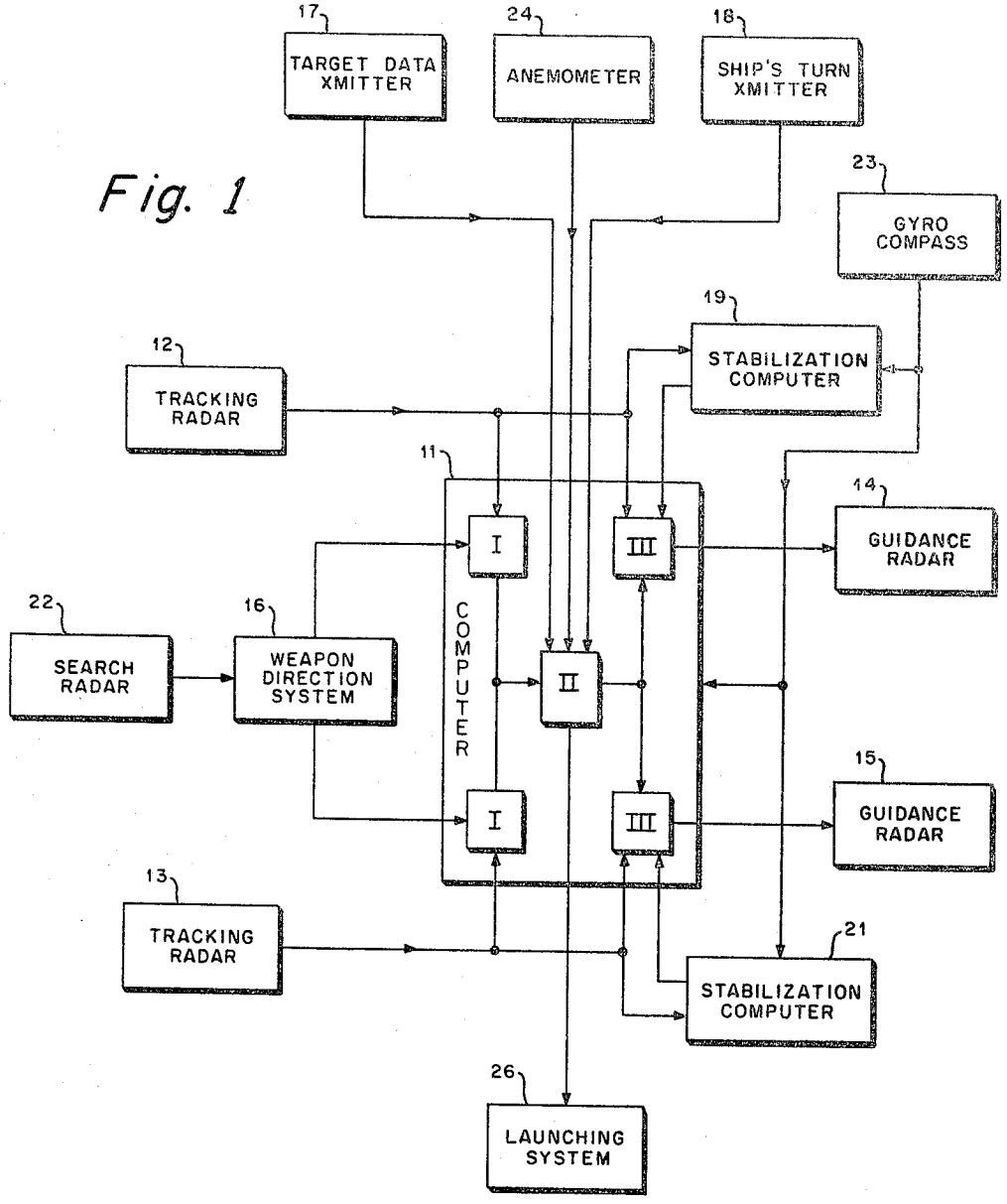
Dec. 5, 1967 D. J. CAMPBELL ETAL 3,356,314

BEAM CAPTURE MISSILE GUIDANCE SYSTEM

Filed Oct. 24, 1963 4 Sheets-Sheet 1

Fig. 1



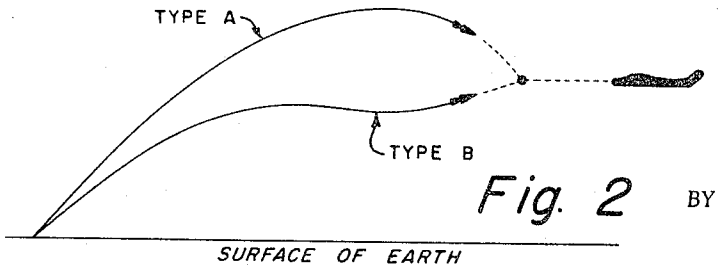


Fig. 2

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Fig. 3

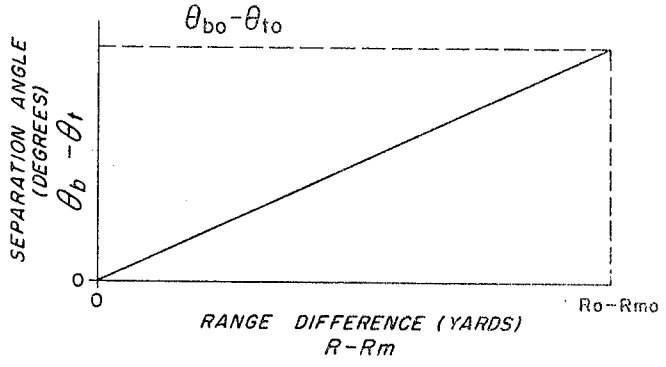
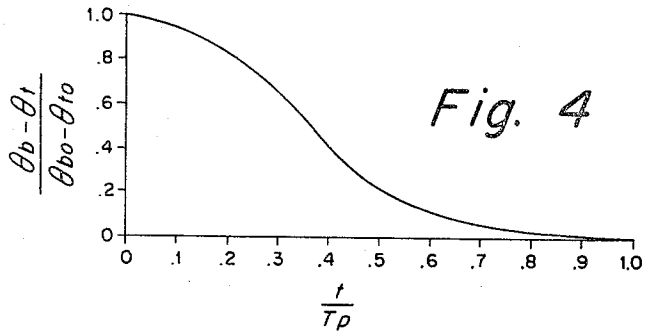


