

"Electronic and Optically Generated Aircraft Displays" by J.M. Ketchel and L.L. Jenny, May 1968, Matrix Corporation, N00014-67-C-0517, JANAR 680505, Unclassified, AD 684-849


APPENDIX TO ACTIVISION'S NOTICE OF PRIOR ART
"Simulation at the Manned Spacecraft Center" by John McLeod, Simulation, Vol. 7, No. 2, August 1966, pp.54-62

"Graphic I - A Remote Graphical Display Console System" by William H. Ninke, Bell Telephone Laboratories, Inc., Fall Joint Computer Conference, 1965

"Graphic Systems for Computers" by Christopher F. Smith, Computers and Automation, November 1965, pp.14-16

"CRT Displays for Simulation" by G.A. Guy, Simulation, December 1965, pp.407-412


"Sketchpad...A Man-Machine Graphical Communication System" by Ivan E. Sutherland, Simulation, May 1964, pp.R3-R14

"Sketchpad III...A Computer Program for Drawing in Three Dimensions" by Timothy E. Johnson, Simulation, June 1964, pp.R3-R8

"Computer Generated Three-Dimensional Movies" by A. Michael Noll, Computers and Automation, November 1965, pp.20-23

-10-

APPENDIX TO ACTIVISION'S NOTICE OF PRIOR ART


"Grail/GPSS: Graphic On-Line Modeling" by J.P. Haverty, June 1968, The Rand Corporation, Santa Monica, California


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Digital Computer Newsletter, Vol 6, No. 3, July 1954, pp.143-144

Chicago Sunday Tribune, Vo. 113, No. 26, June 27, 1954, p.1

Galaxy, Vol. 21, No. 6, August 1963, p.4

APPENDIX TO ACTIVISION'S NOTICE OF PRIOR ART

Journal of the Association for Computing Machinery, Vol. 1, No. 4, October 1954, pp.177-182


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PROOF OF SERVICE BY HAND DELIVERY

I declare that:

I am employed in the County of San Francisco, California. I am over the age of eighteen (18) years and not a party to the within cause, my business address is:
Three Embarcadero Center, 7th Floor, San Francisco, California 94111.

On September 7, 1984, I served the within
ACTIVISION, INC.'S NOTICE OF PRIOR ART AND APPENDIX THEREETO

by personally delivering a copy to:

J. Thomas Rosch, Esq.
Robert L. Ebe, Esq.
McCutchen, Doyle Brown & Enersen
Three Embarcadero Center, 28th Floor
San Francisco, CA 94111

I declare under penalty of perjury that the foregoing
is true and correct.

[Signature]
DENNIS HALL
PROOF OF SERVICE BY MAIL

I declare that:

I am employed in the County of San Francisco, California I am over the age of eighteen (18) years and not a party to the within cause. My business address is Three Embarcadero Center, Seventh Floor, San Francisco, California 94111.

On September 7, 1984, I served the

within

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by placing a true copy thereof enclosed in a sealed envelope, with postage thereon fully prepaid, by air mail, Federal Express addressed as follows:

James T. Williams, Esq.
NEUMAN, WILLIAMS, ANDERSON & OLSON
77 W. Washington Street
Chicago, IL 60602

I, Cheryl Leger, declare under penalty of perjury that the foregoing is true and correct.

Executed on September 7, 1984, at San Francisco, California.

Cheryl Leger
Inventor:
Paul H. Kirchner,
by John E. Carr
His Attorney.
ELECTRONIC CONTACT ANALOG SIMULATOR

Inventor: Paul H. Kirchner,
by Alan E. Lamp
His Attorney.
tween the nose of the aircraft and the direction of one
set of the parallel grid lines fixed with respect to north.
Let \((r)\) be the distance measured in the ground plane
and perpendicularly to a ground line AB, from the observer
(the aircraft) to AB.

Let \(d\) be the spacing between parallel lines of the pattern.
The intersection of \(d\) indicates that a particular line
such as AB is the nth line to the left of the point directly
under the observer or aircraft.

Let \(h\) be the height or altitude of the aircraft above ground.
Let \(a\) be the acute angle in the perspective view of the
aircraft to AB.

