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(71) Applicant: THE MARCONI COMPANY LIMITED, The Grove Warren Lane, Stanmore Middlesex HA7 4LY (GB)

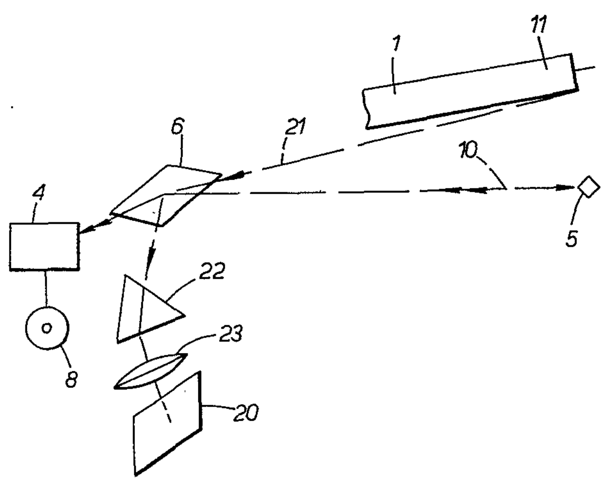
(72) Inventor: Wheeler, Reginald Godfrey, 1, Dalbys Lane Foxton Nr. Market Harborough, Leicestershire LE16 7QY (GB)
Inventor: Sherlock, James, 9, Sandham Bridge Road, Cropston Leicestershire LE7 7GS (GB)

(74) Representative: Hoste, Colin Francis et al, The General Electric Company p.l.c. Central Patent Department (Chelmsford Office) Marconi Research Centre West Hanningfield Road, Great Baddow Chelmsford CM2 8HN, Essex (GB)

(54) **Gun with means for verifying the boreline direction.**

(57) The direction of travel of a shell fired by a gun such as a battle tank depends on the boreline direction of the barrel in the region of the muzzle, and even very small boreline errors can give rise to significant aiming errors at long range. Errors in the boreline direction can often exist in guns having relatively long barrels, as mechanical backlash and slackness in the mounting arrangement, and curvature of the barrel due to thermal stress can shift the position of the muzzle slightly from its true position.

A solid state optical sensor having a two dimensional image surface is arranged to view the muzzle via the sight (periscope) mirror associated with the optical aiming sight of the gun. The optical sensor is positioned closely adjacent to the optical aiming sight so as to enable all position errors between the aiming sight and the muzzle to be removed. The optical sensor is scanned in a television like raster pattern, and window signals are inserted into selected line scans so that the actual position of the muzzle can be very precisely compared with its required position. Any departures from the required position are compensated by feeding correction signals into the optical aiming sight to shift the gunner's aiming mark accordingly.



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TITLE MODIFIED
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Improvements in or relating to guns

This invention relates to guns and is particularly applicable to guns having a relatively long and massive barrel such as a battle tank. The direction of travel of a shell fired by a gun depends on the boreline direction of the barrel in the region of the muzzle, and even very small boreline errors can give rise to significant aiming errors at long range. It has been found that even when relatively sophisticated optical aiming sights are used to lay the gun on a target significant aiming errors can remain. These errors are at least in part due to uncertainties in the direction of the boreline of the muzzle, and they can stem from the presence of temperature gradients across the diameter of the barrel which can cause the barrel to bend slightly and from mechanical slackness in the supports which locate the barrel. It has been proposed elsewhere to compensate for these errors by aligning the aiming mark of an optical sight with a reference image obtained via a reflector mounted on the muzzle of the gun, so that movement of the muzzle caused by distortion of the barrel can be detected.

Practical difficulties are experienced in implementing an optical system for monitoring boreline errors, since the elevation axis of the barrel is invariably off-set from that of the optical aiming sight of the gun or from that of a dedicated optical sensor positioned to receive reflected light via the reflector at the muzzle. This difficulty can be particularly severe in those cases where an arrangement for detecting muzzle boreline pointing errors is to be fitted to an existing battle tank so as to upgrade its performance to enable its firing accuracy to meet present day standards.

According to this invention, a gun includes a barrel mounted so as to be rotatable in elevation; an optical imaging sensor located in the vicinity of an optical aiming sight and arranged so that the muzzle of the barrel is within its field of view for all possible operational angles of elevation of the barrel, whereby it receives an image of the muzzle; and means operative to detect departures of said image from a predetermined expected position related to the nominal angle of elevation of the barrel.

