United States Patent

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[54] JUMP ERROR CORRECTION SYSTEM

13 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **307/11, 89/135**
[51] **Int. Cl.** **H02j 1/00**
[50] **Field of Search** ..... 307/11, 132ER, 112, 149; 89/135 (General); 318/20.050, 20.530

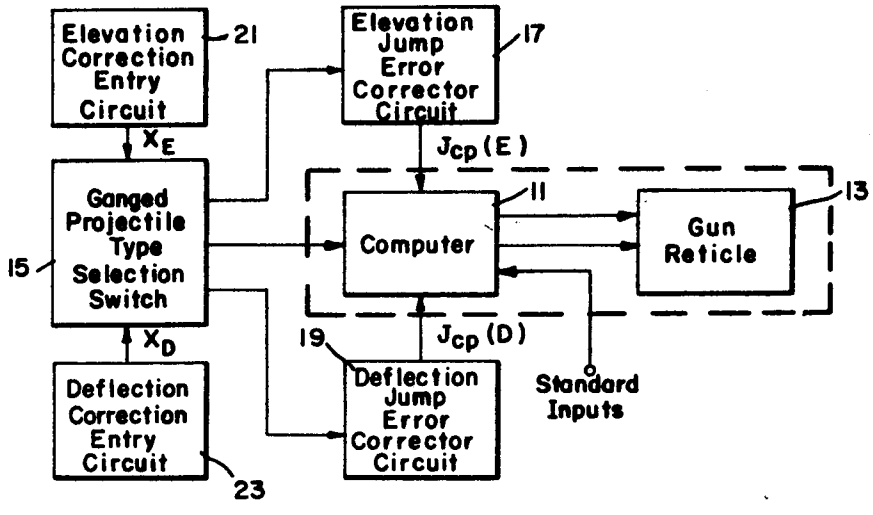
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ABSTRACT: A system for automatically providing to a gun computer in a fire control system the proper jump error correction signals to compensate for the jump errors associated with each of a plurality of different types of projectiles to be fired by a gun. The system comprises elevation and deflection channels, each of which includes a single control for supplying a short term correction signal to compensate for the variation in environmental effects through a switching circuit to a corrector circuit which scales the associated short term correction signal and adds thereto a predetermined fixed jump signature signal derived as a function of the selected projectile type in order to produce the proper jump error correction signal for the selected projectile type.



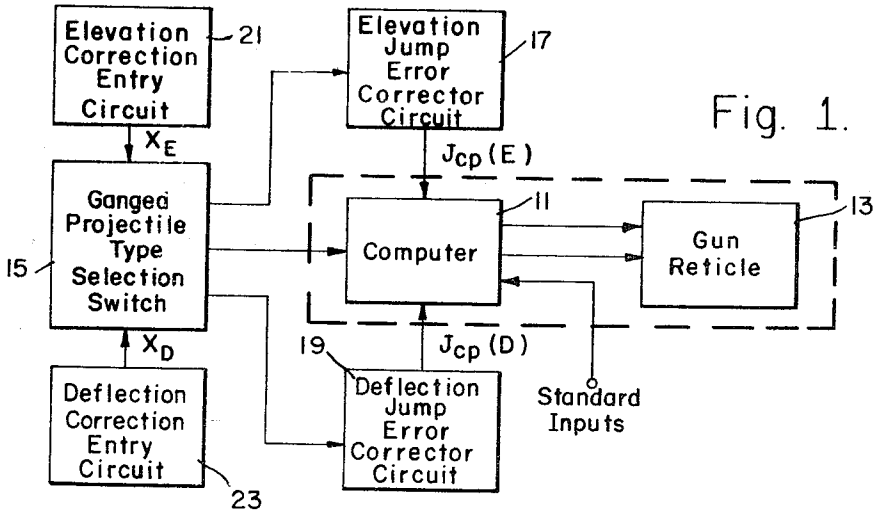


Fig. 1.