Turning now to FIGURE 2, it should be appreciated that
the scene considered consists of a single line, called
AB, plus the horizon. The top portion of FIGURE 2
depicts an entire situation (observer, glass and scene) in
plan view or top view looking perpendicular to the
ground. At the right side of the figure, the entire situation
is shown in profile view or side view. These views are
used to construct a picture on the glass, called the
Front Perspective View.

The observer’s eye is at point O. The glass, represented
by PP (for picture plane) in the figure, is edgewise in
the side view, and coincides with the paper in the front
view. In the top view, the ground plane coincides with
the paper. The glass is considered to be in an erect
position directly in front of the observer, and the point O
is the point on the glass directly in front of the observer’s
eye. The line OO’, therefore, is perpendicular to the
glass and parallel to the front-to-back axis of the aircraft.

In the front view this line is seen endwise at the point O’
in the glass.

The horizon cannot be shown in the top view or side
view, since it is at infinite distance, but its position in the
front view can be determined.

The aircraft is assumed to have a positive (nose up)
pitch angle \(\phi\). To look at the horizon, the observer must
lower his line-of-sight an angle \(\phi\) from the straight-ahead
position through O’. His line-of-sight now pierces the
glass a distance \(p\) tan \(\phi\) below the point O’, where \(p\) is
the distance from O to O’, the shortest distance from his
eye to the glass. All the points on the horizon, when
transferred to the line-of-sight into the glass, form the line
labeled Horizon in the front view, a distance \(p\) tan \(\phi\)
below the point O’.

The line AB is a line along the ground. Therefore, in
the side view, it appears to have a downward tilt \(\phi\).
The ground surface is seen edgewise in the side view, and
is parallel to the line-of-sight from the observer to the horizon
since the ground surface contains the horizon an
infinite distance away. The perpendicular distance from the
observer to the ground plane is \(h\), the altitude of the aircraft.
The position of the line AB on the surface of the
ground is defined by a distance and an angle, both
shown in the top view. The distance is \(r\) which should,
for the time being, be regarded as a single symbol. This
distance is measured from the point on the ground beneath
the observer, perpendicular to the line AB. The angle \(\theta\)
is the difference between the bearing of AB and the heading
of the aircraft.

The position of the picture of AB can be determined by
locating two points on the line. The points chosen are
the points A and B. Point B is where AB appears to
intersect the horizon. Point B is an infinite distance from
the observer. The line-of-sight to point B is thus parallel
to AB. The spot where this line-of-sight pierces the glass
is point B’ in the picture. Its horizontal distance from
point O’ is found, from the top view, to be
\[
p = \frac{\tan \theta}{\cos \phi}
\]
The horizon has already been located.

If the glass and the line AB are extended far enough,
AB will pierce the glass at point A. The line-of-sight to A
also pierces the glass at A. The horizontal distance, in
the picture, from A to B is seen in the top view to be
\[
r = \frac{\tan \phi}{\cos \theta}
\]
and the side view shows the vertical distance to be \(h/\cos \phi\).

The angle \(\phi\) is defined as in FIGURE 2 and its tangent
is expressed as:
\[
\tan \phi = \frac{n/\cos \theta - A \tan \theta}{\tan \theta}
\]
\[
= \frac{n/\cos \theta - \sin \phi \tan \theta}{\cos \phi}
\]
\[
(1)
\]
An arbitrary point on the line AB in the picture is defined
by X and Y, the horizontal and vertical distances from
point B. Since this point is on the line AB:
\[
X = Y \tan \alpha
\]
The deflection voltages which deflect a spot on a cathode
ray tube from B to the point X, Y, are \(KX\) and \(KY\),
where K is the deflection factor of the display tube.

Multiplying both sides of the above equation by K,
Equation 2 is obtained:
\[
KX = KY \tan \alpha
\]
The display is adjusted so that point O’ is the location of
the spot when no deflection voltages are applied. Then
the total deflection voltage, \(V_x\) and \(V_y\), must include the
bias voltages to position the spot at B when X and Y are
zero.