Generally a barrel is also movable in traverse (sometimes termed training) and such a movement may cause the image of the muzzle to shift slightly relative to the optical sensor - the amount of such shift depends on the particular geometry used to mount the barrel and the sensor. In such a case, the position of the image of the muzzle is also compared with its expected position in traverse to detect departures therefrom. Since the muzzle is itself viewed by the optical sensor, the location of the optical sensor is no longer critical with respect to the elevation axis of the barrel, as would be the case if a reflector were used to return a narrow beam of light in the manner of our co-pending patent application published under number 2069105A.

Conveniently part of the optical system of the optical aiming sight is used to receive the image of the muzzle as, in general, the position of the barrel in elevation and traverse is similar to the axis of the optical aiming sight - the elevation of the barrel is varied somewhat above that of the optical sight depending on the range of the target which is to be engaged.

Many existing battle tanks are provided with an optical aiming sight which is positioned to one side of the axis of the barrel and is provided with an adjustable sight mirror (sometimes termed a periscope mirror) whose angle is altered to adjust the viewing angle of elevation of the optical sight. This mirror can also be conveniently used to collect the image of the muzzle, and since the muzzle is laterally off-set from the axis of the optical aiming sight, the two images, i.e. the image of the target and the image of the muzzle, can be easily separated within the aiming sight itself. Preferably the optical sensor comprises an optical detector having a two dimensional image receiving surface which is used to identify the position of the muzzle. Generally there will be a sufficient degree of optical contrast between the muzzle and its background as to enable the muzzle position to be accurately determined using only very simple signal processing. For example, in daylight the muzzle will appear as a very dark shape against a bright sky background. If the image detector is sufficiently sensitive, it may be possible to observe the muzzle by a similar technique even in conditions of twilight or partial darkness. However, it is preferred to position a passive light source at the muzzle so as to facilitate detection of its position during darkness. The passive light source may be of a chemical nature so that its not adversely affected by the vibration and shock experienced by the muzzle when the gun is fired.

If the muzzle departs from its correct position due to distortion of the barrel or mechanical wear in its mounting, an estimate of the magnitude and sense of the error can be made, and a correction signal injected into the optical aiming sight so as to shift the aiming point of the sight to compensate. This correction can be achieved in an automatic manner so that it is not necessary for the gunner to consciously monitor the position of the muzzle in these conditions.

In some cases, the degree of error can be quite significant and can arise from several sources. If the barrel is subject to uneven heating or cooling, thermal stress within it can cause a degree of bending which alters the boreline direction of the barrel in the region of the muzzle. Furthermore, it is customary to mount a barrel within acradle so that it can slide backwards within the cradle when the gun is fired so as to enable the recoil force to be absorbed. Mechanical slackness within the cradle can impart uncertainty to the boreline direction of the barrel, as can mechanical wear occurring within the trunnion bearings which supports the cradle and enable its angle of elevation to be altered.

The invention is further described by way of example with reference to the accompanying drawings, in which

Figures 1 and 2 shows part of the optical system for detecting position errors of the muzzle,

Figure 3 shows the field of view of an optical sensor,

Figure 4 shows part of signal processing circuits by means of which the nature of the position error can be determined, and .

Figures 5 and 6 show explanatory waveforms relating to the operation of Figure 4.

Referring to Figures 1 and 2, only those parts of a battle tank necessary for an understanding of the present invention are illustrated. A barrel 1 is slidably mounted within a cradle 2 which in turn is mounted on trunnion bearings 3 so that the barrel 1 is rotatable in elevation relative to the body of a tank (not shown) on which it is mounted. An optical aiming sight 4 is mounted along side the barrel and is positioned so that a distant target 4 can be viewed via a periscope mirror 6 which is rotatable in elevation about an axis 7. A gunner acquires the target 5 i conventional manner by centering an image of the target within the cross wires of his eyepiece 8. The barrel of the gun and the optical sight are both mounted on a rotatable turret so that they move together in traverse although the sight can be moved relative to the traverse axis and elevati axis to a certain extent. The barrel 1 therefore points in the same general traverse direction as the optical sight, but it is off-set in elevation therefrom by an angle which is related to the range of the target. If the tank is not standing on level ground, or if a strong cross wind is blowing, the optical sight will also be effected somewhat fr the traverse angle of the barrel. Thus in general, the boresight direction 9 of the barrel is somewhat above the li of sight 10 of the optical sight, but is unlikely to differ therefrom by a very large angle.