Fig. 4



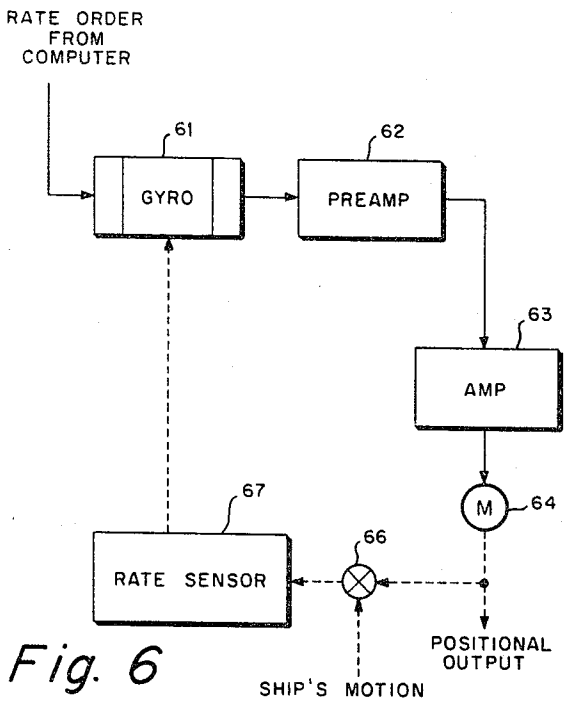


Fig. 6

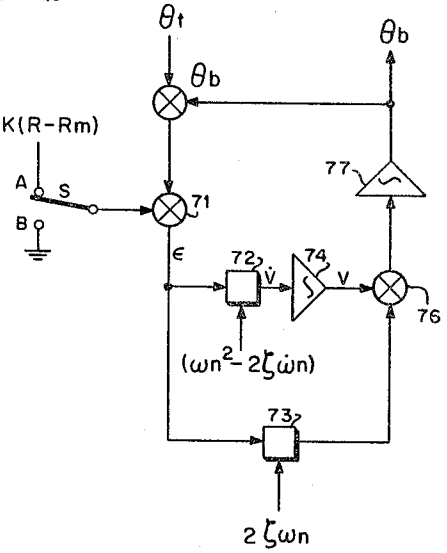


Fig. 5

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BEAM CAPTURE MISSILE GUIDANCE SYSTEM

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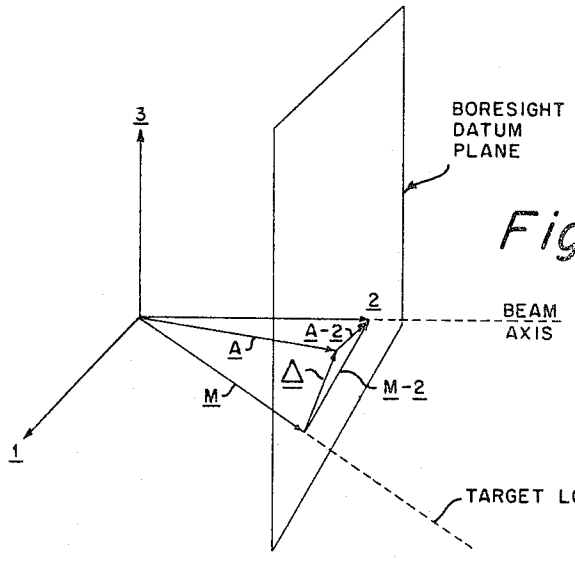


Fig. 7

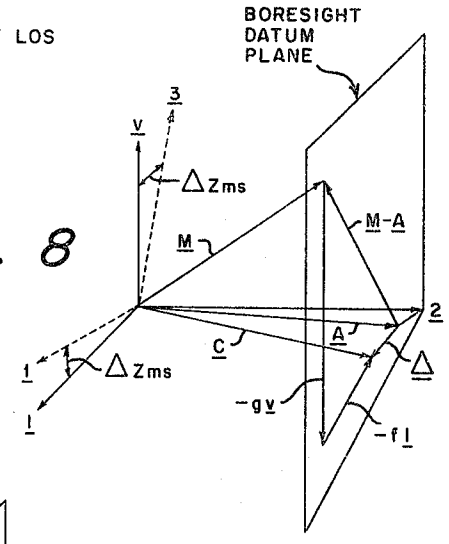


Fig. 8

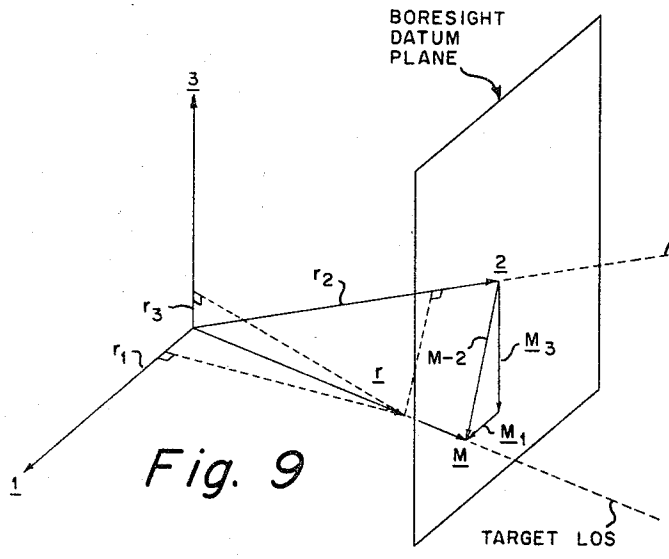


Fig. 9

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BEAM CAPTURE MISSILE GUIDANCE SYSTEM

