

June 20, 1961

V. W. BOLIE
SIMULATED PERSPECTIVE DISPLAY OF AIRCRAFT
LANDING STRIP ON CATHODE RAY TUBE

2,988,821

Filed Aug. 30, 1957

9 Sheets-Sheet 1

FIG 1

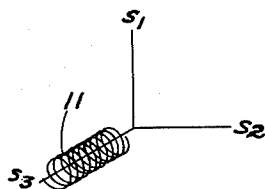
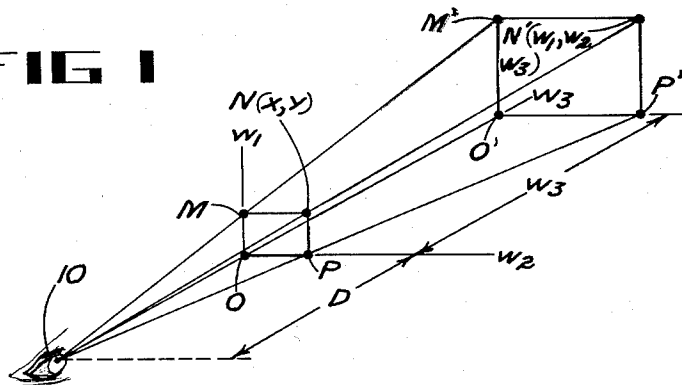


FIG 2

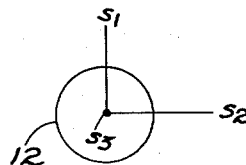


FIG 3

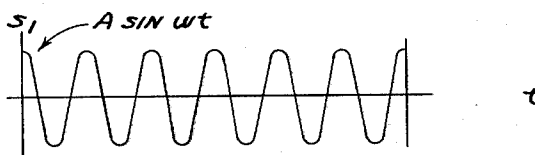


FIG 4(A)

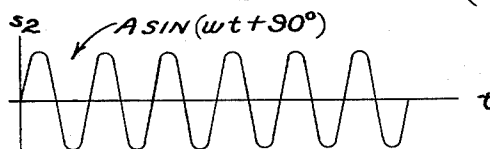


FIG 4(B)



FIG 4(C)

INVENTOR.

VICTOR W. BOLIE

BY

Moody and Goldsman

ATTORNEYS

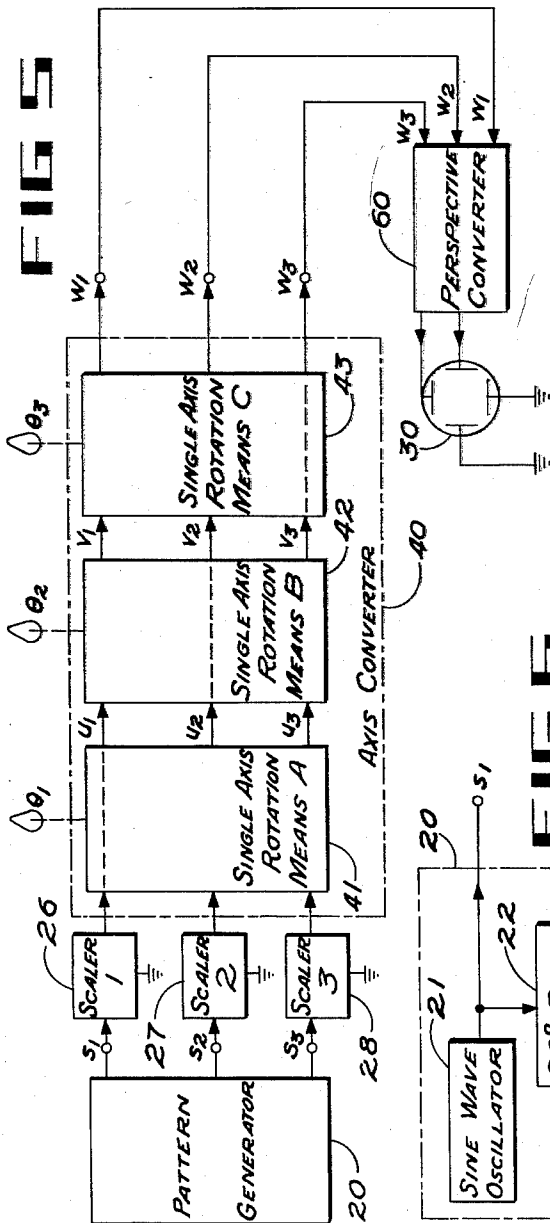
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INVENTOR.

VICTOR W. BOLIE

BY *Moody and Goldman*

ATTORNEYS

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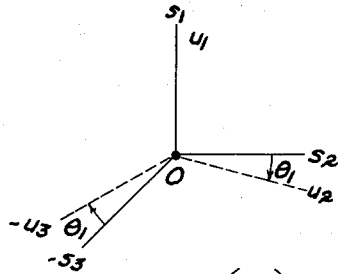


FIG 7(A)

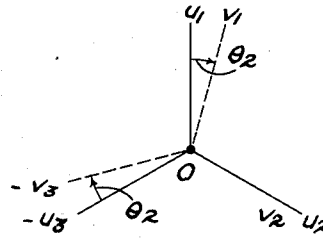


FIG 7(B)

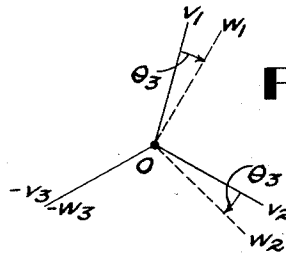
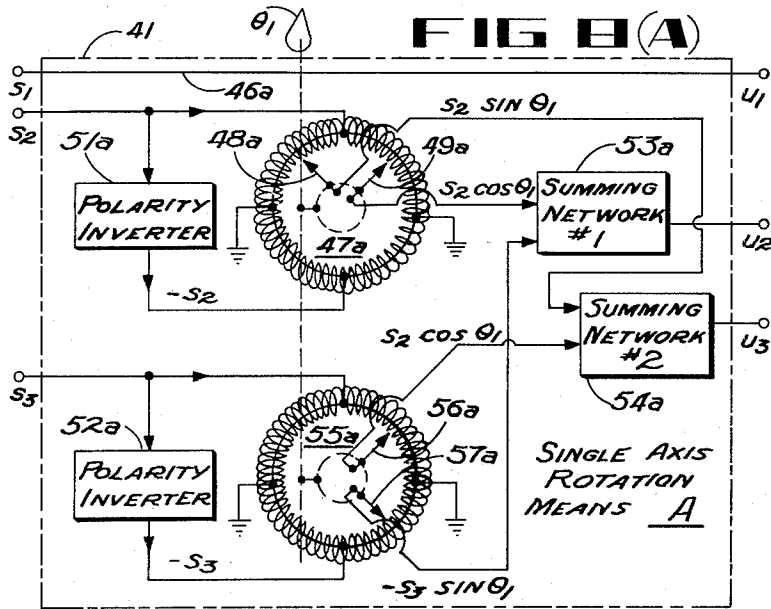


FIG 7(C)



INVENTOR.