Let \(X_0\) and \(Y_0\) be the horizontal and vertical distances
from O’ to B. Then:
\[
V_x = KX + KX_0\quad \text{and} \quad V_y = KY + KY_0
\]
\[
(4)
\]
where
\[
X_0 = -p \tan \theta \quad \text{and} \quad Y_0 = -p \tan \phi
\]
\[
(5)
\]
from FIGURE 2.

Substituting the expressions for \(X_0\) and \(Y_0\) we obtain:
\[
V_x = KX - Kp \tan \theta \quad \cos \phi
\]
\[
(6)
\]
\[
V_y = KY + Kp \tan \phi
\]
\[
(7)
\]
Substitute for \(KX\) the expression: \(KY \tan \alpha\)
Then:
\[
V_x = KY \tan \alpha - Kp \tan \theta \quad \cos \phi
\]
\[
(8)
\]
For \(tan \alpha\), substitute
\[
\frac{n/\cos \phi}{\cos \theta} = \frac{\tan \phi}{\cos \theta}
\]
\[
(9)
\]
To trace AB on the display, the distance \(Y\) is started at
zero and increased uniformly with the time to the limit of
the display. Both deflection voltages \(V_x\) and \(V_y\) are
derived from the time-varying quantity \(Y\).

FIGURES 3 and 4 illustrate the changes in the display
resulting from instantaneous velocities \(v_x\) and \(v_y\) where \(v_x\)
represents the forward component of ground speed, and
\(v_y\) represents the sideward component of ground speed.

In a small interval of time \(dt\) the air craft moves forward
in FIGURE 3 a distance \(v_x dt\). To an observer in the
aircraft, a feature on the ground appears to move back a
distance \(v_y dt\). The apparent change in the location of
the diagonal line AB is that component of its motion which is
70
crosswise to its direction, \(v_y dt \sin \phi\). The other component
of the motion is along the direction of the line and results
in no apparent change in the line.

Similarly, the sideward motion of the aircraft is \(v_x dt\)
to the right in FIGURE 4, of the line \(y/v\) to the left. The
component perpendicular to the line is \(v_y dt \cos \phi\).
These two motions are changes in the distance designated \( n r \). The motion \( \frac{\partial r}{\partial t} \sin \theta \) is in a direction so as to decrease \( n r \), while the motion \( \frac{\partial v_r}{\partial t} \cos \theta \) increases \( n r \). If \( d(nr) \) is the increase in \( nr \) in time \( dt \), then:

\[
d(nr) = v_r \cos \theta \; dt - v \sin \theta \; dt
\]

At this point in the specification it is necessary to expand the interpretation of \( nr \). The line \( AB \) is one of a family of parallel lines, with uniform spacing \( r \). If the symbol \( nr \) is now interpreted as the product of \( n \) times \( r \), \( n \) represents the number of intervals \( r \) contained in the distance \( nr \).

Since \( r \) is a constant, it can be removed from the differential above, and we can write:

\[
rdm = v_r \cos \theta \; dt - v \sin \theta \; dt
\]

Dividing both sides by \( rd \),

\[
\frac{dn}{dt} = \frac{1}{r} (v_r \cos \theta - v \sin \theta)
\]

The pitch angle \( \phi \) and aircraft heading \( \theta \) thus are utilized according to the invention in generating the display. The altitude \( h \) with the speed components and roll angle are also utilized. Since almost all modern aircraft contain an altimeter, a speed indicator, a compass, and a device to determine pitch and roll attitude, conventional methods for generating these quantities are employed in practicing the invention. The trigonometric functions of the angles derived in the invention may be readily derived by function potentiometers or other equally suitable devices.

It will now be evident that all attitudes and motions of the aircraft can be simulated as follows:

1. **Turn, vary \( \theta \)**
2. **Pitch, vary \( \phi \)**
3. **Roll, rotate picture by means of a coordinate rotator.**
4. **Forward motion and sideward motion, vary \( n \).**
5. **Vertical motion, vary \( h \).**

Turning from the mathematical derivation of the energizing potentials which must be supplied to the deflection plates of the cathode ray tube, reference to FIGURE 5 will now be made.