It is customary to use some form of ballistic computer to calculate the actual elevation and traverse angles of the barrel in order to strike a target with a high degree o probability of success. Various factors affect the trajecto of a shell which is fired from the barrel of the gun and amongst other things these factors include the temperature and nature of the ammunition, wind strength and air pressure. All of these factors are taken into account in automatically adjusting the aiming mark of the eyepiece 8 so that it is merely necessary for a gunner to align the aiming mark with the optical image of the target 5. The position of the aiming mark in the eyepiece 8 assumes that the boreline direction of the muzzle 11 is correct, but in practice, the position of the muzzle can alter relative to the body of the tank due to mechanical wear within the cradle and the trunnion bearings as previously mentioned. Even very minor positional errors at the muzzle 11 can alter the boresight direction of the barrel and significantly reduce the probability of successfully striking a target.

The actual position of the muzzle 11 is viewed by an optical detector 20 via optical path 21. The same periscope mirror 6 is used, since in general the angular position of the muzzle will not deviate significantly from that of the target 5. As can be seen from Figure 1, the position of the muzzle is laterally off-set from the optical path 10 by the distance x and thus the optical detector 20 can be readily accommodated along side the optical sight 4. The use of the deflection prism 22 and the lens 23 allow the detector 20 to be located at any convenient position adjacent to that of the optical aiming sight 4.

The optical detector 20 can take any convenient form, but in view of the hostile environment in which it is situated, it is preferable to use a two dimensional solid state optical sensor, which is scanned in a raster pattern in a manner which is similar to that of a television camera arrangement. By using the optical detector 20, the actual position of the muzzle 11 can be compared with stored data relating to its proper position for each angle of elevation and traverse. If any discrepancy is found, a compensating signal can be applied to the optical sight 8, so as to produce a small shift of the aiming position.

As the field of view of the optical detector 20 is an oblique view along the length of the barrel 1, the optical detector receives an image of the kind illustrated diagrammatically in Figure 3. This Figure represents a light background 30, consisting of relatively bright sky and a dark mass 31 representing the bulk of the barrel 1. The curved interface region 32 between light and dark represents the position of the muzzle 11 itself. In order to determine whether the line 32 is in exactly the correct position, two windows 33 and 34 are electrically inserted into the scanning raster of the optical detector and the positions of the windows are chosen so that the line 32 should pass exactly mid-way through both of the windows. Any departure from the mid position generates an error signal which is indicative of the nature and sense of the positional error. Compensation is then applied to the aiming mark in the optical sight, and as the optical sight tracks the changing position of the aiming mark the error is progressively eliminated.

One signal processing system for enabling the error corrections to be generated is illustrated diagrammatically in Figure 4. The output of the optical detector 20 of Figure 2 is in the form of a video signal consisting of sequential line scans in the manner of a conventional television raster. This signal is received at terminal 40 and portions of it corresponding to the two line scans A and B in which the windows 33 and 34 appear are gated out by a gate circuit 41. The portions of the video signal to be gated out are determined by the contents of a data store 42, which is accessed in dependence on the nominal elevation and traverse angles of the barrel 1. These angles are obtained from suitable angular position sensors 43 and 54. The data store 42 thus sets a window generator 44, which generates a window signal corresponding to the duration and position of the two windows 33 and 34. In this example, it is assumed for convenience that both windows 33 and 34 are of identical durations so that a common window generator 44 can be used, but this need not necessarily be the case. The data store 42 controls the gate circuit 41 so as to select appropriate video lines corresponding to the vertical positions of the two windows 33 and 34, the line signal corresponding to the vertical position of window 33 being termed line A and the other video line being termed line B. These two video lines are passed via respective amplifiers and limiters 45 and 46 and applied to three dual input logic gates 47, 48 and 49. The inverse of video line B is applied to the logic gate 49. Each of the three logic gates receives an enable signal from the window generator 44 so that an output logic signal is generated accordingly. The outputs of the three logic gates are subtracted at the two further logic gates 50 and 51, so as to produce the two output signals indicated adjacent to the two output terminals 52 and 53. The signal received at terminal 52 is indicative of any Y axis positional error i.e. elevation error, and the signal produced at terminal 53 is indicative of X axis error, i.e. traverse error.