VICTOR W. BOLIE

BY *Moody and Goldman*

ATTORNEYS

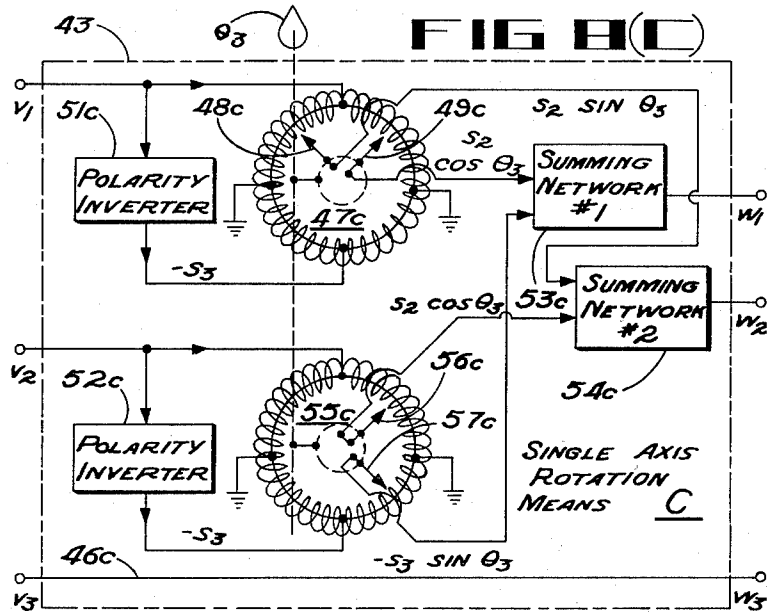
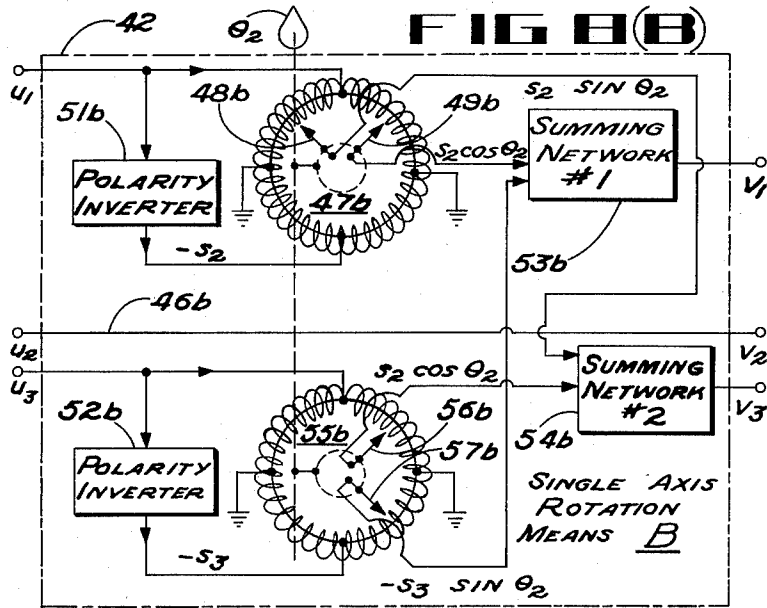
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INVENTOR.
VICTOR W. BOLIE
BY *Moody and Goldman*
ATTORNEYS

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V. W. BOLIE

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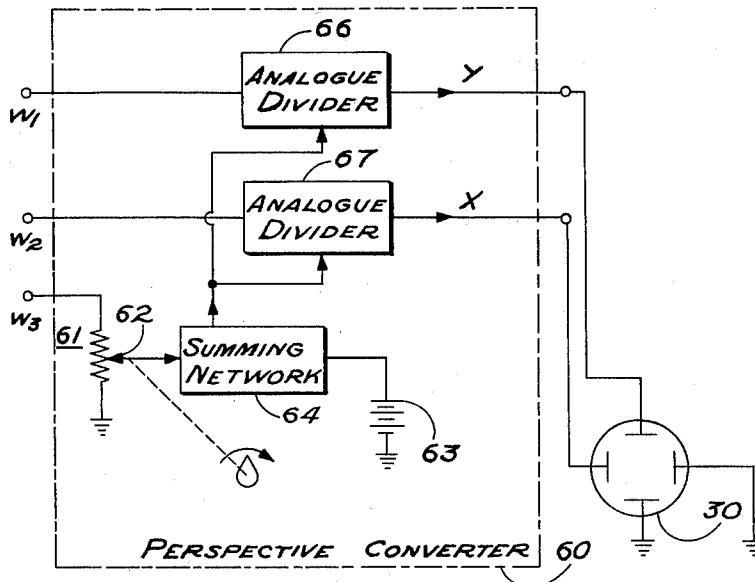


FIG 9

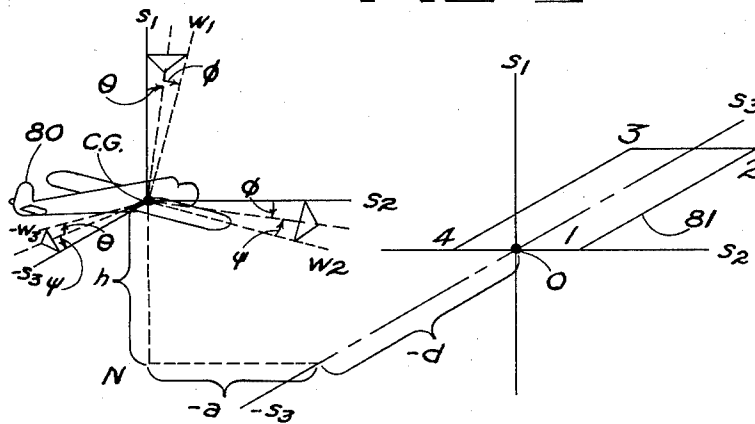


FIG 10

INVENTOR.