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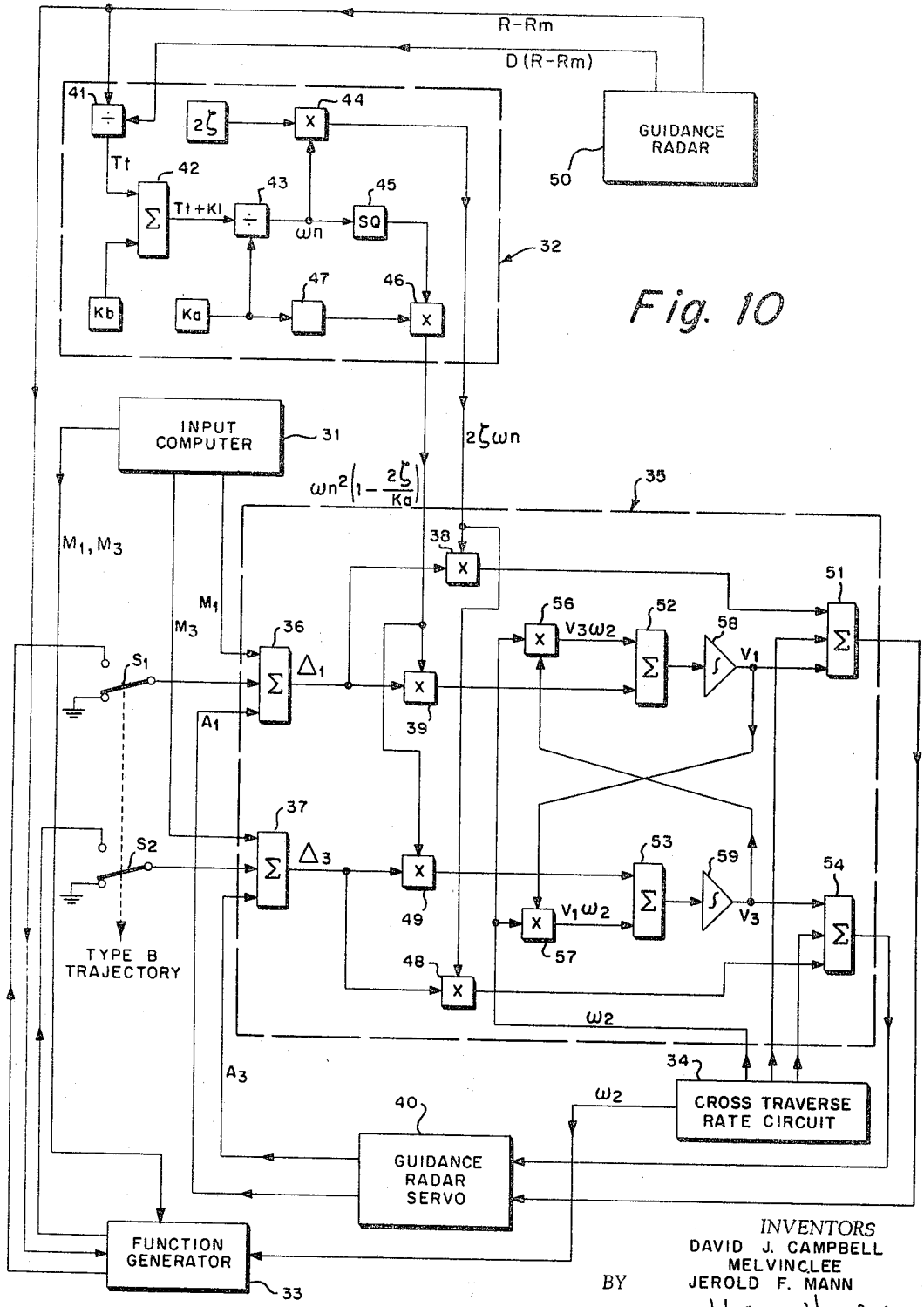


Fig. 10

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3,356,314

BEAM CAPTURE MISSILE GUIDANCE SYSTEM

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Filed Oct. 24, 1963, Ser. No. 319,094
13 Claims. (Cl. 244—3.13)

This invention relates to a computer system and more particularly to a computer system for programming and transmitting guidance information to a beam riding missile.

In a relatively new field of missile guidance, various techniques are used to guide a missile to a predetermined destination. The guiding systems for long range missiles are usually highly complicated inertial guidance systems utilizing computer techniques based on earth or space references. In these missile guidance systems the missile itself contains all or most of the guidance equipment necessary for its own guidance. Thus, the missile guidance system is self contained in a missile and once destination information is set into the guidance system, the missile in effect guides itself to the predetermined destination.

When anticipated targets are within radar range, it is possible to guide a missile to a predetermined destination by external beam guidance techniques. Thus, the bulk of the guidance system may be external to the missile and the missile contains a minimum amount of guidance equipment.