The way in which these signals are generated is illustrated more specifically in Figures 5 and 6, Figure 5A showing the corresponding waveforms which result when the muzzle 11 is correctly positioned, Figure 5B illustrating the waveforms which result when the traverse position of the result is correct, but is low in elevation. Figure 6A illustrates the waveforms for the case in which the elevation position of the muzzle is correct, but the traverse is displaced to the left and finally, Figure 6B illustrates a composite error in which the muzzle is both too high and displaced to the right. In view of the interconnection of the logic circuits which is illustrated in Figure 4, it is believed that the way in which the various waveforms are generated is self-explantory. It will be apparent from Figures 5 and 6 that the polarity of the Y axis signal indicates the sense of the error, and has the zero value when no error is present. However, the X axis signal produces a pair of pulses which are symmetrically balanced when there is no traverse error. The effect of a traverse error is to unbalance the symmetry so that from the relative durations of the pair of pulses, the sense of the error can be readily determined. The two control signals X and Y are applied to the eyepiece 8 in a conventional manner so as to shift the position of the aiming mark which are viewed by a gunner. The nature of the control signals may be fed via a simple decoder so as to convert them to the form in which they can be accepted by the eyepiece 8, but the exact nature of the decoder will, of course, depend on the kind of eyepiece used, and the mechanism by means of which the aiming mark is moved.

CLAIMS

1. A gun including a barrel (1) mounted so as to be rotatable in elevation; an optical imaging sensor (20) located in the vicinity of an optical aiming sight (4) and arranged so that the muzzle (11) of the barrel is within its field of view for all possible operational angles of elevation of the barrel, whereby it receives an image of the muzzle; and means (figure 4) operative to detect departures of said image from a predetermined expected position related to the nominal angle of elevation of the barrel.

2. A gun as claimed in claim 1 and wherein means are provided for detecting errors in the position of said image in both elevation and traverse.

3. A gun as claimed in claim 1 (or 2) and wherein part of the optical system of the optical aiming sight is used to receive the image of the muzzle.

4. A gun as claimed in claim 3 and wherein the image of the muzzle is passed to said optical sensor via an adjustable sight mirror which forms part of the optical aiming sight.

5. A gun as claimed in any of the preceding claims and wherein the optical sensor comprises an optical detector having a two-dimensional image receiving surface, and which is arranged to enable the position of the image on its surface to be determined.

6. A gun as claimed in claim 5 and wherein the optical detector is a solid state device in which the two-dimensional image receiving surface is scanned in a television-like raster pattern.

7. A gun as claimed in claim 6 and wherein the actual position of the image on said surface is compared with an expected position so as to detect departures therefrom.

8. A gun as claimed in claim 7 and wherein the expected position of the image is defined in terms of windows inserted at predetermined positions into selected line scans of the raster pattern.

9. A gun as claimed in any of the preceding claims and wherein departures of said image from its expected position are used to shift an aiming mark in said optical aiming sight so as to compensate for said departures.