VICTOR W. BOLIE

BY

Moody and Goldman

ATTORNEYS

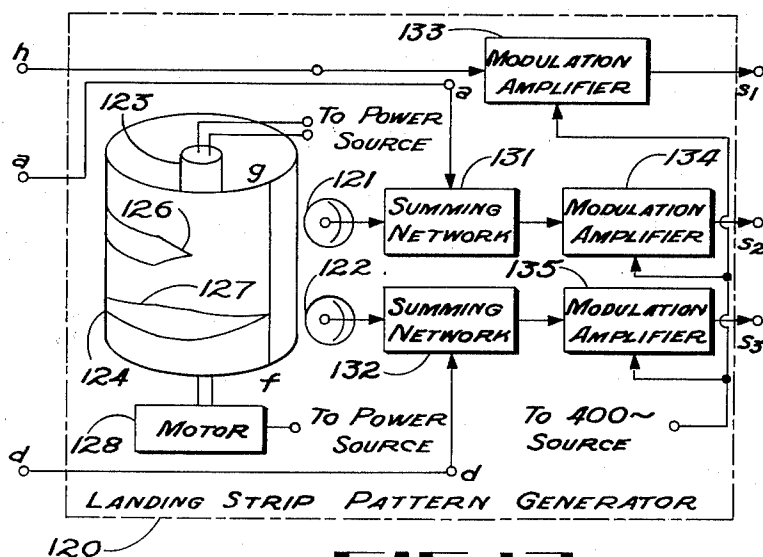
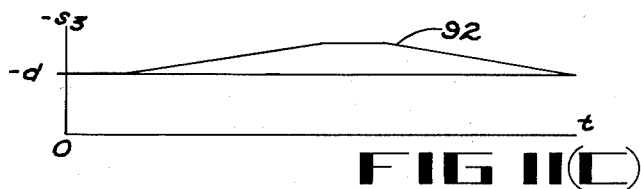
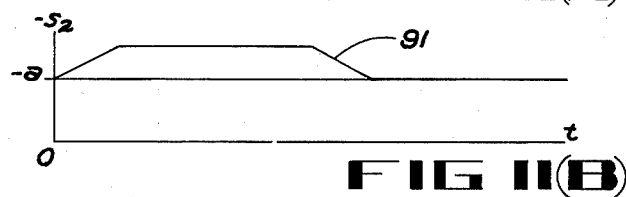
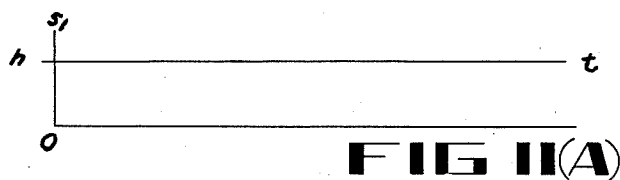
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INVENTOR.

VICTOR W. BOLIE

BY *Moody and Goldman*

ATTORNEYS

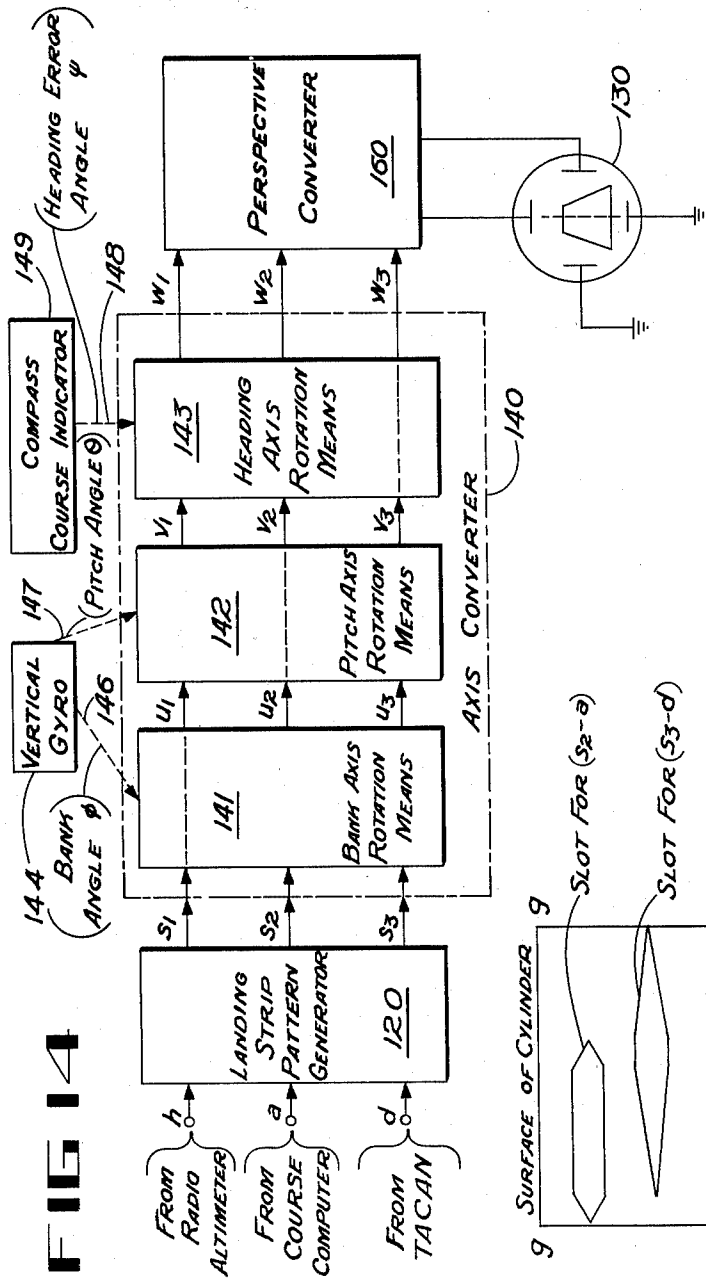
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INVENTOR.

VICTOR W. BOLIE

BY *Moody and Goldman*

ATTORNEYS

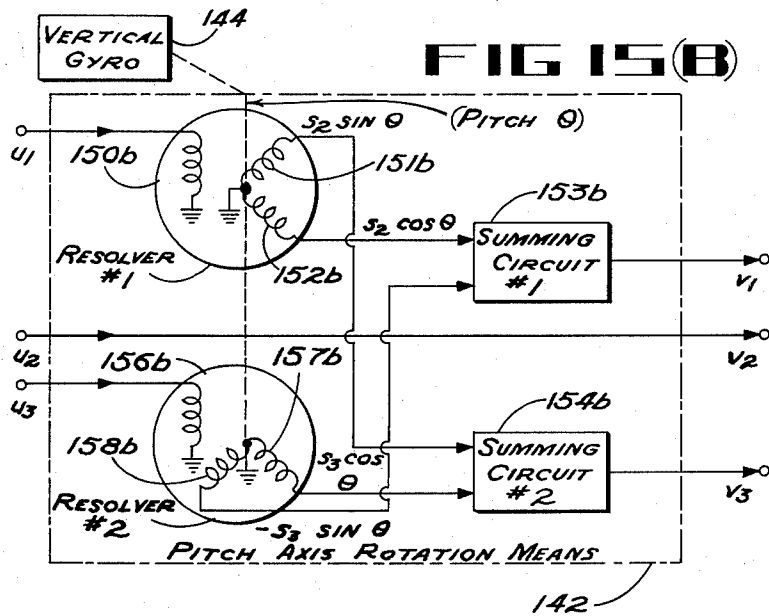
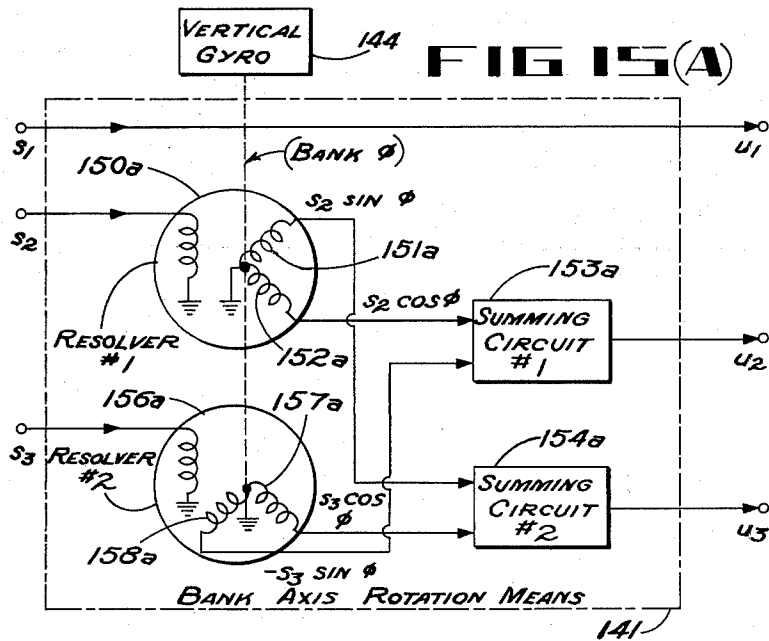
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INVENTOR.