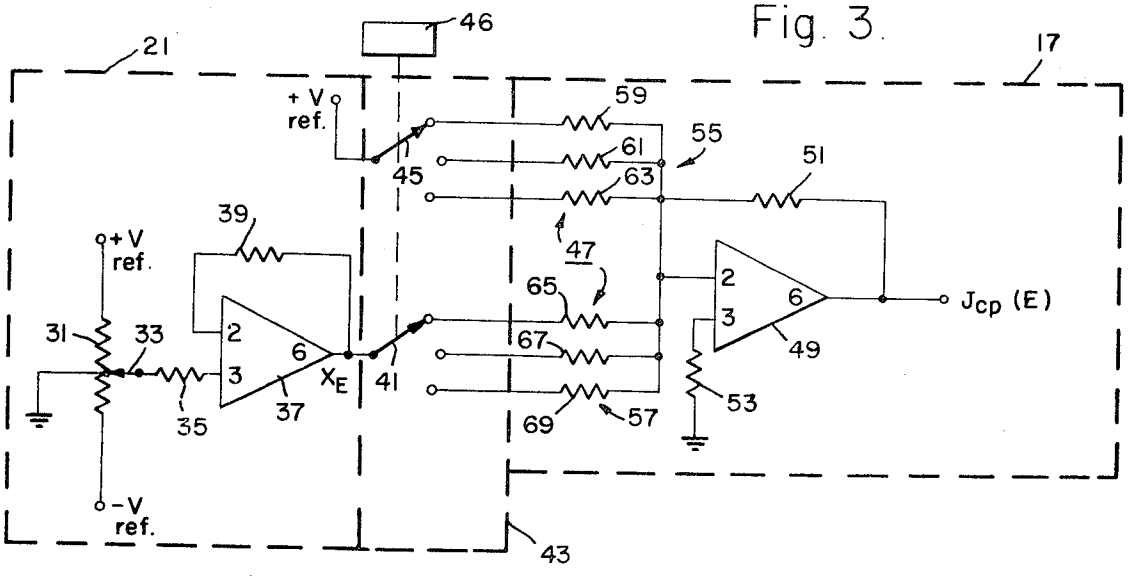


Fig. 3.

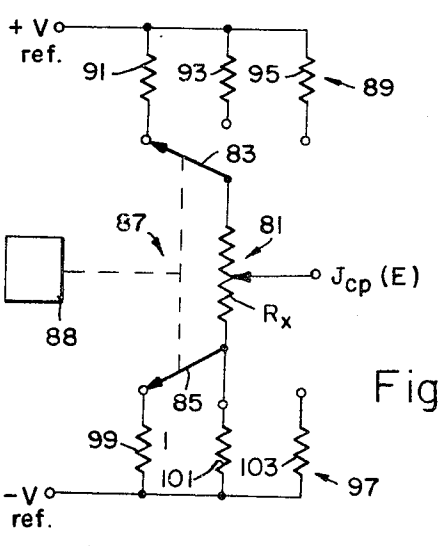


Fig. 4.

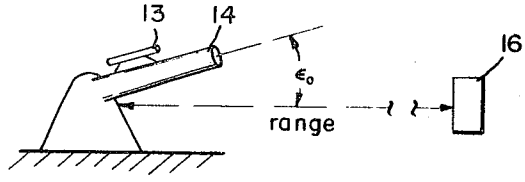


Fig. 2.

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JUMP ERROR CORRECTION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to a system for providing correction signals to a gun computer of a fire control system to compensate for the empirical or jump errors associated with the aiming of the gun and particularly to a system for automatically providing these jump error correction signals when different types of projectiles are used.

In gun fire control systems many standard firing conditions, such as range, time of flight, gun tube wear, etc., can be computed from available input parameters to direct the positioning of the gun. However, there are nonstandard firing conditions known as jump errors, which cannot be computed but must be empirically derived from firing tests on a large number of projectiles. These jump errors represent the angular miss in both deflection and elevation of one or more test projectiles from the computed intercepts of the target position. As a result, jump error correction signals for these jump error values must be included for proper gun aiming. For each type of projectile to be fired by the gun a different pair of elevation and deflection jump error correction signals is required.

Conventional systems for producing these jump error correction signals require a separate set of controls for each type of projectile to be fired by the gun.

At the present time there is no known system for producing these jump error correction signals for a plurality of different projectile types by using only one set of controls.

SUMMARY OF THE INVENTION

Briefly, applicants have provided an improved jump error correction system which utilizes a single set of elevation and deflection controls for selectively providing different pairs of elevation and deflection jump error correction signals to a gun computer, as required for a plurality of different projectile types that may be fired by the gun.

It is therefore an object of this invention to provide an improved jump error correction system.

It is another object of this invention to provide an improved system for developing jump error correction signals in a gun fire control system.

A further object of this invention is to provide a system which uses only one set of elevation and deflection controls to produce the elevation and deflection jump error correction signals associated with any selected one of a plurality of different projectile types to be fired by a gun fire control system.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features and advantages of the invention, as well as the invention itself, will become more apparent to those skilled in the art in the light of the following detailed description when taken in consideration with the accompanying drawings wherein like reference numerals indicate like or corresponding parts throughout the several views wherein:

FIG. 1 illustrates in general form a schematic block diagram of the invention.

FIG. 2 illustrates a computer-controlled gun in a firing situation.

FIG. 3 illustrates a schematic circuit diagram in accordance with one embodiment of the invention.

FIG. 4 illustrates a schematic circuit diagram in accordance with a second embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIG. 1 illustrates in general form a schematic block diagram of the invention in a fire control system. A gun aiming computer 11 is utilized for developing gun elevation and deflection lead angle signals as a function of both standard firing conditions and nonstandard firing conditions. These gun elevation and deflection lead angle signals from the computer 11 are used to position a gun reticle or telescope 13 in elevation and deflection, while not moving the gun barrel (FIG. 2, Item 14), so that the reticle will be directed at the spot where the projectiles from the gun in the fire control system are landing. When the gun reticle 13 has been positioned by the output signals from the computer 11, the gun and reticle are then repositioned to the desired target location, thereby increasing the probability of hitting the target (FIG. 2, Item 16). This type of fire control weapons system is called a disturbed reticle system and is one of many types to which the principles of the invention are applicable. Another type of fire control weapons system in which the system of the invention may be utilized is called a gun director system. In a gun director system, both the gun 14 and the reticle 13 are manually positioned to the desired target 16. The gun 14 is then positioned by the outputs of the computer 11 to compensate for the angular miss of the target 16 while the reticle 13 is held stationary. Therefore, this invention is applicable to both a disturbed reticle system and a gun director system as well as to any other type of gun fire control system in which compensation must be provided for the jump parameter.