In this figure, the numeral 2 has been used to indicate generally the block diagram of the circuitry and components employed in producing deflection potentials. In the lefthand portion of the diagram, the numeral 3 has been used to identify a conventional 2400 p.p.s. oscillator. The oscillator 3 may take the form of a conventional sine wave generator.

The output wave form from the oscillator 3 is applied directly to a pulse generator 4, which includes suitable circuitry for deriving a 2400 p.p.s. output pulse train from the oscillator input signal. The oscillator generator 4 may include conventional differentiating and/or pulse shaping circuitry for producing the 2400 p.p.s. output potential. A portion of the output potential from the pulse generator 4 is applied to a blanking pulse generator 5. The repetitive pulse train from the pulse generator 4 is also applied to the input terminals of a saw tooth generator 6 located directly to the right. The saw tooth generator 6 derives the \( n \) \( Y \)-axis deflection potentials of the cathode ray tube. It will be recalled in this connection that the term \( KY \) merely comprises the product of a linear distance on the cathode ray tube with the deflection factor in volts per unit distance.

The \( KY \) component derived in the saw tooth generator is applied to the input terminals of a computer stage 7 which derives the mathematical expression \( r \cos \phi / h \cos \theta \) from the expression \[ KY = +K cosy \tan \phi \] and adds this value of potential to the term \( KY \). It will be recalled from previous portions of the detailed description that the \( Y \)-axis deflecting potential \( V_y \) is given by the expression \[ KY = +K cosy \tan \phi \] from stage 14A and the voltage \( KY \) derived from saw tooth generator 6 is supplied directly to the input terminals of a computer stage 15A for the purpose of completing the deflection of the \( X \)-axis deflection potential \( V_x \).

The term \( V_y \) must comprise the algebraic sum of three components as indicated in Equation 9. The specific cir-
cuitry which is employed in the block 15A is illustrated in Figure 9 and will be explained in detail in connection with that block.

Continuing with the detailed description of Figure 5 and more particularly with the circuitry and components in the second X-deflection channel, the saw tooth generator 9B in the lower portion of the drawing will now be referred to.

The generator 9B is connected to receive input potential of the "n" from the generator 13B illustrated immediately above. The generator 13B is itself energized by the 60 p.p.s. switching trigger derived from the original 2400 p.p.s. signal by the countdown stage 10. The generator 9B produces the analog component nKY at its output terminal, where the amplitude of the saw tooth voltage is again controlled by the quantity n.

This analog component is supplied to a computing stage 14B in which there is derived the quotient:

\[ \frac{\cos \phi}{\sin \theta} \]

The quotient of these two trigonometric functions is multiplied by the value of the nKY component present at the input terminals. The computer stage 14B will thus be seen to derive an analog potential which is used in developing the complete deflection voltages needed for tracing the east-west perspective lines on the grid pattern of the cathode ray tube.

The potential contribution

\[ nKY \cdot \frac{\cos \phi}{\sin \theta} \]

derived by the computer stage 14B together with the voltage KY derived from the sawtooth generator 6 are supplied to another computer stage 15B. The stage 15B derives two additional contributions to the total analog potential and electronically adds these values to the input component from 14B to produce an X-deflection potential Vx.

It will be recognized that the angle \( \phi \) utilized in the first X-deflection channel differs from the angle \( \theta \) utilized in the second X-deflection channel by exactly 90 degrees.

In generating the north-south lines in the first X-deflection channel, \( \phi \) is the aircraft heading with respect to the north direction. In generating the east-west lines in the second X-deflection channel, \( \phi \) is the aircraft heading with respect to the east direction. Both angles \( \phi \) are readily obtainable from flight instruments in the aircraft.

For the earlier portions of this specification, it will be recalled that the X-axis deflecting potential for the east-west lines is forced by the electronic switch 12 to alternate with the X-axis potential employed in tracing the north-south lines on the cathode ray tube.

Although the north-south and east-west grid patterns would theoretically process an infinite number of lines, the invention provides a finite number of lines in each such set. Half of the group of lines are positioned to the left of the vertical axis of the picture, and the remainder are positioned to the right of the vertical axis. According to the preferred embodiment of the invention, 40 lines may be provided in each set of lines.