VICTOR W. BOLIE

BY

Moody and Goldman

ATTORNEYS

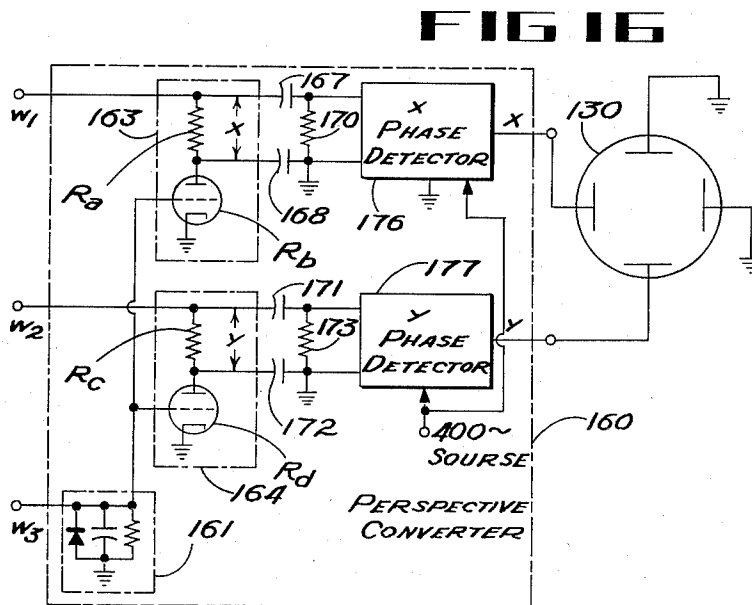
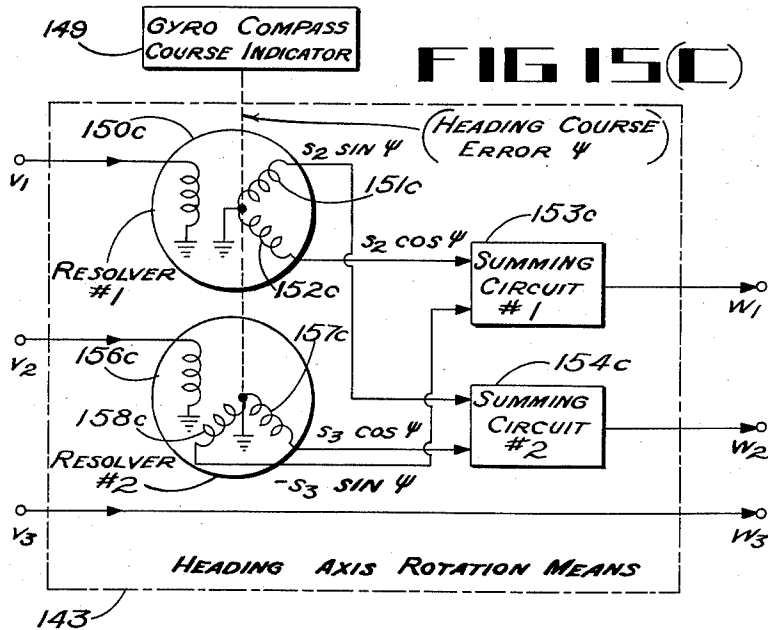
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INVENTOR.

VICTOR W. BOLIE

BY *Moody and Goldman*
ATTORNEYS

1

2,988,821

SIMULATED PERSPECTIVE DISPLAY OF AIRCRAFT LANDING STRIP ON CATHODE RAY TUBE

Victor W. Bolie, Cedar Rapids, Iowa, assignor to Collins Radio Company, Cedar Rapids, Iowa, a corporation of Iowa

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4 Claims. (Cl. 35—10.4)

This invention relates to means for perspective displaying in two dimensions a three-dimensional geometric figure simulated by electronic signals. Perspective viewing of the displayed figure can be provided from any visual angle.

Initially, the invention simulates a geometric figure three-dimensionally by having three electrical signals, each respectively representing a single dimension of movement of a fictitious generating point. Amplitude variations of the signals simultaneously act on the generating point so that it can move in any direction at any instant to generate the required figure. Therefore, each signal controls point movement along each of the three axes X, Y, or Z in the Cartesian coordinate system. Initially, the simulated object is oriented to the coordinates to enable the component signals to be generated electronically in the simplest possible manner. Hence, in the initial generation, viewing angle and perspective need not be considered.

A particular use for the invention is in visualizing an airfield runway on the face of a cathode ray tube within the cockpit of an aircraft. The invention simulates a landing strip to appear in the same perspective and with the same viewing angle as it would appear to the pilot if he were directly viewing the airstrip through the front window of the aircraft. In such case, the invention only needs information as to the point position of the aircraft from the landing strip, which can be obtained from such devices as a TACAN transceiver localizer and glide path receivers and radio altimeter. Accordingly, under blind flying conditions, a pilot can land an aircraft with much the same procedure as is done during clear weather conditions, permitting a view of the landing strip.

The invention includes a pattern generator which provides three output signals that respectively represent the three-dimensional movements of a generating point in the X, Y and Z coordinates. The pattern generator preferably generates signals representing the object when positioned most simply with respect to the coordinates. For example, a cylinder may be positioned with its axis coinciding with one of the coordinates, and then a circle appears in the plane of the remaining coordinates. A circle can be simulated by two single dimensional signals that are sine waves of the same amplitude and 90° out of phase. The third signal is a linear sawtooth function, wherein the period of a sawtooth cycle corresponds to the axial dimension of the cylinder. The rate of circular movement of the generating point is high compared to its axial movement. A lower rate of circular movement will cause the cylinder to look like a helix.

The invention further includes an axis-converter means which electronically modifies the three respective signals to alter the position of the simulated figure with respect to the X, Y and Z axes, which have their position related to the ultimate viewing angle of the object. Three adjustable inputs are provided to the axis-converter means to provide three different angles of rotation. Thus, the axis converter electronically operates upon the three respective single-dimensional signals to, in effect, permit a representation of the generated object from another required viewing angle.