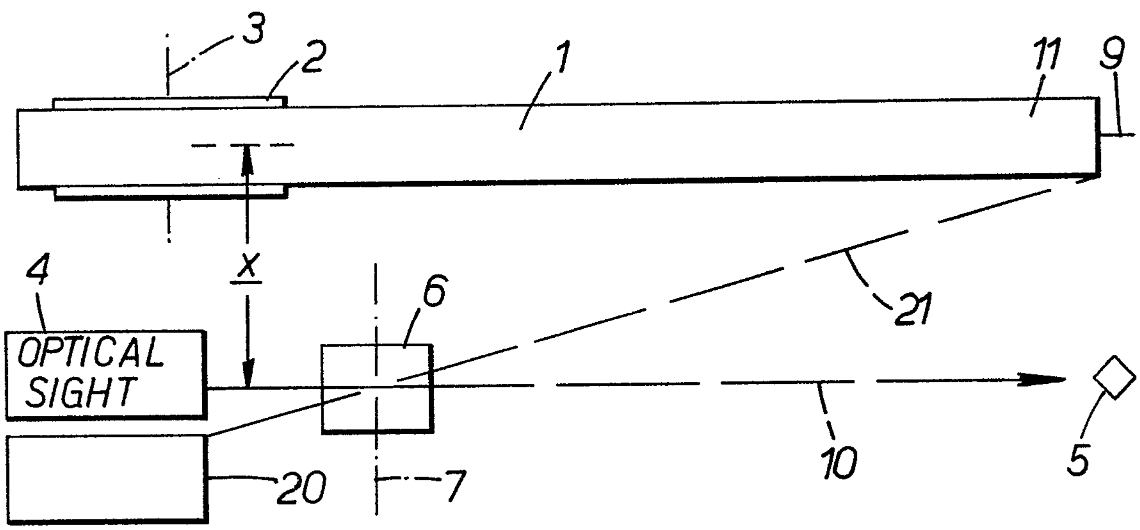

FIG. 1.

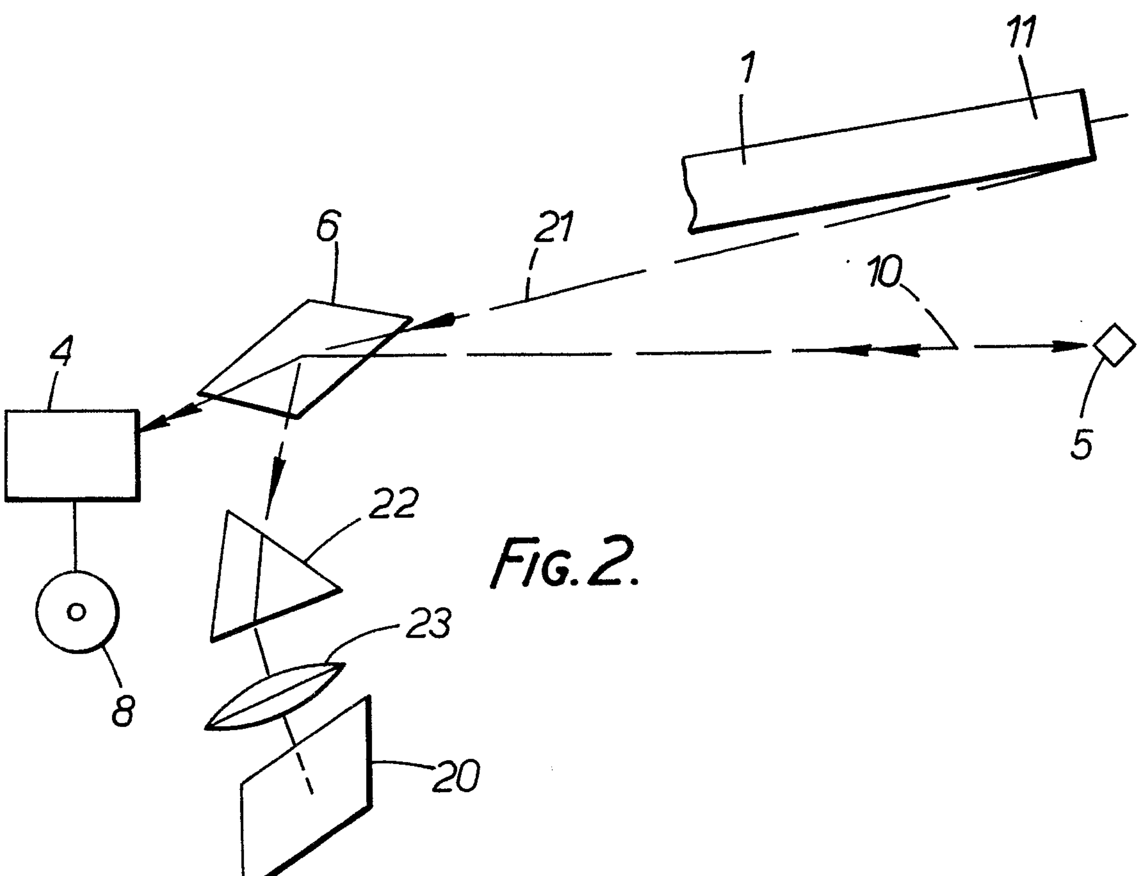

FIG. 2.