The present invention contemplates a computer for providing mid-course guidance for short range anti-aircraft missiles. Mid-course guidance begins when the missile is captured in the programmed guidance beam and ends when homing starts for the self-homing type missile or at target intercept for the remotely detonated missile. After launching of the missile, the missile is captured by the radar guidance beam and thereafter the missile operates as a beam rider. This invention provides a guidance beam program which has a high degree of space stabilization from capture to target intercept. Since excessive residual beam motion or jitter induces unnecessary drag on the missile, the present invention contemplates a beam guidance which substantially eliminates residual beam motion or jitter.

During initial guidance the computer generates outputs which position the guidance beam to cause the missile to follow an up and over trajectory in one mode while in another mode the guidance beam causes the missile to follow a line of sight path to the target. Interception of the missile with the target is effected by bringing the missile and target tracking beams together as the missile reaches the target, i.e., as a function of change in range between target and missile. On arriving at the target the missile warhead may be detonated by a proximity fuse at the end of a homing program initiated somewhat previous to target contact. Alternately beam riding may be continued until there is range coincidence at which time detonation may be commanded remotely.

The missile guidance programmer computer of the present invention forms the principal guidance system of a more complex weapons control system. The weapons control system which forms no part of this invention selects, tracks a target, and calculates all necessary data for launching the missile into the guidance radar beam of the present invention. After the missile is launched and captured by the beam, it is directed to the target by the guidance information contained in the radar guidance beam provided by the present invention. During the course of missile flight the guidance information is furnished to the guidance radar set by the computer based on the continuous tracking information being received from a tracking radar. Upon reaching the vicinity of the target, the missile receives tracking radar energy reflected from the target which it utilizes to home on the target and subsequently to be detonated by a proximity fuse. Alternately the missile may ride the guidance beam all the way to the target and be detonated at the proper instant by a commanded signal transmitted in the guidance beam.

Therefore, it is an object of the present invention to provide a computer system for programming and transmitting guidance information to a beam riding missile.

Another object of the present invention is to provide a computer which selectively programs a missile flight in one of two modes by transmitting a modulated guidance beam to a beam riding missile for guidance of the missile to target intercept.

A further object of the present invention is to provide a mid-course guidance program for a beam riding missile which has a high degree of space stabilization to effectively reduce adverse drag on the missile caused by residual beam motion or jitter.

With these and other objects in view, as will hereinafter more fully appear, and which will be more particularly pointed out in the appended claims reference is now made to the following description taken in connection with the accompanying drawings in which:

FIG. 1 illustrates the weapons control system of which the present invention forms a part;

FIG. 2 illustrates the two missile trajectories which may be programmed by the present invention;

FIG. 3 is a graphical illustration of the type A beam program;

FIG. 4 is a graphical illustration of the type B beam program;

FIG. 5 illustrates a second-order smoothing circuit utilized by the present invention;

FIG. 6 is a simplified block diagram of the guidance transmitter servo loop;

FIG. 7 is a vector diagram for the type A program;

FIG. 8 is a vector diagram for the type B program;

FIG. 9 illustrates the coordinate transformation required for component development; and

FIG. 10 is a more detailed block diagram of a portion of the system of FIG. 1.

Referring now more particularly to FIG. 1 there is shown the weapons control system of which the present invention forms an integral part and which is disclosed to set forth the environment of the present invention to provide an adequate understanding and appreciation of the present invention. The weapons control system as shown in FIG. 1 is an integrated missile guidance system primarily designed as an anti-aircraft device which functions to select or designate, track, intercept, and destroy high speed enemy aircraft. The particular type of missile for which the weapons control system was developed is a short range ram jet propelled beam-rider type whose warhead may be detonated upon receipt of a command signal from the fire control system when the missile is within destruction range of an enemy aircraft or whose warhead may be detonated by a proximity fuse automatically set off when the missile is within destruction range of the enemy aircraft.

The weapon control system shown in FIG. 1 comprises the following major components: the general dual simplex computer system **11** of which Sections III form the subject of the present invention, two radar tracking sets **12** and **13**, two radar guidance sets **14** and **15**, one weapon direction system **16**, one target data transmitter **17**, one ship's turn transmitter **18** and two stabilization computers **19** and **21**. The output of a search radar **22** is connected directly to the weapon direction system **16**.

The general dual simplex system **11** receives specific target assignments and technical commands from the weapon direction system **16** which has outputs connected individually to Section I of general dual simplex computer **11**. Target positional data from search radar **22** and pitch and roll from gyro compass **23** are fed to the general dual simplex computer **11** to initiate the target designation phase. Own ship's data is obtained from ship's turn transmitter **18**, stabilization computers **19** and **21**, anemometer **24**, and are fed as shown into general dual simplex computer **11**. The general dual simplex computer system **11** is designed to handle two targets simultaneously. It is therefore a dual channel device which accounts for the duplication of tracking guidance radars, etc.

Where considering the case of one target, a tracking radar, for example tracking radar **12**, acquires target position data and on this basis tracks the target automatically providing continuous outputs to the general dual simplex computer **11** which smooths this positional information, generates rates and provides a prediction of intercept position. The general dual simplex computer **11** develops necessary computations and corrections of the intercept data for the system's use and transmits orders based on these data to launching system **26** and to guidance radar **14**. Where there are two targets, tracking radar **13** and guidance radar **15** will also be functioning.