The standard firing conditions, such as range, time-of-flight, gun tube wear, etc., are applied to computer 11 as standard inputs since these may be readily calculated. Another standard input term is the projectile type which is provided by the control circuit or ganged projectile-type selection switch 15. In this particular mechanization, the projectile selection switch 15 is composed of three ganged control or switch sections (not shown) which provide control indications of the type of projectile selected to be fired by the gun 14 to the computer 11, the elevation jump error corrector circuit 17 and the deflection jump error corrector circuit 19. The elevation jump error corrector circuit 17 utilizes the control indication of the selected projectile type in conjunction with a short term correction signal X_E supplied by the elevation correction entry circuit 21 to produce an elevation jump error correction signal $J_{cp}(E)$. In a similar manner, the deflection jump error corrector circuit 19 utilizes the control indication of the selected projectile type in conjunction with a short term correction signal X_D supplied by the deflection correction entry circuit 23 to produce a deflection jump error correction signal $J_{cp}(D)$. It should be noted at this time that each of the leads drawn from the selection switch 15 to the error corrector circuits 17 and 19, respectively, represents a composite of the corresponding short term correction signal (X_E or X_D) and the control indication of the selected projectile type.

The elevation and deflection jump error corrector circuits, 17 and 19, may be mechanized for either, or both, local or remote operation to utilize the control indication, or switch position, from the selection switch 15 to determine, as a function of the selected projectile type, to which one of a plurality of internal circuits in a network (Item 47 in FIG. 2 and Items 89 and 97 in FIG. 3) the respective short term correction signal will be applied. If remote operation is desired, each of the error corrector circuits 17 and 19 may include, for example, electronic switches such as a bank of field effect transistors (FETs, not shown) each of which is selectively enabled as a function of the position of the selection switch 15. The enabled transistor would, in turn, steer the short term correction signal from its input terminal (source) to its output terminal (drain) and then to its associated internal circuit in the network. These electronic switches would then ultimately perform the same function in the error corrector circuit (17 or 19) in remote operation that the switch 15 by itself would perform in local operation. The embodiments shown in FIGS. 2 and 3 basically illustrate local operation. However, it is to be understood that both local and remote operation of each of the error corrector circuits 17 and 19 are within the purview of the invention.

The elevation and deflection jump error correction signals compensate for the jump errors caused by the effects of nonstandard firing conditions, which cannot be readily calculated,

but must be empirically derived. The signals representing the standard firing conditions are applied to the computer **11** to position the gun reticle **13** in order to compensate for the known calculable factors. The gun is then positioned at a target and test fired. Any angular deviations in elevation and deflection from the computed target location are caused by these nonstandard conditions and are known as jump errors. It is to the correction or compensation of these jump errors in elevation and deflection that this invention is directed. More particularly, the elevation correction entry circuit **21** and the deflection correction entry circuit **23** each utilize only a single control (to be described later) to produce the short term correction signal, which is used with the plurality of projectiles to be fired by the computer-controlled gun.

The circuitry for producing the jump error correction signal for each of the elevation and deflection channels can be mechanized from the equation

$$J_{cp}=K_{1p}+(K_{2p})(X) \tag{1}$$

where:

J_{cp}=the jump error correction signal.
X=a dial setting with the range, for example, from -1.0 to $+1.0$.
K_{1p}=a constant of jump correction associated with each projectile type.
K_{2p}=a constant of jump correction associated with each projectile type and dependent upon the X quantity.
p=an integer from 1 to N, denoting which one of N projectile types is to be fired by the gun.

It is to be noted, as indicated by the subscript p, that each K-term in equation 1 will change and thereby change the jump error correction value whenever the projectile type is changed.

The $K_{1\mu}$ term, which is not affected by the X value, represents the true jump or jump signature of the projectile type. The jump signature of each projectile type is designated as the misalignment of the gun boresight axis with the projectile's initial velocity vector. The magnitude of the jump signature correction term $K_{1\mu}$ for a given projectile type in the elevation and deflection channels is determined by empirical firing tests on a large number of projectiles of that type. Each of the test firings of the selected projectile type may result in an angular miss in both deflection and elevation from the computed intercepts of the target plane in a shot pattern. The average angular miss of the selected projectile type in elevation (as represented by the shell landing short of or overshooting the computed intercepts of the target plane) represents the true jump or jump signature $K_{1\mu}$ of that selected projectile type. In like fashion, the average angular miss of the selected projectile type in deflection (to the right or to the left of the computed intercepts of the target plane) represents the true jump or jump signature $K_{1\mu}$ of that selected projectile type for the deflection channel. Once these jump signatures of each projectile type are determined, they remain constant for that projectile type and therefore the $K_{1\mu}$ term can be automatically provided in each of the elevation and deflection channels whenever a particular projectile type is selected.