Since the terrain on the cathode ray tube contains two such sets of lines, the reason for providing symmetrically identical X-deflection channels in Figure 5 will now be more fully appreciated. By means of the electronic switch 12, one picture is first painted by tracing all of the lines in one 40-line set, following which all the lines in the other 40-line set are traced on the inner surface of the cathode ray tube.

In the black diagram of the invention illustrated in Figure 5, thirty complete pictures per second are traced upon the inner end surface of the cathode ray tube. The over-all rate of tracing lines is then 40-lines per second times 2 times 30 pictures per second, or 2400 lines per second. As earlier explained, the output voltages of the two X-deflection channels are alternately applied to the X-axis deflection plates of the cathode ray tube at the rate of 90 cycles per second by the electronic switch 12. It will be appreciated that other output values of the computer frequency and line-tracing rates will fall equally well within the purview of the appended claims.

The 2400 c.p.s. triggering of saw tooth generator 6 in the channel for producing the Y-axis deflection potentials causes the electron beam of the cathode ray tube to sweep vertically. The saw tooth generators 9A and 9B in the individual X-deflection channels are triggered synchronously in order to cause the electron beam to sweep horizontally. The amplitude of the saw tooth potential in each X-channel is controlled by the magnitude of n, as provided by the n generator 13A and 13B associated with the respective channels. The horizontal line in the grid pattern is traced by sweeping the X-direction with no vertical sweep.

Turning from the generalized description of the block diagram to the details of the several individual stages therein, reference to Figure 6A and Figure 6B will now be made.

The value n which is supplied to the saw tooth generator 9A and 9B in the X-channels, is actually comprised of two component wave forms. The lower waveform is illustrated as a staircase wave \( n \) in Figure 6A. In order to paint each of the lines of a complete 40-line set in succession, the staircase wave \( n \) begins at a negative lower limit such as \(-V\). The potential of the \( n \) signal is then increased time-wise by unit increments for each successive line, up to an upper limiting value of positive potential such as \(+V\). In practicing the invention, values of +20 volts and -20 volts for \(+V\) and \(-V\) yielded satisfactory results. During the tracing of each line, the wave \( n \) is held at a constant value. This wave form can be simply produced by applying pulses of fixed amplitude and duration to the input of an conventional integrator circuit connected within the \( n \) generator stage. Such pulses are repeated at a basic rate of 2400 p.p.s. and the complete cycle is repeated at a constant rate such as 60 c.p.s. in the embodiment of the invention illustrated in Figure 5.

The other component of potential produced in each of the \( n \) generator stages takes the form of a gradual saw tooth wave form \( n_2 \). The component \( n_2 \) is a slowly varying component which simulates motion. To prevent unusual response in the potentials derived, lower limiting value -\( V \) whenever it has gradually ascended to the upper limiting value of potential +\( V \). The upper and lower limiting values may be set at +.5 and -.5 volt respectively.

The component \( n_2 \) has the function of maintaining the same number of lines on each side of the center line of the cathode ray tube. That is, once each line which is traced upon the tube move around from left to right as a result of the aircraft motion, and the last line on the right disappears, a new line immediately appears on the left of the grid pattern to keep the picture balanced and symmetrical. The component \( n_2 \) shown in Figure 6B exhibits rather slow time variation, and is characterized by a period measureable in seconds. According to the present invention, a linear potentiometer is arranged for continuous rotation of a motor driven slider tap to generate the saw tooth component \( n_2 \). The speed of the motor is proportional to \( V \cos \theta \) and \(-V \sin \theta \).

In order to explain in detail the circuitry and components which make up each of the \( n \) generator stages shown in the block diagram form of Figure 6A, reference is made to Figure 7, which illustrates an \( n \)-generator, will now be made.

From the earlier portions of the detailed description, and more particularly from Equation 12 it will be recalled that the quantity \( n \) occurs in the expression

\[ \frac{\sin \omega t}{\sin \theta} = 1 \frac{1}{V_0 \cos \omega \theta \sin \sin \theta} \].