The orders from Section II of general dual simplex computer **11** position the launching platform and the guidance radar **14** so that the missile will be launched into the guidance radar beam. When the missile is launched and captured by the guidance radar beam it is directed to the target by the guidance radar beam from guidance radar **14**. Throughout the course of its flight, guidance information is furnished to the guidance radar **14** from general dual simplex computer **11** which information is based on the continuous tracking information being received from tracking radar **12**. The missile uses this information to home on the target and subsequently to be detonated by a proximity fuse or alternately the missile may ride the guidance beam all the way to the target to be detonated at the proper instant by a commanded signal in the guidance radar beam intelligence.

The above description of FIG. 1 is intended as background information only and no attempt will be made to describe FIG. 1 in rigorous detail since it forms no part of the present invention.

The general dual simplex computer **11** comprises three sections which perform particular functions. Section I of which two are required, performs the:

(a) computation of search orders for radar designation (acquisition and designate mode),
(b) conversion of target coordinate (gimbal computer),
(c) prediction of intercept point and position (prediction computer).

Section II of which only one is required performs the:

(a) generation of capture angles (capture computer), dead zone computation (dead zone computer),
(b) generation of missile launching orders (launching computer).

Section III which embodies the present invention and of which two are required comprises the guidance control.

Thus, Sections I and II of general dual simplex computer **11** contain preengagement computation equipment while the third section, Section III, contains the missile guidance control equipment.

Section I of the general dual simplex computer **11** functions to perform the computations to position the tracking radar for target acquisition to predict target intercept conditions. These operations are executed within Section I of the computer by a coordinate converter, elevation search programmer, and predictor. By means of the coordinate converter and search programmer, the weapon

control system of FIG. 1 designates target to tracking radars by supplying to the computer East-West and North-South slant range components of target position and the minimum and maximum target height or true target elevation angles. Section I of the computer then generates an elevation search program which causes the tracking radar to scan up and down in true elevation at the designated true bearing.

The maximum and minimum elevations for the scan functions are determined by the designated target height limits and the slant range of the target. The elevation scan rate is an inverse function of slant range so that the probable acquisition times remain approximately the same at all ranges. Smaller acquisition times result whenever the spread between the height limits is decreased or when more accurate height information is available to the weapon control station.

By appropriate means true bearing and elevation angles are transformed into deck angles of the station. These angles are then transmitted as point orders to the tracking radar **12**. The predictor circuit contained in Section I of the computer utilizes data representing target present position, intercept position and time-to-intercept to predict a value of time to fire to the computer.

The point orders necessary for missile launching are generated in Section II of the general dual simplex computer **11** and fed to launching system **26**. Section II of the general dual simplex computer **11** contains a capture computer unit which generates in stable coordinates the bearing and elevation angles at which the missile will be captured in the guidance beam. At medium and long ranges the capture bearing angle is given by the present position of the target plus a lead angle based on the horizontal velocity and a fixed value for the flight time, thereby resulting in a decreasing lead angle as the range increases. The elevation angles at the ranges are functions of predicted target intercept position such that the maximum allowable superelevation is obtained. At short ranges both bearing and elevation capture angles are directly representative of the intercept position of the target.

Section III of the general dual simplex computer **11** forms the subject matter of this invention. It is this device which programs the missile flight. The beam program generated by Section III is designed to combine the required smoothing and programming functions in a circuit the time constant of which is a function of the remaining time of flight of the missile. The beam programming function of Section III of the general dual simplex computer consists of five basic blocks. These five basic blocks comprise input computer **31**, beam sensitivity computer **32**, function generator **33**, cross traverse rate circuit **34**, and smoothing circuit **35**.

FIG. 10 illustrates Section III of the general dual simplex computer **11** showing the details of beam sensitivity computer **32** and smoothing circuit **35**. Input computer **31**, function generator **33** and cross traverse rate circuit **34** are shown as blocks.

Input computer **31** transforms launcher angles into quantities required by the guidance control system and provides these transformed launch angles as inputs to the smoothing circuit **35** for generating transmitter orders for missile capture. During lift-off of the missile from the launcher, the transmitter beam is held stationary in space. Following capture of the missile by the transmitter beam, input computer **31** provides target angles through smoothing circuit **35** and radar tracking information is processed to produce the appropriate input signals to the smoothing circuit **35** for the guidance mode. All appropriate switching which places the system in aiming memory and guiding modes of operation is included within the input computer **31**.

The beam sensitivity computer **32** which is connected to smoothing circuit **35** varies the sensitivity of the smoothing circuit **35** as a function of time to intercept. Thus,

smooth beam riding characteristics are obtained in the early part of mid-course guidance when the input data to the guidance system may be noisy without sacrificing accuracy when the missile approaches the intercept point. Depending upon tactical conditions, the smoothing circuit may be used to generate alternate trajectories, such as the type A trajectory, or the line of sight trajectory B.

The up and over trajectory type A is realized by a function generated in function generator **33** which when added to the inputs of the smoothing circuit **35** causes the missile to follow an up and over trajectory.

The two trajectories type A and type B are illustrated in FIG. 2. With no input to the smoothing circuit **35** from function generator **33**, type B trajectory will be automatically programmed. When function generator **33** is connected to smoothing circuit **35** as more fully discussed hereinbelow, the type A or up and over trajectory is programmed.

Since there may be a dynamic error in the torques applied to the elevation and traverse gyros which position the beam when there is any angular velocity about the line of sight when other angular velocities are present, a cross traverse rate circuit **34** is provided to generate the appropriate correction torques for application to the traverse and elevation gyros.

Smoothing circuit **35** is a second order smoothing circuit wherein the second integration is performed by the traverse and elevation gyros on the antenna mount of the launching platform. In actuality, the outputs of the first stage of the smoothing circuit **35** are transmitted to the guidance transmitter for presetting the elevation and traverse gyros of the antenna mount. The gyro pickoffs themselves provide the final outputs of the smoothing circuit and these outputs are used to control antenna power servos thus producing the desired motion of the beam.