The produce term $(K_{2\mu})(X)$ is a more complex quantity. The X-factor of the $(K_{2\mu})(X)$ term is scaled by the constant $K_{2\mu}$. This X-factor is empirically derived periodically (for example on a day-to-day basis) to compensate for the deviation of a particular projectile fired from a particular gun at a particular time. Although the X-factor is determined for one projectile type, it is equally applicable to all of the projectile types. This X-factor is scaled by the $K_{2\mu}$ factor in order to compensate for the different projectile types being more or less sensitive to such firing conditions as the projectile speed being different than calculated, a change in the temperature of the projectile and a change in the closeness of the fit of the projectile in the gun barrel, etc. Each of the above conditions, which may contribute to the amount of the projectile deviation, may be greater or less than the calculated values.

The deviations of the projectile trajectories from the computer predicted value of elevation may be due to a variance in the true jump or gun tube droop or to an error in the computed value of super-elevation (ϵ_o). Super-elevation (ϵ_o), under standard conditions, may be defined as the angle by which the projector (such as the gun barrel **14** in FIG. **2**) is pointed above the line-of-sight to a target and is illustrated in FIG. **2**. Errors in the computed value of the super-elevation ($\Delta\epsilon$) will occur when a plurality of nonstandard conditions effects are not included in the computation for reasons of simplicity or because of the unavailability of the appropriate sensors. Operational factors which are not included in the system for which the elevation jump error corrector circuit **17** is intended include projectile powder temperature (T_g), gun tube wear (E.F.C.), ambient air temperature (T_A) and variation in air pressure (P). In considering the effects of these operational factors it is reasonable to assume that the deviation in elevation of the projectile trajectories will be caused by $\Delta\epsilon$.

An equation for the standard conditions super-elevation ϵ_o (S) is:

$$\epsilon_o=\frac{mg}{2KV_0^2}\left(\frac{e^{2RK/m^{-1}}}{2RK/m}-1\right) \tag{2}$$

where:

R=the gun to target range.
$m/_K$=the normalizing constant for each projectile type (R_n).
m=the projectile mass.
K=a constant basically related to the drag characteristics affecting the projectile and caused by such factors as air pressure, air temperature, the aerodynamics of the projectile, etc.=$\frac{m}{R_n}$.
g=the acceleration due to gravity in meters per second squared.
V_0=the projectile velocity upon leaving the gun tube.
ϵ_o=super-elevation.

In order to determine the value to be assigned to $K_{2\mu}$ in the elevation channel, it is necessary to take the partial derivatives of ϵ_o, where ϵ_o was developed in equation number **2**, with respect to V_0 and with respect to K in order to derive the resultant correction factors introduced by the above-mentioned nonstandard condition terms (i.e., ΔT_g, ΔE.F.C., ΔT_A and ΔP). The equation for the partial derivative of ϵ_o with respect to V_0 is given by

$$\Delta\epsilon_{V_0}=(-2\epsilon)\frac{\Delta V_0}{V_0} \tag{3}$$

The equation for the partial derivative of ϵ_o with respect to K is given by

$$\Delta\epsilon_K=\left[-2\epsilon+\frac{g}{2}\frac{R_n}{V_0^2}(e^{2R/R_n}-1)\right]\frac{\Delta K}{K} \tag{4}$$

From an inspection of equations **2** through **4**, it is apparent that while the coefficients for ΔK and ΔV_0 are different, they are both proportional to $\frac{R_n}{V_0^2}$ for a given $\frac{R}{R_n}$ ratio. The $\frac{R}{R_n}$ ratio is determined by the projectile type that is being fired. The $\frac{R}{R_n}$ ratio is typically established at that range at which it is desired to fix the weights of ΔV_0 and ΔK and may be set at the maximum desired range or the most probable range. For illustrative purposes, assume the weights of ΔV_0 and ΔK are to be fixed at the maximum desired range such that, as in a typical case, the ratio $\frac{R}{R_n}=3/8$. By substituting the chosen value of the $\frac{R}{R_n}$ ratio in equations **3** and **4**, the following equations will respectively be derived.

$$\Delta\epsilon_{V_0}\cong\left(\frac{R_n}{V_0^2}\right)(5)\left(\frac{\Delta V_0}{V_0}\right) \text{ and,} \tag{5}$$

$$\Delta\epsilon_K\cong\left(\frac{R_n}{V_0^2}\right)(1.2)\left(\frac{\Delta K}{K}\right) \tag{6}$$

The value of the (K_{2p}) (X) term of equation 1 is given by the equation

$$(K_{2p})(X) \cong \Delta\epsilon_{V_0} + \Delta\epsilon_K \quad (7)$$

Since X, as previously defined, has a maximum value of one at the maximum range, the X-factor on the left-hand side of equation 1 drops out. The K_{2p} value for the elevation channel is then approximately equal to the sum of the jump corrections of and $\Delta\epsilon_K$, and is given by the equation

$$K_{2p} \cong \frac{R_n}{V_0^2}\left(5\,\frac{\Delta V_0(\text{max. range})}{V_0} + 1.2\,\frac{\Delta K(\text{ max. range})}{K}\right) \quad (8)$$

In typical case, $\frac{\Delta V_0(\text{max. range})}{V_0}$ $=.1$ and $\frac{\Delta K\ (\text{max. range})}{K}=.2.$

By substituting the values of these ratios in equation 7, the approximate value of K_{2p} is given by the relationship

$$K_{2p} \cong \frac{R_n}{V_0^2}\ (.74) \quad (9)$$

The approximate value of K_{2p} for the deflection channel is determined in a manner similar to that for the K_{2p} value in the elevation channel.