A perspective-converter means in the invention receives

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the three output signals from the axis-converter means and converts them into two signals capable of acting on a generating point to create in two dimensions a picture of the initial object in perspective and from the viewing angle chosen for the axis-converter means. This generating point provides the display and can be the point of light provided by a cathode ray tube (CRT). Hence, the perspective-converter means changes the three signals from the axis-converter means into two signals which can actuate the beam of a CRT in a manner which displays the simulated pattern in perspective form at a viewing angle chosen by setting the controls of the axis-converter means.

Further objects, features and advantages of this invention will become apparent to a person skilled in the art upon further study of the specification and the accompanying drawings, in which:

FIGURE 1 illustrates a principle of perspective viewing;

FIGURE 2 illustrates three-dimensionally a helical figure;

FIGURE 3 shows the pattern in FIGURE 2 viewed axially;

FIGURES 4(A), (B), and (C) are wave-forms of three single-dimensional signals electronically representing the helix shown in FIGURES 2 and 3;

FIGURE 5 is a block diagram of a form of the invention;

FIGURE 6 is a block diagram of one type of figure pattern generator;

FIGURES 7(A), (B), and (C) illustrate axis rotation operations within the invention;

FIGURES 8(A), (B) and (C) illustrate the three component axis controlling circuits of one type of axis-converter means of the invention;

FIGURE 9 illustrates a form of perspective-converter means;

FIGURE 10 illustrates a landing strip with respect to an aircraft;

FIGURES 11(A), (B) and (C) respectively represent electronically signals simulating an airstrip viewed from the center of gravity of an aircraft, without regard to the attitude of the aircraft or the perspective of the landing strip;

FIGURE 12 illustrates an object pattern generator capable of providing signals shown in FIGURES 11(B) and (C);

FIGURE 13 illustrates a component of the apparatus of FIGURE 12;

FIGURE 14 is a block diagram of a system providing a simulated-perspective-pictorial display of an approached airstrip;

FIGURES 15(A), (B) and (C) show component single-axis rotation means for injecting the attitude of the aircraft into the display; and,

FIGURE 16 shows another type of perspective converter.

Now referring to the drawings for a more detailed discussion of the invention, FIGURE 1 represents the appearance of a distance rectangle O'M'N'P' as viewed by an eye 10 upon a plane represented by axes OW₁ and OW₂. Eye 10 is located a short distance D from the viewing plane; and rectangle O'M'N'P' is located a distance W₃ from the viewing plane W₁W₂. Thus, the rectangle appears on the viewing plane as a smaller rectangle OMNP which has its dimensions related to the original rectangle as sides of similar triangles which can be stated algebraically by the following formulas:

$$X = \frac{DW_2}{D+W_3} = \frac{W_2}{1+\left(\frac{W_3}{D}\right)} \quad (1)$$

$$Y = \frac{DW_1}{D+W_3} = \frac{W_1}{1 + \left(\frac{W_3}{D}\right)} \quad (2)$$

Although the transformation indicated by Expressions 1 and 2 is not linear orthogonal, it does exhibit some linear properties. For example, a straight line apparent in the original pattern from the direction of eye 10 will appear as a straight line in its projection on the W_1W_2 plane. In other words, it is obvious that a perspective transformation of a straight line is still a straight line although the length of the perspective segment may be altered.

The invention in effect simulates an object in the W_1W_2 plane taking into consideration the distances D and W_3 without necessarily requiring the existence of an actual object such as represented by rectangle $O'M'N'P'$.

For example, let it be assumed that it is desired to illustrate the helix shown in FIGURE 2 while maintaining flexibility in viewing angle and proportioning of the helix. The helix is first simulated electronically by three signals representing the required movement of a generating point as a function of time. This is done in its simplest manner by orienting the axis of the helix with the S_3 axis. Consequently, the generating signals represent the geometric figure viewed from its simplest angle. Viewed axially along axis S_3 , which is perpendicular to the paper in FIGURE 3, the helix appears as a circle. Thus, the generating point must move in a circle in the S_1S_2 plane and move linearly in the S_3 direction. It is well known that a circle can be generated by a Lissajous figure consisting of two sine waves equal in amplitude and 90° out of phase as illustrated in FIGURES 4(A) and 4(B). The third dimension of depth is a linear function of time which is provided by the saw-tooth signal illustrated in FIGURE 4(C). The sine waves have a frequency much higher than the repetition rate of the saw-tooth wave.

A pattern generator 20 shown in FIGURE 6 generates the signals of FIGURES 4(A), (B) and (C). It includes a sine-wave oscillator 21 which provides output signal S_1 , and a 90° phase-shaft circuit 22 which is connected to the output of oscillator 21 to provide a signal S_2 that is 90° out of phase with signal S_1 . A sawtooth generator 23 provides signal S_3 .

The form of the invention in FIGURE 5 includes a pattern generator 20, which may be of the type shown in FIGURE 6. A plurality of scalars 26, 27 and 28 are respectively connected in tandem with the outputs S_1 , S_2 and S_3 of generator 20. Each scalar is an attenuator, such as a potentiometer, which is used to adjust the level of its respective signal and controls the proportions of a simulated figure.

An axis converter 40 receives the scaled signals S_1 , S_2 and S_3 and modifies them so that the simulated figure ultimately viewed in perspective on the face of CRT 30 appears from any desired viewing angle. Axis converter 40 is comprised of three component rotation means 41, 42 and 43. Each of these rotation means controls a single degree of the three degrees of rotation necessary to obtain complete rotational control of a viewed pattern. In effect, each angle-axis rotation means provides an analogue solution of an algebraic matrix which converts a point position from a first set of three-dimensional axes to another set having a common axis of rotation. Such single-axis conversion is illustrated in each of FIGURES 7(A), (B) and (C). Thus, FIGURE 7(A) shows geometrically a set of axes S_1 , S_2 and $-S_3$ rotated about axis S_1 by an angle θ_1 to a new position which corresponds to a new set of axes U_1 , U_2 and $-U_3$. Note that axis U_1 and axis S_1 are common to both coordinate systems. The result of the transformation is that any signal represented in the coordinates of S_1 , S_2 and S_3 is, after the single-axis transformation, represented in the coordinates of U_1 , U_2 and U_3 . Second single-axis rotation means 42 takes the new set of axes U_1 , U_2 and U_3 and rotates them

by an angle θ_2 about axis U_2 to provide a new set of coordinates V_1 , V_2 and $-V_3$ as shown in FIGURE 7(B).