The derivation of an analog potential which properly represents this function of the aircraft heading angle \( \theta \) is accomplished by the
system illustrated in FIGURE 7. To accomplish this, the angle $\theta$ is applied simultaneously to a cosine potentiometer 16 and a sine potentiometer 17. The electrical representa the sideward component of ground speed is applied to the cosine potentiometer 16. The negative amplitude of $v$, which reflects the forward component of ground speed is applied to the sine potentiometer 17. The output potentials from each of the potentiometers are applied to a summing amplifier 18. The algebraic sum of $(v_1 \cos \phi - v' \sin \phi)$ appears in the output of the amplifier 18 and is multiplied by the ratio $Y/r$ in a conventional multiplier stage 19. The resulting product is applied directly to the motor 20 to control the output speed thereof.

Directly to the left of the motor 20 there is provided a linear potentiometer 21 which has a slider tap 22 connected to receive torque from the motor 20. Potential from a suitable source of unidirectional voltage 23 is dropped across the resistance portion of the potentiometer 21. The voltage drop sampled by the motor driven slider tap 22 is applied by way of conductor 24 to a summing amplifier 25. Directly to the left of the summing amplifier 25 there is illustrated an integrator stage 26. The integrator stage 26 is connected to receive repetitive input potentials of 2400 p.p.s. and 60 p.p.s., respectively. It will be recalled that the production of the $n_1$ signal may be accomplished by applying pulses of fixed amplitude and duration to the input of such an integrator. As derived by FIGURE 7, these pulses are delivered at the rate of 2400 p.p.s., and the cycle repeats itself 60 times each second in response to the 60 c.p.s. triggering signal which is supplied to the integrator.

The output contribution $n_1$ of the integrator stage 26 is combined with the potential contribution from the potentiometer 21 in the summing amplifier 25 to produce the complete $n_1$ signal.

Continuing with the detailed description of other aspects of the invention, and more particularly with the explanation of the computing blocks 14A and 14B in FIGURE 5, the circuitry for deriving the analog contribution

$$ K_Y \cos \phi + \frac{K_Y}{\tan \phi} $$

will now be explained in conjunction with FIGURE 8. In this figure, the analog component $\frac{K_Y}{\tan \phi}$ is applied to an amplifier 27 which is characterized by a gain of $r$. The output potential of the amplifier 27 consequently corresponds to the product $-n_2K_Y$.

This product is applied to a conventional cosine potentiometer 28. The cosine output potential from the potentiometer 28 is applied to a high gain amplifier 29 shown immediately to the right of the potentiometer 28. The output potential of the high gain amplifier 29 is summed across a linear potentiometer 30. The fraction of the voltage drop received from the potentiometer 30 is controlled by a slider arm which varies in position in accordance with the instantaneous value of the quantity $h$ or altitude.

By this means, the analog counterpart of the altitude is developed and is applied to cosine potentiometer 31. The cosine potentiometer is condition responsive to the variation $h$ which represents the heading angle of the aircraft. Variations in $h$ are allowed to control the cosine potentiometer 31 by means of a shaft angle input, or the like. The output signal developed by the potentiometer 31 is applied to the high gain amplifier 29. The gain of the feedback loop around this amplifier will be seen to correspond to the term $h \cos \phi$.

The composite output potential made available by the high gain amplifier 29 comprises part of the $K_X$ contribution which is developed by each of the two X-deflection channels of the system. The complete $K_X$ contribution, of course, is given by the expression

$$ K_Y \left( \frac{K_Y}{\cos \phi} \right) $$

Turning to the circuitry and details necessary to derive the remaining terms of $V_x$, reference to FIGURE 9 will now be made.

In this figure $K_Y$ from sawtooth generator 6 is multiplied by $\sin \phi$ by means of sine potentiometer 32. The potentiometer 32 is connected to reflect changes in the variable $\phi$ in terms of slider or tap displacement within the unit. An analog voltage $-K_Y$ is applied to high gain amplifier 33. The output signal from amplifier 33 is sampled by a cosine potentiometer 34 which reflects changes in the variable $\phi$ by experiencing changes in the position of a movable slider or tap within the unit. It will be apparent to those skilled in the art that the quantity $\cos \phi$ defines the gain of the feedback loop around the high gain amplifier 33.