In order to provide a cogent detailed description of FIG. 10 it is necessary to start with the general case, where the type A program can be expressed analytically as follows:

$$\theta_b-\theta_t=K(R-Rm) \tag{1}$$

where:

$$K=\frac{\theta_{bo}-\theta_{to}}{Ro-Rmo}$$

$\theta_b-\theta_t$=angular separation between the guidance and tracking beams,

$R-Rm$=missile-target range difference, and

the symbol o is used to denote conditions at the start of the beam program.

The type A beam program as may be seen by reference to FIG. 3 is a linear function of the difference between the slant ranges to the target and the missile. Target intercept occurs when the range difference reduces to zero. At this point, the angular separation between the guidance and tracking beams also reduces to zero, thereby resulting in a crossover between the two beams. The type B program is defined by the cosine-squared expression:

$$\theta_b-\theta_t=\tfrac{1}{4}(\theta_{bo}-\theta_{to})\left(1+\cos\frac{\pi_t}{Tp}\right)^2 \tag{2}$$

FIG. 4 illustrates the type B program as having a shape that approaches zero asymptotically in the vicinity of the target intercept point. This makes an exact measure of the time-to-intercept unnecessary and thus the type B program depends less upon range than does the type A program.

In generating the type B beam program, the computer utilizes the properties of a second-order smoothing circuit shown in FIG. 5. The first stage of integration is provided by the computer and the second by the guidance radar closed loop response. Target and beam positional data are compared in differential **71** to produce an error.

This error, ϵ, is multiplied in multipliers **72** and **73** by the beam sensitivity parameters $2\zeta\omega n$ and

$$(\omega n^2-2\zeta\dot{\omega}n)$$

respectively. The output from multiplier **73** is combined with the output from multiplier **72** in differential **76** after it has been integrated in integrator **74** to generate a guidance beam rate. This rate is then converted into an angular output by the guidance radar servo system represented symbolically by integrator **77**. Depending on whether the type A or type B program is considered, the type of operation of the guidance control loop is either predominantly steady-state or predominantly transient. The type A program results in steady-state operation, whereas the type B program utilizes the transient response of the guidance loop.

When the switch in FIG. 5 is in the B position, the following parametric equations can be written:

$$\epsilon=\theta_t-\theta_b \tag{3a}$$

$$\dot{V}=(\omega n^2-2\zeta\dot{\omega}n)\epsilon \tag{3b}$$

$$\dot{\theta}_b=2\zeta\omega n\epsilon+V \tag{3c}$$

The equation which relates the beam separation angle to the target in the beam program is the one of interest. Eliminating θ_b and V from the above three equations yields the desired equation:

$$\ddot{\epsilon}+2\zeta\omega n\dot{\epsilon}+\omega n^2\epsilon=\ddot{\theta}_t \tag{4}$$

Equation 4 can be used to demonstrate that in the steady-state condition, the circuit does not exhibit a lag due to input rates. Assuming that ωn is a constant, the Laplace transform of this equation is given by:

$$\frac{E(s)}{\theta_t(s)}=\frac{s^2}{s^2-2\zeta\omega ns+\omega n^2}$$

A series expansion of the foregoing expression in increasing powers of s results in the following error expression:

$$E(s)=\left[\frac{s^2}{\omega n^2}-\frac{2\zeta s^3}{\omega n^3}-\cdots\right]\theta_t(s)$$

Since the lowest order term of Equation 4 is represented by the second derivative (or acceleration) of the input, it is apparent that the steady-state error is zero for a non-accelerating input.

Considering the physical properties of the circuit of FIG. 5 also makes it apparent that the circuit does not have rate lag. For a constant input rate, the first integrator charges up to the desired rate as the error in the loop reduces to zero. When the steady-state condition is reached, the stored rate in this integrator maintains a constant rate output and the loop operates with zero error. Constrasting this circuit with first order circuits with respect to system lags, this circuit has an advantage over a first order circuit because a comparable degree of accuracy is obtainable with a lower level of loop sensitivity. Used in conjunction with the beam programmer of the present invention, this feature is desirable because a decrease is required loop gain results in decreased system bandwidth and, consequently, in heavier smoothing. This is desirable since it is only necessary to provide sufficient gain near target intercept to enable the system to respond to target maneuvers.

In the generation of the type B beam program proper control of the beam sensitivity parameters makes it possible to match the step-function response of the guidance loop to the cosin-squared program shape. To obtain the required function for this control it is necessary to substitute the appropriate time expressions determined from the cosine-squared formula for ϵ and its derivatives in Equation 4. From this a function of ωn is obtained which, if it is applied to the guidance loop, controls the error response to produce a cosin-squared program shape. In practice, it is not necessary to simulate the complex func-

tion exactly and a sufficiently close approximation to the desired curve may be obtained by allowing ωn to vary inversely with time-to-intercept by the following equation:

$$\omega n = \frac{Ka}{Tt}$$

Substituting this equation into the Equation 4 results in the following expression of Equation 4:

$$\ddot{\epsilon} + \frac{2\zeta Ka}{Tt}\dot{\epsilon} + \frac{Ka^2}{Tt^2}\epsilon = \ddot{\theta}_t$$