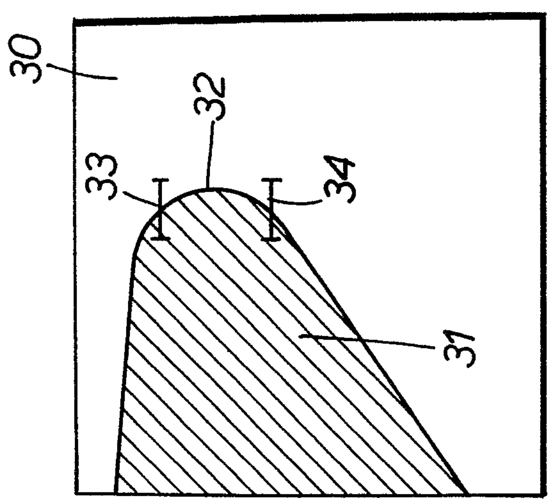
30
31
32
33
34

FIG. 3.

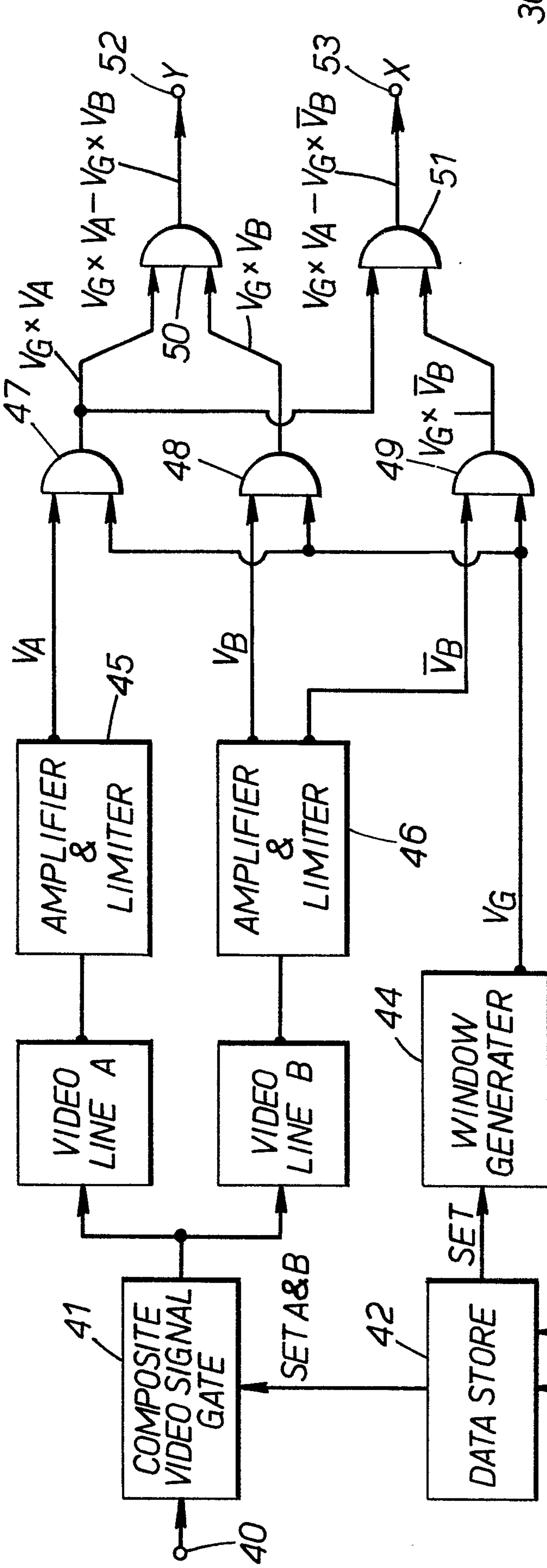
40
41
COMPOSITE VIDEO SIGNAL GATE
SET A&B
42
DATA STORE
43
ELEVATION ANGLE
54
TRAVERSE ANGLE
SET
44
WINDOW GENERATER
VIDEO LINE A
VIDEO LINE B
45
AMPLIFIER & LIMITER
46
AMPLIFIER & LIMITER
V_A
V_B
$\overline{V}_B$
V_G
47
48
49
50
51
$V_G \times V_A$
$V_G \times V_B$
$V_G \times \overline{V}_B$
$V_G \times V_A - V_G \times V_B$
$V_G \times V_A - V_G \times \overline{V}_B$
52
Y
53
X

FIG. 4.