The output signal from amplifier 33 takes the form

$$ +K_P \cos \phi $$

while the output signal from sine potentiometer 32 takes the form $K_Y \sin \phi$. These two signals are applied to the input terminals of summing amplifier 35 to derive the sum

$$ K_Y \sin \phi + \frac{K_P}{\cos \phi} $$

This sum is multiplied by $\sin \phi$, utilizing a second sine potentiometer 41. The output of potentiometer 41 is a voltage analog of the quantity

$$ (K_Y \sin \phi + K_P \cos \phi) $$

which, of course, is identical with

$$ -K_Y \sin \phi + K_P \tan \phi $$

This signal is applied to the input terminals of summing amplifier 44, together with the signal

$$ n_K \cos \phi $$

derived from earlier computer stages. These two contributions are summed in amplifier 44 to complete the deflection voltage $V_x$, and produce the total voltage

$$ n_K \cos \phi + K_Y \sin \phi + K_P \tan \phi $$

It will be recalled that this form of the $V_x$ deflecting potential was set forth in Equation 9 earlier in the specification.

Cirucitry for computer stage 7 which derives the term

$$ +K_P \tan \phi $$

is seen by reference to FIGURE 10. In this figure an analog contribution $+K_P$ is applied in the form of an input D.C. potential to a sine potentiometer 44. The potentiometer is connected to reflect changes in the variable $\phi$ in terms of slider or tap displacement within the unit. From the potentiometer 44 the output function $+K_P \sin \phi$ is applied to the input terminals of a high gain amplifier 45. The output signal from the amplifier 45 is sampled by a cosine potentiometer 46. The potentiometer 46 reflects changes in the value of the variable $\phi$ by experiencing changes in the physical
position of a movable slider or tap provided within the unit.

The output of cosine potentiometer 46 is re-applied to the input of the high gain amplifier 48. It will be apparent to those skilled in the art that the quantity, cos θ, defines the gain of the feedback loop around the high gain amplifier 48.

The output signal from amplifier 48 takes the form

$$+K_p \sin \phi \overline{\cos \phi}$$

which is of course identical with $+K_p \tan \phi$. This term is applied to summing amplifier 47. The contribution $K_Y$ produced by saw tooth generator 6 is also applied to the amplifier 47. The output signal of the amplifier 47 comprises the $V_y$ deflection potential for the cathode ray tube, and takes the form $K_Y + K_p \tan \phi$. It will be recalled that this form of the $V_y$ deflection potential was set forth in Equation 7 earlier in the specification.

In concluding the detailed description of the several stages and components of the invention, reference to FIGURE 11 will now be made. The performance of the inventive system in accordance with the mathematical relationships derived from FIGURE 2 may be regarded as satisfactory through substantially all ranges of the variables such as θ, φ, h and the like. When the heading angle θ approaches 90°, the limitation of those expressions where cos θ appears in the denominator to sufficiently large finite values may be advisable. Such limitation produces only imperceptible deviations from the ideal grid pattern sought to be produced.

The modified cosine potentiometer structure illustrated in FIGURE 11 may be employed in order to completely avoid the problem. In the potentiometer system illustrated in this figure the 90° zero voltage point is actually "jumped over" to eliminate the problem. This potentiometer is modified in order to provide a jumper 37 connected to the resistance winding 40 at the 89° and 91° positions, said jumper 37 having a gap 38 at the 90° position of the winding 40. The potential $V_y$ of FIGURE 11 is thereby prevented from going through zero in order to eliminate attempts by the computers in the system to utilize magnitudes of zero in the denominator any expressions where cos θ occurs.

While particular embodiments of the invention have been shown and described herein, it is not intended that the invention be limited to such disclosures but that changes and modifications can be made and incorporated within the scope of the claims.