To further explain the control system of the invention, FIG. 2 illustrates a gun 14 with the gun reticle 13 mounted thereon and positioned in super-elevation ϵ_o to fire at target 16 at some range.

FIG. 3 illustrates a schematic circuit diagram in accordance with one embodiment of the invention. It should be noted however, that only the elevation channel is shown since the deflection channel is identical to the elevation channel with the possible exception of the use of different values for the components. A potentiometer 31 is connected at one end to a source of a positive reference voltage $+V_{Ref}$ and at the other end to a source of a negative reference voltage $-V_{Ref}$. As an example, $+V_{Ref}$ may be a positive 1.0 volts and $-V_{Ref}$ may be a negative 1.0 volts. The potentiometer 31 also has a center tap connected to a reference potential or ground in order to provide a less critical method of adjusting the movable arm 33 to zero volts and to minimize the loading of the potentiometer 31. The movable arm 33 is coupled through a resistor 35 to a noninverting input terminal (designated by the number 3) of an operational amplifier 37. The operational amplifier 37 can be a Fairchild μA709 high performance operational amplifier, manufactured by the Fairchild Semiconductor Corporation and described and illustrated in their handbook, Fairchild Semiconductor Linear Integrated circuits, Application Handbook, 1967. The operational amplifier 37 has an inverting input terminal (designated by the number 2), a noninverting input terminal (designated by the number 3) and an output terminal (designated by the number 6). A feedback resistor 39 is coupled between the output terminal 6 and the inverting input terminal 2 of the operational amplifier 37. The resistors 35 and 39 and the operational amplifier 37 present a high input impedance to the potentiometer 31 so as to prevent the loading and possible erroneous dial setting of the potentiometer 31, and also provide a noninverting unity gain output signal (X_E) at the output terminal 6 of the operational amplifier 37. For example, if the movable arm 33 were positioned such that there was +0.5 volts applied between the noninverting input terminal 3 and ground, the output signal (X_E) of the operational amplifier 37 would be equal to +0.5 volts. The circuit connections required for the operational amplifier 37 to present a high input impedance with a unity gain output (either inverted or noninverted) is well known in the art and is described in the Philbrick Researches Inc., Applications Manual for Computing Amplifiers, 1966, on page 40 of Section II.2. In this embodiment, the circuitry comprised of the potentiometer 31, resistors 35 and 39 and operational amplifier 37 correspond to the elevation correction entry circuit 21 of FIG. 1, with the output signal of the operational amplifier 37 representing X_E.

The X_E output from the operational amplifier 37 is applied to a movable pole 41 of a ganged two-pole, three-position switch 43, which represents one of the three switch sections (not shown) included in the selection switch 15 of FIG. 1. A local or remote control unit 46 is used to position the switch 43 as a function of the selected projectile type from either a local or remote position, depending upon the desired operation, as previously discussed in relation to FIG. 1. The other pole 45 of switch 43 is connected to the source of the positive reference potential $+V_{Ref.}$ While each pole of the switch 43 is shown to have three positions, it is to be understood that any desired number of positions could be utilized. Each of the positions for the poles 41 and 45 of switch 43 represents a projectile type that could be fired by the gun controlled by the computer 11. The X_E output from operational amplifier 37 and the positive reference potential are respectively applied through poles 41 and 45 to a switched resistor network 47 which in turn is connected to the inverting input terminal 2 of an operational amplifier 49. The operational amplifier 49 is similar to the operational amplifier 37 and provides a high input impedance to the resistor network 47. A feedback resistor 51 is connected between the output terminal 6 and the inverting input terminal 2 of the operational amplifier 49. The operational amplifier 49 may be connected as an inverter since the output of the resistor network 47 is applied to the inverting input terminal 2. The noninverting input terminal 3 of the operational amplifier 49 is connected through resistor 53 to the reference potential or ground in order to minimize the bias current error inherent in operational amplifiers.

The switched resistor network 47 includes first and second sets of parallel resistance branches 55 and 57, respectively. The first set of parallel branches 55 is composed of resistors 59, 61 and 63, each having a value representative of a different K_{1p}, and is coupled through the pole 45 to receive the positive reference voltage $+V_{Ref}$ in order to produce the selected K_{1p} term of equation 1. The second set of parallel resistance branches 57 is composed of resistors 65, 67 and 69, each having a value representing a different K_{2p}, and is coupled through pole 41 to receive the elevation short term correction signal X of the (K_{2p}) (X) term of equation 1. This second set of parallel resistance branches 57 produces the K_{2p} value which scales the X output (X_E) from the operational amplifier 37 as a function of the selected projectile type to produce the (K_{2p}) (X) term of equation 1. The K_{1p} term from the first set of parallel resistance branches 55 and the K_{2p}-scaled X value, or the (K_{2p}) (X) term, are applied to and summed at the inverting input 2 of the operational amplifier 49. The output signal at the output terminal 6 of the operational amplifier 49 is the jump error correction signal $J_{cp}(E)$ for the selected projectile type and is applied, as shown in FIG. 1, to the computer 11 to correct for the elevation jump error associated with the selected projectile type.