Since $Tt=Tp-t$, i.e., time-to-go before intercept equals the total program time minus the elapsed time, for the case with no target motion, Equation 4 can be written as follows:

$$Tt^2\ddot{\epsilon} - 2\zeta KaTt\dot{\epsilon} + Ka^2\epsilon = 0$$

The solution of the above equation represents the beam program and is given by the expression (where at $Tt=Tp-t$, $\epsilon=\epsilon_0$ and $\dot{\epsilon}=0$):

$$\epsilon = \epsilon_0\left[\left(\frac{\alpha}{\alpha-\beta}\right)\left(\frac{Tt}{Tp}\right)^{\beta} - \left(\frac{\beta}{\alpha-\beta}\right)\left(\frac{Tt}{Tp}\right)^{\alpha}\right]$$

where:

$$\alpha = \tfrac{1}{2}[(1+2\zeta Ka)^2 + \sqrt{(1+2\zeta Ka)^2 - 4Ka^2}]$$

$$\beta = \tfrac{1}{2}[(1+2\zeta Ka)^2 - \sqrt{(1+2\zeta Ka)^2 - 4Ka^2}]$$

For the type A beam program, the guidance radar must respond to keep the error between the forcing function, $K(R-R_m)$, in FIG. 5 and the beam separation angle small. To accomplish this, the guidance loop should approach steady-state operation as soon as practicable. This requirement for a relatively rapid response calls for loop sensitivities which are substantially higher than those normally encountered in the type B program. While additional loop gain is supplied to increase the response, caution has been exercised to guard against too great a loss in system smoothing. Therefore, an arrangement which maintains ωn constant during a major portion of the trajectory is required. Since increased system sensitivity necessary to insure proper target intercept is required only near the end of the beam program, ωn starts out being a constant and, at a predetermined time before intercept, switches over to a variable mode. The present computer arrangement features an $\omega n=0.16$ radian per second until 52.5 seconds before intercept. Below this value of time-to-intercept, ωn increases to 1 radian per second according to the following relationship:

$$\omega_n = \frac{Ka}{Tt+Kb} \qquad (5)$$

This arrangement produces three categories of system response:

(a) settling time fixed,
(b) settling time a given percentage of total time-of flight, and
(c) a combination of both.

Of these categories the one applicable to any particular engagement is strictly a function of the initial time-to-intercept. In any situation, however, the settling time is never larger than that resulting from the case in which ωn is a constant. System response to the forcing function for either the constant or variable case is readily obtainable from the error equation of the system. If ϵ is redefined to signify the error between the beam separation angle and the forcing function, Equation 4 can be rewritten as:

$$\ddot{\epsilon} + 2\zeta\omega n\dot{\epsilon} + \omega n^2\epsilon = \ddot{\theta}_t - K(\ddot{R} - \ddot{R}m) \qquad (6)$$

In the case of a stationary target and assuming that the range to the missile varies linearly, the above equation reduces to:

$$\ddot{\epsilon} + 2\zeta\omega n\dot{\epsilon} + \omega n^2\epsilon = 0$$

This equation is similar in form to the error equation for the type B program but ϵ is now representative of the error between the forcing function and the missile-target angular difference. Initially, the beam separation angle is equal to the forcing function which makes ϵ equal to zero. Since the system is initially at rest, $\dot{\epsilon}$ is equal to the rate of change of the forcing function or:

$$\dot{\epsilon}(0) = -K\dot{R}m = -KVm$$

Where the above initial conditions are present and for ζ equal to unity and ωn equal to a constant, the solution to the second equation above is:

$$e(t) = -KVmte^{-\omega nt}$$

When:

$$\omega_n = \frac{Ka}{Tt+Kb}$$

$$\epsilon(t) = \frac{KVmTp}{\sqrt{4Ka+1}}\left[\left(\frac{Tt}{Tp}\right)^{\alpha} - \left(\frac{Tt}{Tp}\right)^{\beta}\right]$$

where:

$$\alpha = \tfrac{1}{2}(1+2\zeta Ka+\sqrt{4Ka+1})$$

and:

$$\beta = \tfrac{1}{2}(1+2\zeta Ka-\sqrt{4Ka+1})$$

In the discussion on beam guidance presented above which described the operation of the guidance loop it was assumed that it was for a shipboard system in which all deck-referenced information had been transformed into stable quantities. Actual control of the guidance beam would then be preformed in the vertical and horizontal planes with the beam being programmed separately in elevation and bearing. However, such a system requires several major coordinate transformations with each involving a long chain of resolvers. As conventional resolvers do not possess sufficient accuracy to meet the collimation and stabilization requirements of the system, this procedure for generating the beam program is not practicable. Therefore, a concept whereby the motion of the guidance beam is controlled at the plane determined by the guidance beam itself and the line-of-sight to the target was adopted. With the guidance radar control axes selected as the basic reference for the system, the guidance picture is one in which vectors are used to represent the relative position of the guidance beam with respect to the target line of sight. In order to facilitate a discussion of this vector concept, a brief description of the operation of guidance radar operation will be given.

As pointed out above, the second stage of integration in the guidance loop is provided by the guidance radar. This is due to the fact that the guidance radar behaves as a rate servo in its response to orders from the computer. FIG. 6 illustrates a simplified symbolic block diagram of the guidance transmitter servo loop. Rate orders from the computer cause a physical torque to be applied on the gimbal of gyro **61**. Gyro in turn generates a proportional voltage which drives motor **64** after passing through preamplifier **62** and amplifier **63**. The motor rotates the antenna mount about the axis on which gyro **61** is mounted. The output of motor **64** is fed to differential **66** the second input of which is ship's motion. This differential is representative of the transmission of ship's motion to the antenna line of sight through the antenna mount. Rate sensor **67** which is symbolic of the rate sensing action of the gyro is connected between differential **66** and gyro **61** and counteracts the torque on the gimbal of gyro **61**. When the torque applied by rate sensor **67** to gyro **61** has matched the applied torque caused by the input from the computer the guidance mount has assumed the rate called for by gyro rate orders.