What is claimed is:

1. In an airborne electronic system for visually indicating the posture of an aircraft with respect to the ground terrain beneath the aircraft on a cathode ray tube, a first channel for deriving Y-axis deflection voltages which includes a saw tooth generator and a buffer stage connected to said said saw tooth generator for computing the analog contribution $+K_p \tan \phi$; and second and third channels for deriving a pair of X-axis deflection voltages, said channels each including a saw tooth generator and computer stages connected to said saw tooth generator for deriving and combining the analog contributions $K_X$ and $K_p \tan \phi \overline{\cos \phi}$

2. In an airborne electronic system for visually indicating the posture of an aircraft with respect to the ground terrain beneath the aircraft on a cathode ray tube, a first channel for deriving Y-axis deflection voltages which includes a saw tooth generator and a computer stage connected to said saw tooth generator for computing the analog contribution $+K_p \tan \phi$; and second and third channels for deriving a pair of X-axis deflection voltages, said channels each including a saw tooth generator and computer stages connected to said saw tooth generator for deriving and combining the analog contributions $K_X$ and $K_p \tan \phi \overline{\cos \phi}$

3. In an airborne electronic system for visually indicating the posture of an aircraft with respect to the ground terrain beneath the aircraft on a cathode ray tube, a first channel for deriving Y-axis deflection voltages which includes a saw tooth generator and a computer stage connected to said saw tooth generator for computing the analog contribution $K_p \tan \phi$; and second and third channels for deriving a pair of X-axis deflection voltages, said channels each including a saw tooth generator and computer stages connected to said saw tooth generator for deriving and combining the analog contributions $K_X$ and $K_p \tan \phi \overline{\cos \phi}$

4. In an airborne electronic system for visually indicating the posture of an aircraft with respect to the ground terrain beneath the aircraft on a cathode ray tube, a source of time-spaced voltage pulses, first means connected to said source of time-spaced voltage pulses to derive a Y-axis deflection signal for application to the Y-axis deflection plates of the cathode ray tube, frequency reduction means connected to said source of voltage pulses, second means comprising a pair of symmetrically identical channels, the first channel connected to said source of time-spaced voltage pulses and to the output of said frequency reduction means to derive a first X-axis deflection signal and the second channel connected to said source of voltage pulses and to the output of said frequency reduction means to derive a second X-axis deflection signal, and electronic switching means connected to said first and the second X-axis deflection signals alternately available to the X-axis deflection plates of the cathode ray tube.

5. The system of claim 4 in which the first and the second channels of said second means each include a computer stage for receiving and operating upon altitude, pitch angle and heading angle data of the aircraft to derive the X-axis deflection signals.

6. In an airborne electronic system for visually indicating the posture of an aircraft with respect to the ground terrain beneath the aircraft on a cathode ray tube, first means including an oscillator and a pulse generator connected to said oscillator for producing time-spaced voltage pulses, second means including a saw tooth generator connected to said oscillator and a computer stage connected to said saw tooth generator to derive a Y-axis deflection signal, frequency reduction means connected to said first means, third means connected to said first means and to the output of said frequency reduction means to derive a first X-axis deflection signal, fourth means connected to said first means and to the output
of said frequency reduction means for deriving a second X-axis deflection signal, coordinate rotator means connected to said second means for electrically modifying the Y-axis and the first and second X-axis deflection signals prior to application to the respective pairs of deflection plates of the cathode ray tube, and electronic switch means connected to said frequency reduction means and to said third and said fourth means to render the first and the second X-axis deflection signals alternately available to said coordinate rotator means.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,390,840</td>
<td>Koren</td>
<td>Dec. 11, 1945</td>
</tr>
<tr>
<td>2,432,029</td>
<td>Manildi</td>
<td>Dec. 2, 1947</td>
</tr>
</tbody>
</table>

FREEHAFER 2,529,601 Nov. 14, 1950
EWING 2,532,158 Nov. 28, 1950
ERGEN 2,596,472 May 13, 1952
FLYER 2,616,078 Oct. 28, 1952
PARKER et al. 2,648,061 Aug. 4, 1953
WHITE 2,849,707 Aug. 26, 1958
LONGERICH 2,879,002 Mar. 24, 1959
STEINHAUSER 2,967,263 Jan. 3, 1961

OTHER REFERENCES