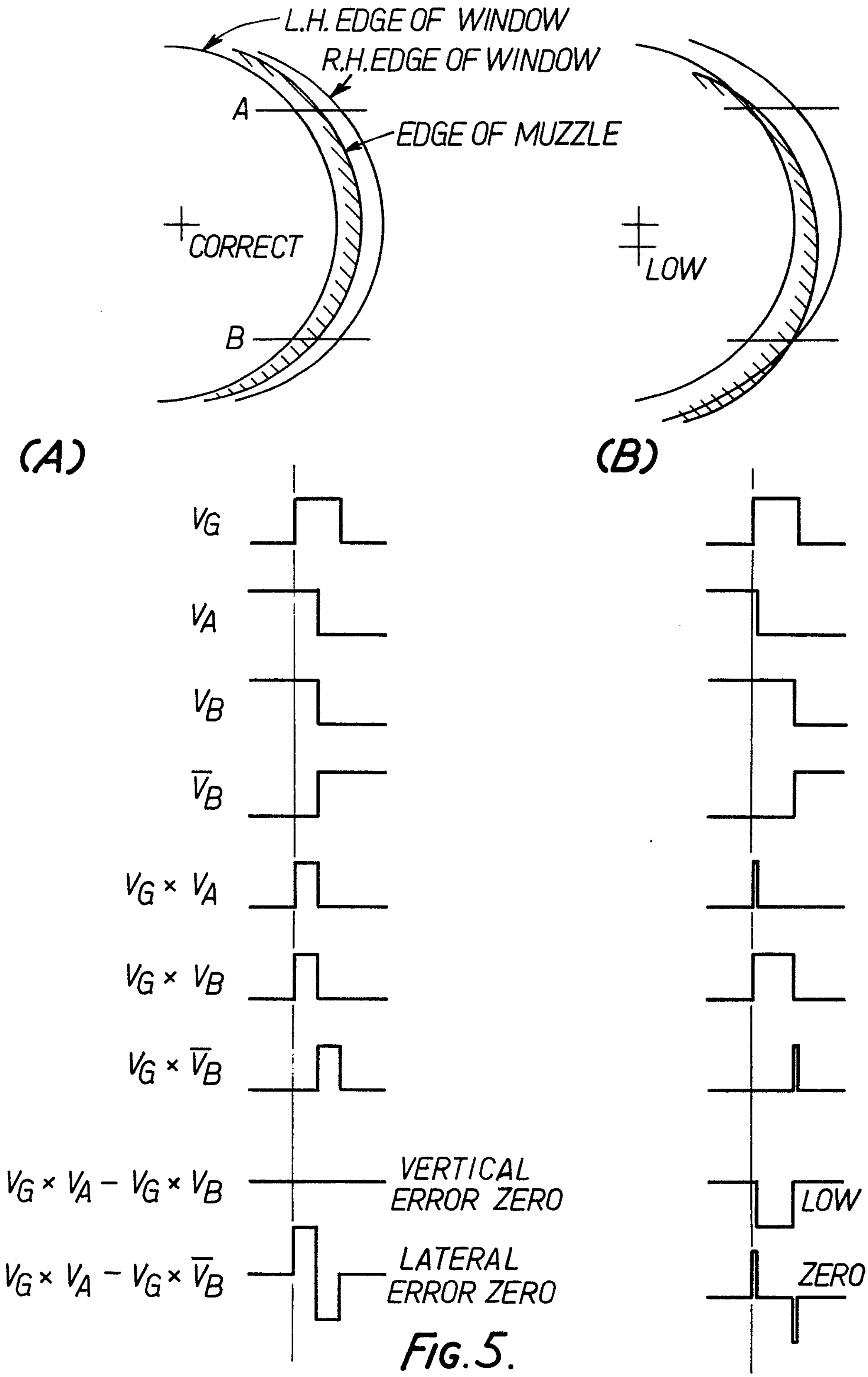
L.H. EDGE OF WINDOW
R.H. EDGE OF WINDOW
A
EDGE OF MUZZLE
CORRECT
B
LOW
(A)
(B)
V_G
V_A
V_B
$\overline{V}_B$
$V_G \times V_A$
$V_G \times V_B$
$V_G \times \overline{V}_B$
$V_G \times V_A - V_G \times V_B$
VERTICAL ERROR ZERO
LOW
$V_G \times V_A - V_G \times \overline{V}_B$
LATERAL ERROR ZERO
ZERO

FIG. 5.