The operation of the circuitry of FIG. 3 will now be mathematically analyzed to correlate the operation thereof with equation 1. In general, the gain of an operational amplifier is controlled by the ratio of the feedback resistance to the input resistance. With switch 43 in the position shown, which indicates projectile type number 1 is to be fired, the gain of operational amplifier 49 would be determined by resistors 51, 59 and 65, the positive reference voltage $+V_{Ref}$ and the amplitude of the output signal X_E from operational amplifier 37, and is given by the equation

$$J_{cp_1}(E) = \left(+V_{\text{Ref}}\right)\left(\frac{R_{51}}{R_{59}}\right) + (X_E)\left(\frac{R_{51}}{R_{65}}\right) \quad (10)$$

where:

$J_{cp_1}(E)$ = the elevation jump error correction signal for projectile type number 1.

$+V_{Ref}=V_{K1p_1}=V_{K1p_2}=V_{K1p_3}$

X_E = the output of operational amplifier 37 which is determined by the mechanical setting of the movable arm 33 of potentiometer 31.

R_{51} = the feedback resistance of resistor 51 in the operational amplifier 49.

R_{59} = the resistance of the first set of parallel resistance branches 55 (resistor 59) which is switched into the circuit when projectile type number 1 is to be fired.

R_{65} = the resistance of the second set of parallel resistance branches 57 (resistor 65) which is coupled through pole 41 to the output terminal of the operational amplifier 37 when projectile type number 1 is selected to be fired.

In like fashion when switch **43** is placed in the second position, which indicates that projectile type number **2** is to be fired, the gain and hence the output of the operational amplifier **49** would be determined by the equation

$$J_{cp_2}(E)=(+V_{Ref})\left(\frac{R_{51}}{R_{61}}\right)+(X_E)\left(\frac{R_{51}}{R_{67}}\right) \quad (11)$$

and finally, when switch **43** is placed in the third position, which indicates that projectile type number **3** is to be fired, the output of the operational amplifier **49** would be determined by the equation

$$J_{cp_3}(E)=(+V_{Ref})\left(\frac{R_{51}}{R_{63}}\right)+(X_E)\left(\frac{R_{51}}{R_{69}}\right) \quad (12)$$

The first term on the right-hand side of any of the equations of **10**, **11** or **12** corresponds to the first term on the right-hand side of equation number **1** and the second term of any of the equations **10**, **11** and **12** corresponds to the second term on the right-hand side of equation **1**. As mentioned before, the mechanization, operation and mathematical analysis of the deflection channel, other than differences in value, are identical to those of the elevation channel illustrated in FIG. **3**.

A second embodiment of the invention is illustrated by the schematic circuit diagram of FIG. **4**. For the sake of simplicity, only the elevation channel is illustrated in FIG. **4** since the deflection channel is identical in structure, operation, and analysis to that of the elevation channel, with the exception of changes in the value of the components. A potentiometer **81**, which represents the elevation correction entry circuit **21** of FIG **1**, is connected between the movable poles **83** and **85** of a ganged two-pole, three-position switch **87**, which represents one of the three switch sections included in the selection switch **15** of FIG. **1**. A local/remote control unit **88** is used to position the switch **87** as a function of the selected projectile type from either a local or remote position in a manner similar to the local/remote control unit **46** of FIG. **3**. A first set of parallel resistance branches **89** includes the resistors **91**, **93** and **95**, which are respectively connected on one side to corresponding stationary terminals associated with the pole **83** of switch **87**. The junction point of the other side of the resistors **91**, **93** and **95** is connected to a source of positive reference potential $+V_{Ref.}$ A second set of parallel resistance branches **97** includes the resistors **99**, **101** and **103**, which are respectively connected on one side to corresponding stationary terminals associated with the pole **85** of switch **87**. The common junction point of the other side of the resistors is connected to a source of negative reference potential, $-V_{Ref.}$ A comparison of the circuitry of FIG. **3** to that of the elevation channel of FIG. **1** reveals that potentiometer **81** corresponds to the elevation correction entry circuit **21** of FIG. **1**; selection switch **87** corresponds to one of the three sections (not shown) in ganged projectile type selection switch **15**, and the first and second sets of parallel resistance branches **89** and **97** are contained within the elevation jump error corrector circuit **17** of FIG. **1**.

The operation of the circuit of FIG. **4** will now be explained in relation to the position of selection switch **87** as shown in FIG. **4**, which indicates that projectile type number one is to be fired. In this position the relationship of resistor **91** to resistor **99** will affect the value of the K_{1p_1} term of equation **1**. This is due to the fact that in position one, resistors **91** and **99** are placed in series with the entire resistance of potentiometer **81** and therefore the total current flowing from the source of positive reference potential ($+V_{Ref}$) to the source of the negative reference potential ($-V_{Ref}$) is fixed and is not affected by the position of the movable arm of the potentiometer **81**. The X value of equation **1** can be correlated with the position of the movable arm of potentiometer **81** and is basically just the mechanical setting of the potentiometer **81** which, for example, may vary from +1 to −1. The total resistance of the potentiometer **81** in relation to the resistances of resistors **91** and **99** will affect the K_{2p} value, and hence provide a scaling factor to the X value, by determining what portion of the total voltage applied will be dropped across the total resistance of the potentiometer **81**. It will be recalled that the setting X of the potentiometer will be scaled as a function of the selected projectile type by this K_{2p} value. A portion of the voltage drop across the potentiometer, as determined by the setting X of the potentiometer, will be tapped off as the output jump error correction signal $J_{cp}(E)$. In order to determine the amplitude of the elevation jump error correction signal $J_{cp_1}(E)$ which is applied to the computer **11** in FIG. **1**, the resistance between the movable arm of the potentiometer **81** and the resistor **99** must be determined and will hereinafter be referred to as R_X. Since X is the mechanical setting of the potentiometer **81**, when the movable arm is positioned all the way up, the dial setting X = 1 and R_X = the resistance of R81; when the movable arm is positioned halfway up, the dial setting of X = **0** and R_X = ½ of the resistance of potentiometer **81**; and when the arm is all the way down, the dial setting X = −1 and R_X = 0. This information can be inserted in the general equation of a straight line in order to show the relationship of R_X to the dial setting in terms of the resistance of potentiometer **81** (R_{81}) as follows:

$$R_X=\left(\frac{X+1}{2}\right)(R_{81}) \quad (13)$$

where the total current through the serially connected resistances of the resistors **91** and **99** and the potentiometer **81** can be determined by the equation

$$I_T=\frac{V_{Ref}-(-V_{Ref})}{R_{91}+R_{81}+R_{99}} \quad (14)$$

Using the information from equations **13** and **14** the output jump error correction signal $J_{cp_1}(E)$ can be determined by the equation

$$J_{cp_1}(E)=\left[\frac{V_{Ref}-(-V_{Ref})}{R_{91}+R_{81}+R_{99}}\right]\left[\left(\frac{X+1}{2}\right)R_{81}+R_{99}\right]-V_{Ref} \quad (15)$$

where:

R_{91} = the resistance of resistor 91 which is the resistance presented by the first set of parallel resistance branches 89 to one side of the potentiometer 81 when the selection switch 87 indicates that the first projectile type is to be fired.

R_{99} = the resistance of resistor 99 which is presented by the second set of parallel resistance branches 97 to the other side of potentiometer 81 when the selection switch 87 indicates that the first projectile type is to be fired.

X = the mechanical dial setting of the movable arm of the potentiometer **81** which may have a range of +1.0 to −1.0. The equation **15** may be readily reduced and rewritten as

$$J_{cp_1}(E)=\left(\frac{2V_{Ref}}{R_{91}+R_{81}+R_{99}}\right)\left(\frac{X.R_{81}}{2}\right)+\left(\frac{2.V_{Ref}}{R_{91}+R_{81}+R_{99}}\right)\left(R_{99}+\frac{R_{81}}{2}\right)-V_{Ref} \quad (16)$$

The equation 16 can then be written in the form

$$J_{cp_1}(E)=V_{Ref}\left[X\left(\frac{R_{81}}{R_{91}+R_{81}+R_{99}}\right)+\left(\frac{R_{99}-R_{91}}{R_{91}+R_{81}+R_{99}}\right)\right]-V_{Ref} \quad (17)$$

It is therefore apparent that, when projectile number one is to be fired, the K_{1p} term of equation 1 in the elevation channel can be given by the equation

$$K_{1p_1}(E)=\frac{R_{99}-R_{91}}{R_{91}+R_{81}+R_{99}} \quad (18)$$

and that the value for K_{2p} for the elevation channel can be determined by the equation

$$K_{2p_1}=\frac{R_{81}}{R_{91}+R_{81}+R_{99}} \quad (19)$$

As shown in equation number 17, the K_{2p_1} value scales the value of X.

When the selection switch 87 is placed in the second position, indicating that the projectile type number two is to be fired, resistors 93 and 101 are serially coupled to the potentiometer 81; and when selection switch 87 is in the third position, indicating that the projectile number three is to be fired, resistors 95 and 103 are serially coupled to the potentiometer 81. The K_{1p} and K_{2p} quantities, when the selection switch 87 is placed in either the second or third position, are derived in a similar manner to that described in relation to position one. In a like manner, the K_{1p} and K_{2p} values for the deflection channel in each of the three positions of the selection switch 87 can be similarly derived.

In the embodiment shown in FIG. 4 it is necessary that the output jump error correction signal $J_{cp}(E)$ must first be applied to a high input impedance voltage follower (not shown) similar to the operational amplifier 37 of FIG. 2 before being applied to the computer 11 in order to prevent the loading of the potentiometer 81. This is due to the fact that any loading of the potentiometer 81 would cause errors in the value of the jump error correction signal.

The invention thus provides a system for generating jump error correction signals to compensate for the jump errors associated with each of a plurality of different projectile types to be fired by a gun, wherein only a single control is required for each of the elevation and deflection channels although a plurality of different projectile types may be fired.

While the salient features have been illustrated and described with respect to two particular embodiments, it should be readily apparent that modifications can be made within the spirit and scope of the invention as set forth in the appended claims.

We claim:

1. A system having elevation and deflection channels for supplying error correction signals to a gun computer to correct for firing errors respectively associated with a plurality of different types of projectiles wherein each of the channels comprises:

entry means for providing a short term channel correction signal for the plurality of projectile types;

control means coupled to said entry means for providing a selection of the projectile type; and

corrector means coupled to said control means and being responsive to the short term correction signal and to the selection of the projectile type for scaling the corresponding short term channel correction signal as a function of the selected projectile type to develop the proper channel error correction signal.