The third single-axis rotation means 43 provides a rotation about the third axis V_3 by an angle θ_3 to provide the final transformation to the coordinates W_1 , W_2 and $-W_3$. Thus, the coordinate system represented by axes W_1 , W_2 and W_3 can be shifted by three degrees of rotational freedom with respect to axes S_1 , S_2 and S_3 . Coordinate conversion is well known mathematically, and can be accomplished by solving the following system of equations. The conversion shown in FIGURE 7(A) is:

$$U_1 = S_1 \quad (3)$$

$$U_2 = S_2 \cos \theta_1 + S_3 \sin \theta_1 \quad (4)$$

$$U_3 = -S_2 \sin \theta_1 + S_3 \cos \theta_1 \quad (5)$$

The following conversion by rotation means 42 is given mathematically by the following equations:

$$V_1 = U_1 \cos \theta_2 + U_3 \sin \theta_2 \quad (6)$$

$$V_2 = U_2 \quad (7)$$

$$V_3 = -U_1 \sin \theta_2 + U_3 \cos \theta_2 \quad (8)$$

And the last single-axis conversion provided by means 43 is given by the expressions:

$$W_1 = V_1 \cos \theta_3 + V_2 \sin \theta_3 \quad (9)$$

$$W_2 = -V_1 \sin \theta_3 + V_2 \cos \theta_3 \quad (10)$$

$$W_3 = V_3 \quad (11)$$

One form of circuitry for obtaining rotation means 41, 42 and 43 is illustrated by FIGURES 8(A), (B) and (C) respectively. Since direct-current components are presumed involved, such as illustrated for the signals of FIGURES 4(A), (B) and (C), the respective signals must be handled by direct-current amplifiers and devices. Single axis-rotation means 41 in FIGURE 8(A) receives signals S_1 , S_2 and S_3 at its input terminals. Note from Equation 3 above that its output signal U_1 is directly provided by its input signal S_1 . Thus, a through connection is provided by lead 46a.

FIGURES 8(B) and 8(C) are constructed similarly to FIGURE 8(A) except that the signal inputs and outputs are transposed as shown. Thus, a through connection is provided between signals U_2 and V_2 in means 42; while a through connection is provided between signals V_3 and W_3 in rotation means 43, as is also illustrated by dotted lines within the respective rotation means in FIGURE 5.

A pair of resistor-type resolvers 47 and 55 are used to obtain trigonometric operation on the direct-current type signals in each of means 41, 42 and 43. Such resistor-type resolvers are well known in the art and are described in "Introduction to Electronic Analogue Computers" by C. A. A. Wass, pages 131-137. Induction type resolvers can also be used provided that the signals are modulated onto a carrier signal as is done in another embodiment described below. Each resistance-type resolver includes a pair of taps 48-49 or 56-57. Each pair of taps is mechanically rotatable as a unit. Each tap picks off a voltage which varies as a trigonometric function of its rotational position. The taps are fixed relative to each other at a mechanical angle of 90° , so that one tap provides a sine-function output while another tap provides a cosine-function output of the shaft angle. Since negative signals are required by resistor-type resolvers to provide complete trigonometric freedom, a pair of polarity inverters 51 and 52 respectively receive the signals directed to the resolvers. The inverted polarity signals are connected to opposite sides of the respective resolvers so that trigonometric functions can be obtained for 360° of variation of angle θ . A pair of summing networks 53 and 54 add respective resolver outputs to provide the analogue solutions of Equations 4 and 5 in FIGURE 8(A), Equations 6 and 8 in FIGURE 8(B), and Equations 9 and 10 in FIGURE 7(C). Thus, the summing networks 53(a) and 54(a) in FIGURE 8(A) provide signals U_2 and U_3 ; summing networks 53(b) and 54(b) in FIGURE 8(B) provide outputs V_1 and V_3 ; and

summing networks 53(c) and 54(c) in FIGURE 8(C) provide signals W_1 and W_2 .

The axis-converter output signals W_1 , W_2 and W_3 are provided as inputs to a perspective converter 60 in FIGURE 5 which is shown in more detail in FIGURE 9. Perspective converter 60 provides an analogue solution of Equations 1 and 2 above and converts the respective three-dimensional signals W_1 , W_2 and W_3 into two-dimensional signals X and Y having perspective characteristics. In FIGURE 9 a potentiometer 61 receives signal W_3 . Its tap 62 is set to provide a signal equal to W_3/D . If the potentiometer resistance varies uniformly with length, tap movement is related to D (distance of eye to viewing area) by a factor of $1/D$ and may be calibrated accordingly where D is adjustable. If one volt is taken as unity for an analogue computation of Equations 1 and 2, a battery 63 is provided which provides one volt that is added to the output of tap 62 by a summing network 64 to provide an output of

$$1 + \frac{W_3}{D}$$

Analogue dividers 66 and 67 respectively receive the inputs W_1 and W_2 and divide each of them by the output of summing network 64 to provide signals X and Y as outputs of perspective converter 60.

Signals X and Y are provided to the horizontal and vertical plates respectively of CRT 30 to generate a perspective view of the simulated pattern generated by pattern generator 20 and angularly positioned by axis converter 40.

Accordingly, where helix signals generated by the device in FIGURE 6 are used, a helix appears in perspective on the face of CRT 30 with any viewing angle selected by rotating the knobs of axis converter 40.

Object pattern generator 20, which produces the signals for a helix, can also be made to produce signals to represent a cylinder. This is done by making the frequency of its output signals S_1 and S_2 very high with respect to the repetition rate of the sawtooth wave signal S_3 . In such case, the lines of the helix become so close together that they appear as a continuous surface.

Any type of geometric pattern or object can be made to appear perspective on the face of CRT 30 by designing object pattern generator 20 to generate three-dimensional signals with respect to the three directions of a coordinate system, with the simplest arrangement of signals generally being preferable.

Perspective is useful in judging depth (distance perpendicular to the viewing surface) of a two-dimensional display. Thus, in the case of landing an aircraft, the pilot views a landing strip as he approaches it and judges distance and angle of descent by the apparent size and perspective shape of the landing field, as well as other objects about the landing field.

The invention teaches how the geometric configuration of a landing strip can be simulated on the face of a CRT located in an airplane cockpit so that the landing strip is presented in perspective and position in much the same manner as it would appear to a pilot looking through his cockpit window while landing the aircraft. Such a CRT presentation can enable a blind landing during zero visibility conditions.

A situation is illustrated in FIGURE 10 of an aircraft 80 flying with respect to an airstrip 81. The position of the aircraft with respect to the landing strip can be illustrated by means of a set of three-dimensional coordinates S_1 , S_2 and S_3 wherein coordinate S_3 passes down the center line of the field, coordinate S_2 is horizontal and perpendicular to coordinate S_3 along the closest edge of the airstrip, and coordinate S_1 is vertical passing through the point O of intersection of S_2 and S_3 . The position of the aircraft in this coordinate system is given by the position of its center of gravity CG, which has the posi-

tion h , $-a$, $-d$; where h is the altitude of the aircraft, $-a$ is the distance of the aircraft from point O projected on coordinate S_2 , and $-d$ is the distance of the aircraft projected on coordinate S_3 .

The information of the location of CG with respect to point O is made available by means of sources such as distance measuring equipment (TACAN) and a radio altimeter. Many other ways are possible for determining various of the coordinate positions of point CG. Thus, localizer radio information can be used to compute distance a , or VOR bearing information in conjunction with DME determined distance d can be used to compute distance a . Furthermore, this information can also be obtained from a ground radar installation and be continuously transmitted to the aircraft by means of data communications.