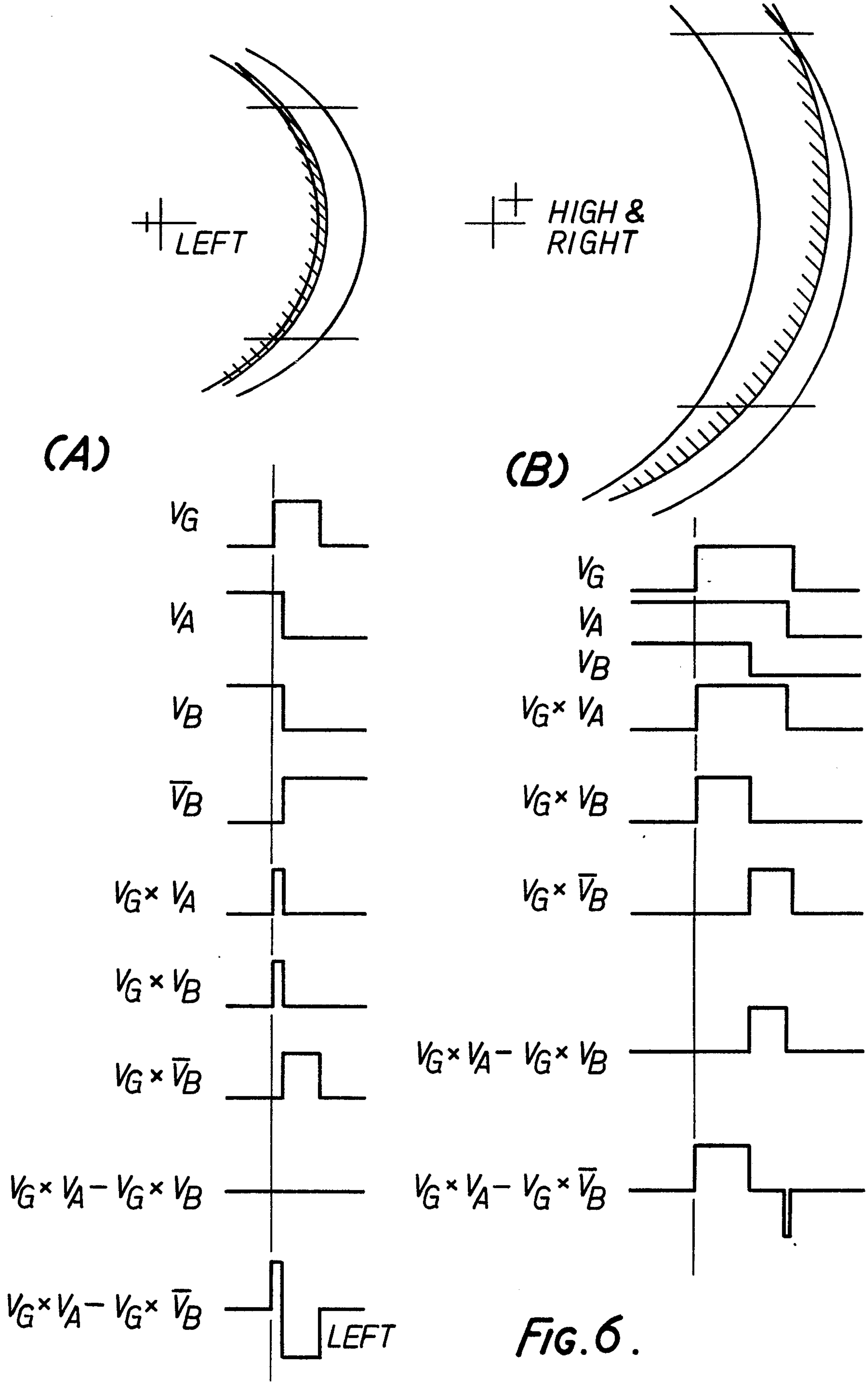
LEFT
HIGH & RIGHT
(A)
(B)
V_G
V_A
V_B
$\overline{V}_B$
$V_G \times V_A$
$V_G \times V_B$
$V_G \times \overline{V}_B$
$V_G \times V_A - V_G \times V_B$
$V_G \times V_A - V_G \times \overline{V}_B$
LEFT

FIG. 6.