pages 257 and 467 of the textbook Electron Tube Circuits, by Samuel Seely, Ph.D., published in 1950 by McGraw-Hill Book Co., Inc.

The circuits of the phase discriminator 32 can be readily provided by the skilled electronics engineer. Typical circuits for this purpose being shown and described in page 521 of the textbook Waveforms (vol. 19, M.I.T. Radiation Lab. Series), by Louis Ridenour, published in 1949, by McGraw-Hill Book Co., Inc.

The electronic tube 46 shown in FIGURE 2 performs the function of correlating two information displays in the form of light patterns or images A and B. The tube consists of a photo-emissive cathode 48 which emits electrons proportional to the amount of light falling on it. The images A and B are separately focused by a lens 50 on the cathode 48. The electrons emitted from the cathode are accelerated toward and focused on a storage grid 52 by means of proper biasing and a magnetic focusing field produced by a cylindrical permanent magnet 56. A collector element 54 is positioned adjacent the forward surface of the grid 52 and collects the electrons that are emitted from the grid as a result of secondary emission. The first image A, in the form of a charge pattern on the storage grid 52 is an electronic reference map.

The second image B is subsequently focused upon the cathode 48. The electrons emitted from the cathode are accelerated toward and focused on the storage grid by the electric field between the cathode and grid and the permanent or electro-magnet 56. These electrons are also deflected electro-magnetically by means of two pairs of magnetic coils or yokes 58 and 60 placed between the cathode and storage grid. The yoke alternating current voltage controls the deflection path of the electrons as theretofore described and shown in FIGURE 1.

The number of electrons that flow through the storage grid 52 is a product of the electrons of image A and B and a measure of the correlation between the two images. The number of electrons that flow through the grid is dependent upon the electron storage threshold of the grid and the charge on the separate portions of the grid. These electrons strike a phosphorous readout or viewing screen 62. The intensity of the image on the viewing screen is a function of the correlation between the two images. When the images A and B are substantially matched the viewing screen will have a maximum light intensity. A lens 64 focuses the light energy emanating from the viewing screen on a phototube 66. The phototube 66 measures the light intensity and sends an output signal to the phase discriminator 32.

The electronic tube 68 shown in FIGURE 3 functions to electrically store A and B information and to correlate the A and B information. During the correlation time the tube provides a continuous electrical readout signal which is a function of the degree of correlation. The information is supplied to the tube by a writing gun 70. Read-in yokes 72, such as magnetic coils, deflect the input electrons into an A electron pattern which is focused upon a first storage grid 74. A biased collector 76 is

positioned adjacent the first grid to uniformly distribute the electron pattern of the first grid. By regulating the current of the read-in yokes and the potential or bias of the first grid the A electrical input electrons may be subsequently transferred to a second storage grid 78 which is axially aligned with and behind the first storage grid 74.

The A electron pattern on the first grid 74 is transferred to the second grid 78 by a uniform beam of electrons. A flooding gun 80 generates the electrons and the magnetic field caused by the read-in yokes uniformly disperses the electrons on the first grid 74. While the first grid is flooded, specific electrons pass through the first grid and are stored on the second grid 78. The electron pattern which is transmission modulated by the first storage grid 74 is accelerated toward and focused on the second storage grid 78 by a biased collector element 82 extending across the face of storage grid 78 and a permanent magnet 34 surrounding the tube and extending between the first and second storage grids. The A electron pattern is now on the second grid.

An alternative procedure is to adjust the potential of collector 76 and grid 74 so that they are essentially transparent to electrons. A image can then be read directly on grid 78 with proper potentials on magnet 84 and collector 82.

The B input information is introduced into the tube by the writing gun 70 and focused upon the first storage grid 74 where it is stored as a B electrical charge pattern. A uniform beam of electrons is generated in the tube by the flooding gun 80 to transfer the B electrical pattern to the second grid. Correlator yokes 86 positioned between the grids move the B electrical charge pattern relative to the A electrical charge pattern in response to signals from the deflection circuitry 40. The number of electrons that pass through the second grid and strike the signal electrode 88 is a measure of the correlation between A and B charge pattern. When the patterns are substantially matched a maximum output signal is obtained from the electrode 88. The output signal is fed to the phase discriminator 32.