Thus, it is apparent that an aircraft can have available to it the coordinates h , a , and d of point CG in the coordinate system S_1 , S_2 and S_3 . However, this information is insufficient from the viewpoint of the pilot, because it does not consider the attitude of the aircraft. This information may be analogized to that obtainable from an upright person positioned at the center of gravity looking at the field. However, the pilot is seated in a relatively fixed position with respect to the aircraft and has the attitude of the aircraft when looking forward through the cockpit window. The portion of the window through which he views the landing strip provides him with the relative position of the strip with respect to the aircraft. In other words, the pilot views the landing strip with respect to a set of coordinates that are fixed with respect to the aircraft. These coordinates are designated W_1 , W_2 and W_3 ; in which W_3 passes along the fuselage axis of the aircraft, W_2 passes through CG perpendicular to coordinate W_3 and symmetrically through the wings of the aircraft, and coordinate W_1 passes through CG perpendicular to both coordinates W_2 and W_3 . Hence, the position of the airstrip with respect to the aircraft is determined by the pilot (often subconsciously) utilizing both of these coordinate systems. The three-dimensional angle between the coordinate systems is a function of the pitch θ , bank ϕ , and heading Ψ of the aircraft as illustrated in FIGURE 10. The pitch and bank angles θ and ϕ are obtained from a vertical gyro located on the aircraft, and the heading information is obtained from the aircraft compass, since the direction of the airstrip center line S_3 is known. The information θ , ϕ , and Ψ causes the landing strip to be viewed by the pilot through a particular portion of the window. That is, the landing strip will appear to the left, to the right, above or below the center of the window, according to the attitude of the aircraft.

The invention utilizes the two types of information (h , a , d and θ , ϕ , Ψ) to stimulate a landing strip in perspective and with the proper relative position on the face of a CRT located in the cockpit to provide a view of the landing strip in much the same manner that it would appear to the pilot looking through the front window of his aircraft. Thus, when the airfield is not visible, such as during fog or low ceiling, the pilot can guide the aircraft to a landing by viewing the CRT.

FIGURE 14 illustrates a form of the invention providing this type of presentation on the face of a CRT 130.

In the prior embodiment of FIGURE 5, the viewer was always presumed in an upright position and only the coordinates S_1 , S_2 and S_3 were necessary about which to choose a viewing angle. There, the desired viewing angle was known or was determinable by adjustment until the object appeared with the required viewing angle. This cannot be done in the case of the airplane landing strip, since the position of the strip is unknown to the viewer until he sees it on the face of the CRT. However, the required viewing angle is determined by the attitude coordinates relative to the aircraft position coordinates S_1 , S_2 and S_3 . Since the viewing angle in the coordinates

S_1 , S_2 and S_3 is immediately known, and is a relatively simple type of information, it can be directly provided to a pattern generator 120 so that the signals representing the airstrip contain this viewing-angle information and are signals S_1 , S_2 and S_3 in FIGURE 14. Perspective is not considered by the landing-strip pattern generator 120. An example of pattern generator 120 is given in FIGURE 12. Note that altitude information h is passed directly through generator 120 and accordingly is not altered by it, although it is modulated onto a carrier. The landing strip pattern signals are generated photoelectrically by a pair of photoelectric cells 121 and 122 which are separated from an elongated light source 123 by a cylindrical opaque card 124, which has light openings 126 and 127. Cylinder 124 is rotated by a motor 128. The shapes of openings 126 and 127 of core 124 are shown in FIGURE 13. It is well-known that the intensity of the signal increases as the width of the slot increases. Accordingly, the output from slot 126 will vary with signal 91 in FIGURE 11(B); and the signal generated from slot 127 will vary with signal 92 in FIGURE 11(C). The variation and timing of signals 91 and 92 will move a fictitious generating point to inscribe a rectangle that simulates a runway or landing strip. Motor 128 rotates at sufficient speed (above 16 revolutions per second) so that the generating point outlines the picture of the landing strip at a fast rate compared to movement of the aircraft and the persistence of the human eye. Since the position of the aircraft is not presumed to substantially change during the period of a single inscription of a landing strip pattern, the position signals h , a , d shown in FIGURES 11(A), (B) and (C) are steady D.C. signals. The D.C. value of signal 91 represents distance $-a$ in FIGURE 11(B). Similarly, the D.C. value of signal 92 in FIGURE 11(C) represents distance $-d$. Consequently, the effect of the position of the CG in coordinates S_1 , S_2 and S_3 effects the direct-current components of the signals and can be easily superimposed upon the alternating current components generated by rotation of cylinder 124. This is done in FIGURE 12 by the respective summing networks 131 and 132.

In practice, it is generally easier to handle information modulated on an A.C. carrier than it is to directly handle direct-current information. Accordingly, modulators 133, 134 and 135 are provided in FIGURE 12 to respectively modulate signals S_1 , S_2 and S_3 onto a 400 cycle-per-second carrier. Such modulators are well-known in the art and are provided, for example, by choppers. Hence, alternating-current amplifiers can be utilized as well as alternating-current trigonometric computers such as well-known resolvers.

Again referring to FIGURE 14, an axis converter 140 (basically similar to axis converter 40 previously described) receives the respective outputs S_1 , S_2 and S_3 from landing strip pattern generator 120. Converter 140 is comprised of three single-axis rotation means 141, 142 and 143 of the same type specified in FIGURE 5, except that the system of FIGURE 14 handles alternating-current modulated information instead of direct-current information.

Each of the three rotation means in FIGURE 14 is operated by an aircraft-attitude sensing device. Accordingly, a vertical gyro 144 provides a bank-angle input 146 to rotation means 141, and provides a pitch-angle input 147 to second rotation means 142. Similarly, a compass course indicator provides a heading-error angle input 148 to rotation means 143.

Circuitry comprising rotation means 141, 142, and 143 is shown respectively in FIGURES 15(A), 15(B) and 15(C) which respectively solve the three groups of Equations 3 through 11 given above. Each rotation means includes a pair of resolvers 150 and 156 which have their rotors coupled to the respective angle input shown in FIGURE 14. Each resolver includes two rotor windings

displaced by 90° so that one provides an output that is a function of the sine of its shaft angle, while the other winding provides a cosine signal output. A pair of summing circuits 153 and 154 are also included within each rotation means, wherein summing means 153 has its inputs connected to the outputs of rotor windings 152 and 158, and the signal inputs to summing circuit 154 are connected to rotor windings 151 and 157. Thus, rotation means 141 solves Equations 4 and 5. Similarly connected components are shown in FIGURE 15(B) for rotation means 142 to provide the required solutions to Equations 6 and 8, and FIGURE 15(C) illustrates similar connections for rotation means 143 to solve Equations 9 and 10.

The outputs W_1 , W_2 and W_3 from axis converter 140 are provided to a perspective converter 160, shown in FIGURE 16, which translates the nonperspective three-dimensional signals into perspective two-dimensional signals. Perspective converter 160 operates upon its input signals in the same manner as perspective converter 60 in FIGURE 9, except that the signals provided to converter 160 are modulated on an alternating-current carrier. Amplitude-modulation detector 161 receives signal W_3 and detects it to provide an output proportional to the modulation information of signal W_3 . Each of the signals W_1 and W_2 is connected to a respective computer circuit 163 and 164 which comprises a triode R_b or R_d having its cathode connected to ground and having a resistor R_a or R_c connected in series with its plate. The other end of resistor R_a of circuit 163 receives signal W_1 .