2. The system of claim 1 wherein said corrector means includes circuitry for producing first and second constant values, using the second constant value to scale the short term correction signal as a function of the selected projectile type and adding the scaled short term correction signal to the first constant value so that the proper channel error correction signal is produced for the selected projectile type.

3. The system of claim 1 wherein said entry means includes a variable resistor having an adjustable output terminal.

4. The system of claim 1 wherein:

said control means of the elevation channel includes an elevation selector switch; and

said control means of the deflection channel includes a deflection selector switch ganged with said elevation selector switch, each of said elevation and deflection switches including first and second ganged poles, each of said ganged poles having a plurality of corresponding switch positions respectively corresponding to the plurality of different types of projectiles to be fired by the gun.

5. The system of claim 4 wherein said entry means includes a variable resistor having an adjustable output terminal.

6. The system of claim 3 wherein:

said corrector means includes first and second pluralities of resistors; and

said control means includes first and second switching circuits, said first switching circuit being coupled between said first plurality of resistors and one side of said variable resistor, and said second switching circuit being coupled between said second plurality of resistors and the other side of said variable resistor, said first and second switching circuits respectively coupling one resistor from each of said first and second pluralities of resistors in series with said variable resistor as a function of the selected projectile type; whereby the channel error correction signal is supplied from each channel to the gun computer from said adjustable output terminal as a function of the ratio of the values of each of the resistors coupled in series with said variable resistor to each other and to said variable resistor along with the setting of said adjustable output terminal.

7. The system of claim 6 further including:

first means coupled to said first plurality of resistors for receiving a first reference potential; and

second means coupled to said second plurality of resistors for receiving a second reference potential, said channel error correction signal being supplied from said adjustable terminal of said variable resistor as a function of the first and second reference potentials and the position of said adjustable terminal on said variable resistor, the value of said variable resistor, and the relative values of the resistors respectively coupled in series with said variable resistor as a function of the selected projectile type.

8. The system of claim 1 wherein said entry means comprises:

a variable resistor having a grounded center tap, a first terminal for receiving a first reference potential, a second terminal for receiving a second reference potential, and an adjustable arm; and

first amplifier means coupled to said adjustable arm of said variable resistor for applying the short term channel correction signal to said control means.

9. The system of claim 8 wherein said corrector means includes first and second pluralities of resistors selectively coupled to said control means as a function of the selected projectile type.

10. The system of claim 9 wherein said control means further includes:

first means coupled to said first terminal for receiving the first reference potential;

second means coupled to said first amplifier means for receiving the short term channel correction signal;

a first switching circuit coupled between said first plurality of resistors and said first means; and

a second switching circuit coupled between said second plurality of resistors and said second means; whereby said first and second switching circuits respectively couple one resistor from each of said first and second pluralities of resistors in series with each other as a function of the selected projectile type.

11. The system of claim 1 wherein:

said control means includes first means for receiving a first reference potential; and

said corrector means includes amplifier means having an input circuit for receiving the scaled short term channel correction signal and an output circuit for supplying the output channel error correction signal to the gun computer, and first and second pluralities of resistors selectively coupled between said input circuit of said amplifier means and said control means; whereby the gain of said amplifier means is a function of the respective resistors from said first and second pluralities of resistors applied thereto, the short term correction signal from said entry means and the first reference potential, and the output of said amplifier means is a function of the gain of said amplifier means.

12. The system of claim 8 wherein:

said control means includes first means for receiving the first reference potential; and

said corrector means includes second amplifier means having an input circuit for receiving an input signal and an output circuit for supplying the output channel error correction signal to the gun computer, and first and second

pluralities of resistors selectively coupled between said input circuit of said second amplifier means and said control means; whereby the gain of said second amplifier means is a function of the respective resistors from said first and second pluralities of resistors applied thereto, the output of said first amplifier means and the first reference potential, and the output of said second amplifier means is a function of the gain of said second amplifier means.

13. The system of claim 12 wherein said control means further includes:

first means for receiving the first reference potential;

second means coupled to said first amplifier means for receiving the short term channel correction signal;

a first switching circuit coupled between said first plurality of resistors and said first means; and

a second switching circuit coupled between said second plurality of resistors and said second means; whereby said first and second switching circuits respectively couple one resistor from each of said first and second pluralities of resistors in series with each other as a function of the selected projectile type.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,551,688 Dated Dec. 29, 1970

Inventor(s) Roger, H. Edelson, Millard M. Frohock, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 59, "product" instead of "produce".

Column 4, line 19, "$\varepsilon_o = \frac{mg}{2KV_o^2}\left(\frac{e^{2RK/m}-1}{2RK/m} - 1\right)$" instead of

"$\varepsilon_o = \frac{mg}{2KV_o^2}\left(\frac{e2RK/m^{-1}}{2RK/m} - 1\right)$".

Column 5, line 7, "equation 7" instead of "equation 1".

Column 5, line 9, after "of" and before "and" insert

"$\Delta\varepsilon_{V_o}$".

Signed and sealed this 18th day of May 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR
Commissioner of Patents