While there have been shown, described, and pointed out the fundamental novel features of the invention as applied to the preferred embodiment, it will be understood that various omissions, substitutions, changes in form and details of the apparatus illustrated may be made by those skilled in the art, without departing from the spirit of the invention. It is intended to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. An electronic tube means for correlating two information displays in the form of light images A and B having a photo-emissive cathode to receive the light images, an electron storage grid means spaced in substantially parallel relation from the cathode to accumulate the electrons emitted from the cathode in response to reference light image A, a viewing screen for receiving electrons passed through the storage grid and to produce readout information which is a function of the number of received electrons, a magnetic yoke surrounding the tube means for accelerating and focusing the electrons emitted from the cathode toward and on the storage grid means, separate magnetic yoke means surrounding the tube means for deflecting the electrons emitted from the cathode in response to active light image B to provide relative movement on the storage grid between the stored electron pattern of image A and the electron pattern of image B, whereby the number of electrons passed through the storage grid means and striking the viewing screen being a function of the correlation between image A and B, and means to measure the read-out information on the viewing screen.

2. An electronic tube means for correlating two information displays in the form of light images A and B comprising a photo-emissive cathode to receive the light images, an electron storage grid means positioned in the tube means in spaced relation for the cathode to accumu-

late and the store the electrons emitted from the cathode in response to reference light image A, a signal electrode positioned adjacent the rear surface of the grid means sensing electrons passing through the storage grid means and providing read-out information which is a function of the number of sensed electrons, yoke means surrounding the tube means for focusing the electrons emitted from the cathode in response to active light image A on the storage grid means, and means for projecting and nutating the electrons emitted from the cathode in response to active light image B onto the storage grid means to provide relative movement between the stored electron pattern of image A and the projected electron pattern of image B, the number of electrons passing through the storage grid means and striking the viewing screen being a function of the correlation between image A and B.

3. An apparatus for electrically storing and correlating A and B information comprising an electronic tube having first and second electron storage grid means, said grid means being axially separated to divide the tube into separate areas, writing means for supplying the tube with an electron pattern which is indicative of the A and B information; means for accelerating and focusing said electron patterns on one of the grid means whereby the A electron pattern is stored on the second grid means and the B electron pattern is stored on the first grid means, means for flooding the first grid means with a uniform beam of electrons to transfer the B electron pattern to the second grid means, means positioned between the grid means being operative to move the B electron pattern relative to the A electron pattern, the number of electrons flowing through the second grid means being a function of the correlation between the A and B electron patterns, and a signal electrode positioned adjacent the second grid means to measure the number of electrons that pass through the second grid means.

4. The combination in an image matching system of means for producing an optical image, means for converting a first and second optical image to first and second electron images, grid means for storing the first electron image, means for focusing the second electron image on the grid means, electrical means for nutating the complete focused second electron image relative to the stored first electron image, means for sensing the number of electrons that pass through the grid means to produce an output signal which is a function of the correlation between the first and second electron images, and discriminating means connected to the nutating means and the sensing means for receiving output signals therefrom to produce error signals.

5. In an electronic image correlation tube the combination of

an enclosed housing drawn to a vacuum,

a photo-emissive cathode at one end of the housing to receive optical image input information,

a storage grid in the tube spaced in substantially parallel relation to the cathode to store a projected first electronic image as a positive voltage charge pattern thereon,

a read-out electrode at the other end of the tub in close-spaced substantially parallel relation to the storage grid to receive all electrons passed through the storage grid,

a magnetic yoke surrounding the tube between the cathode and the storage grid to accelerate all total electron images emitted from the cathode and focus the accelerated electron images on the storage grid, and

two pairs of electromagnetic coils surrounding the magnetic yoke to controllably deflect an accelerated total electron image to effect relative movement of one particular image to an electron image stored on the storage grid whereby the number of electrons passed through the storage grid as received by the read-out electrode is a function of the correlation between the one particular accelerated electron image and the stored electron image.

6. An electronic image correlation tube as set forth in claim 5 wherein a collector element is positioned in the tube between the storage grid and the cathode in close spaced substantially parallel relation to the storage grid to collect electrons emitted from the storage grid as a result of secondary emissions.

7. An electronic image correlation tube according to claim 5 wherein the storage grid stores the first electronic image projecter thereon as a positive voltage charge pattern to transmission modulate all subsequent electronic images projected thereon without loss of charge.

8. An electronic image correlation tube according to claim 5 which utilizes associated phase discrimination and deflection circuitry to close the loop by determination of offset image errors to generate error signals to achieve image match.

9. An apparatus for electrically storing and correlating A and B information comprising an electronic tube having first and second electron storage grid means, said grid means being axially separated to divide the tube into separate areas, writing means for receiving optical images indicative of the A and B information and supplying the tube with electron patterns thereof; means for focusing said electron patterns down the tube whereby the A electron pattern is stored on the second grid means and the B electron pattern is stored on the first grid means, means for flooding the first grid means with a uniform beam of electrons to transfer the B electron pattern to the second grid means, means positioned between the grid means being operative to move the B electron pattern relative to the A electron pattern, the number of electrons flowing through the second grid means being a function of the correlation between the A and B electron patterns, and a signal electrode positioned adjacent the second grid means to measure the number of electrons that pass through the second grid means.

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