Similarly, the opposite end of resistor R_c of circuit 164 receives signal W_2 . The grids of both tubes R_b and R_d are connected to the output of detector 161.

Computer circuit 163 provides an analogue solution to the following equation:

$$X = \frac{R_a W_1}{R_a + R_b} \quad (12)$$

Similarly, circuit 164 provides an analogue solution to the equation:

$$Y = \frac{R_c W_2}{R_c + R_d} \quad (13)$$

The above Equations 12 and 13 are obtained by applying Kirkoff's law to the respective circuits 163 and 164. The tube resistance R_b and R_d is thus a function of signal W_3 , and the resistance of resistors R_a and R_c is determined according to the distance of the pilot's eyes from the viewing face of CRT 130. Equation 12 may be compared to Equation 1 above to see that circuit 163 solves Equation 1. Similarly, Equation 13 may be compared with Equation 2 above to show that circuit 164 solves the respective requirements of Equation 2.

The outputs X and Y from circuits 163 and 164 are unsymmetrical with respect to ground potential. Thus, means is provided to reduce the A.C. axis of the signal to ground level. This can be provided by transformer means or capacitor means. The latter is shown in FIGURE 16, wherein a pair of blocking capacitors 167 and 168 couple an output resistor 170 across resistor R_a in circuit 163, with one end of resistor 170 being grounded. Hence, the X signal across resistor 170 has its A.C. axis reduced to ground level.

In a similar manner, a resistor 173 having one end grounded is coupled by a pair of blocking capacitors 171 and 172 to opposite ends of resistor R_c of circuit 164.

A phase detector 176 is connected across resistor 170 to detect the signal X amplitude modulation on the carrier and provide an output polarity depending upon the polarity of the carrier.

Second phase detector 177 receives the output of resistor 173 and similarly amplitude detects signal Y while correlating phase with polarity in the well-known manner. Each phase detector 176 and 177 may be of the

type described in "Principles of Radar," M.I.T., published in 1946, page 12-36, FIGURE 32. Accordingly, the horizontal and vertical plates respectively of a CRT 130 are connected to the two signals X and Y to provide a perspective display of the approached airstrip, at a position on the face of the scope dependent on the position of the airfield with respect to the attitude of the aircraft. Thus, if the airfield appears at the lower right-hand side of the CRT, then the landing strip actually is in that direction from the aircraft. A vertical line may be drawn bisecting the face of the scope to indicate when the aircraft is lined up with the field, which will occur when the scope line centers down the viewed runway. Furthermore, an artificial horizon can also be provided on the face of the scope to provide the aircraft with pitch and roll information. The provision of an artificial horizon is well-known in the art and is not described herein, and such artificial horizon does not require any perspective display.

In the general case of the invention in FIGURE 5, there may be instances where three-dimensional control of the viewing angle is not necessary. In such case, two-dimensional control can be obtained by having only two single-axis rotation means instead of three within axis converter 40. Similarly, if only a single degree of rotational control is required of the viewing angle, only one single-axis rotation means need be used for axis converter 40, thus simplifying its over-all structure. The scaling attenuators 26, 27 and 28 can be used to adjust the respective dimensions of the perspective pattern viewed on scope 30. By having the scaling attenuators operate upon the respective signals before axis adjustment, distortion is prevented.

Although this invention has been described with respect to particular embodiments thereof, it is not to be so limited as changes and modifications may be made therein which are within the full intended scope of the invention as defined by the appended claims.

I claim:

1. Display means for perspectively displaying a pattern, comprising a pattern generator providing three signals representing the movement of a point in respectively different directions, with said point circumscribing said pattern, three scalars respectively receiving the signals of said generator to adjust their proportions, an axis converter means receiving the outputs of said scalars, said axis converter means respectively rotating the coordinates of said signals to rotate said pattern about at least a single axis, a perspective converter receiving the output signals of said axis converter means, said perspective converter including plural computers, each computer electronically multiplying one of said signals by a factor D and electronically dividing their product by the sum of D and a common one of said signals to provide a computed signal, and point-scanning means receiving the signal of said computers to move a point accordingly and present a perspective display of said pattern.

2. Perspective converter means for translating first, second and third signals respectively representing point-movement in three dimensions to describe a required pattern, comprising first and second analogue dividers including numerator inputs receiving said first and second signals, a unit potential source, and resistor means receiving said third signal, a summing network connected to said unit source and said resistor means to provide an output representing their sum, denominator inputs of each of said analogue dividers being connected to the output of said summing network, the outputs of said pair of analogue dividers representing point-movement required to describe said pattern perspectively in two dimensions.

3. Landing-strip pattern generating means for exhibiting perspectively on a cathode ray tube a simulated landing strip as it would appear from an aircraft, comprising means for generating first and second signals respec-

tively representing longitudinal and transverse dimensional point-motions that describe a rectangle simulating said landing strip, means providing signals proportional to the altitude, distance, and a transverse displacement of said aircraft with respect to said landing strip, means for summing said generated transverse signal with said transverse-displacement signal, and means for summing said distance signal with said generated longitudinal signal, signals S_1 , S_2 and S_3 being provided respectively by the outputs of said summing networks and said altitude signal, axis converter means for translating the axis of said pattern represented by said three signals into output signals W_1 , W_2 and W_3 , said axis converter having three angular inputs ϕ , θ , and Ψ , vertical gyro means providing a bank input ϕ and a pitch input θ , and compass means providing a heading input Ψ , perspective converter means for receiving said axis converter means output signals W_1 , W_2 and W_3 and providing respective point-motion signals X and Y for moving a point source to describe said pattern in two-dimensional perspective presentation, said perspective converter means including computer means for computing

$$X = \frac{W_1}{1 + \frac{W_3}{D}}$$

and

$$Y = \frac{W_2}{1 + \frac{W_3}{D}}$$

where D represents the distance between the viewing distance to the perspective pattern.

4. A landing-strip pattern display means as defined in claim 3 including means for modulating onto a carrier frequency the signals S_1 , S_2 and S_3 , said axis converter comprising three single-axis rotation conversion means connected in tandem, each single-axis conversion means having first, second and third input terminals and first, second and third output terminals, with one of said single-axis conversion means having a through-connection between its first input and output terminals, another conversion means having a through-connection between its second input and output terminals, and the last conversion means having a through-connection between its third input and output terminals; each single-axis conversion means including an angular input, a pair of resolvers, with their inputs respectively connected to the remaining input terminals of the respective single-axis conversion means, each resolver providing a pair of outputs, one being the sine of its angular input and the other being its cosine, a pair of summing circuits, each having a pair of inputs, with one summing circuit having one input connected to the sine output of one of said resolvers and its other input connected to the cosine output of the other of said resolvers, the inputs to said other summing circuit being connected to the remaining outputs of said resolvers, and the outputs of said summing networks connected respectively to the remaining output terminals of the respective axis conversion means.

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