A beam coordinate system is used as the basic reference for the guidance loop of the guidance radar with the coordinate system being represented by a set of orthogonal unit vectors along the elevation, beam, and traverse axes

of the antenna mount. A rotation about the line-of-sight occurs when ship's motion is present. This rotation about the line-of-sight gives rise to several quantities upon which the computer is dependent for successful operation, namely, the cross-traverse angle and the cross-traverse rate. The significance of these quantities will become apparent in the following description of the guidance concept as it applies to the computer.

FIG. 7 illustrates the vector relationship between the guidance and tracking beams. As shown in FIG. 7 a boresight datum plane has been constructed perpendicular to the tip of the line of sight or $\underline{2}$ axis of the beam coordinate system. The vector $\underline{A}$ lies along gyro reference axis and terminates at the boresight plane. This vector represents the desired line-of-sight of the guidance beam as determined by the torques exerted on the gyros by the computer. The vector $\underline{2}$ represents the actual direction of the beam and is ordinarily coincident with $\underline{A}$. Any separation between the two constitutes a lag in the power servos of the guidance mount. $\underline{M}$ is a vector also terminating at the boresight plane. However, this vector points in the direction of the target. The space separation between the two beams is given by $(\underline{M}-\underline{2})$, which is the vector in the boresight plane connecting the tips of the $\underline{2}$ and $\underline{M}$ vectors. The separation in the boresight plane between the programmed and actual positions of the guidance transmitter is denoted by $(\underline{A}-\underline{2})$. The separation between the programmed vector and the $\underline{M}$ vector is represented by the vector $\underline{\Delta}$, or $(\underline{M}-\underline{A})$. Proper control of $\underline{\Delta}$ in magnitude and direction can program the $\underline{A}$ vector toward the target line-of-sight. Therefore, the $\underline{\Delta}$ vector is directly analogous to the quantity ϵ in Equation 3*a*. Also, the vector rates and accelerations are analogous to the angular rates and accelerations given in Equations 3*b* and 3*c*. Thus, for the type B program, the vector solution to the problem is given by the following equations:

$$\underline{\Delta}=\underline{M}-\underline{A} \tag{7a}$$

$$\dot{\underline{V}}+(\dot{\underline{2}}\cdot\underline{V})\underline{2}=(\omega n^2-2\zeta\dot{\omega}n)\underline{\Delta} \tag{7b}$$

$$\dot{\underline{A}}+(\dot{\underline{2}}\cdot\underline{A})\underline{2}=2\zeta\omega n\underline{\Delta}+\underline{V} \tag{7c}$$

where $\dot{\underline{V}}+(\dot{\underline{2}}\cdot\underline{V})\ \underline{2}$ represents the component of $\dot{\underline{V}}$ perpendicular to $\underline{2}$, $\dot{\underline{A}}+(\dot{\underline{2}}\cdot\underline{A})\ \underline{2}$ represents the component of $\dot{\underline{A}}$ perpendicular to $\underline{2}$ and $\underline{V}\cdot\underline{2}=0$.

When the guidance loop is mechanized to solve the above equations, $\underline{\Delta}$ reduces to zero in accordance with the type B beam program. The shape of the program is slightly distorter for cases in which the beam separation is large. However, the program distortion is a minor consideration because the dynamic properties of the beam program are not altered.

In order to utilize equations 7*a*, 7*b* and 7*c* it is necessary to express them in terms of components along the elevation and traverse axes of the guidance radar as follows:

$$\Delta_1=M_1-A_1 \tag{8a}$$
$$\Delta_3=M_3-A_3 \tag{8b}$$
$$\dot{V}_1=(\omega n^2-2\zeta\dot{\omega}n)\Delta_1-V_3\omega_2 \tag{8c}$$
$$\dot{V}_3=(\omega n^2-2\zeta\dot{\omega}n)\Delta_3+V_1\omega_2 \tag{8d}$$
$$\dot{A}_1=2\zeta\omega n\Delta_1+V_1+\omega_3-A_3\omega_2 \tag{8e}$$
$$\dot{A}_3=2\zeta\omega n\Delta_3+V_3-\omega_1+A_1\omega_2 \tag{8f}$$

The forcing function must be converted into vector form as illustrated in FIG. 8 for the type A beam program. A vector $\underline{C}$ has been added such that $\underline{\Delta}$ is now given by $\underline{C}-\underline{A}$. Also, a pseudo-stable, or cross-traverse stabilized set of axes is shown, together with the beam coordinates. The essential feature of this pesudo-stable coordinate system is that it carries with it the initial cross-traverse orientation of the guidance beam for each particular beam program.

In the generation of the type A beam program, the forcing function is first referenced to this coordinate system and then transformed into beam coordinates by a resoltuion through the incremental change in the cross-traverse angle. The vector $\underline{C}$ moves in accordance with the forcing function and the vector $\underline{\Delta}$ supplies the error which is used to enable the vector $\underline{A}$ to keep up with $\underline{C}$. The equation for $\underline{\Delta}$ is as follows:

$$\underline{\Delta}=(\underline{M}-\underline{A})-f\underline{l}-g\underline{v}$$

where $\underline{l}$ and $\underline{v}$ represent, respectively, the local lateral and vertical references axes in the boresight plane, and f and g are magnitudes of the respective components of the forcing function along the pseudo-stable reference axes. The f and g scalar quantities determine the shape of the beam program and are given as follows:

$$f=\frac{M_{1_o}}{(R-Rm)_o}(R-Rm)$$

$$g=\frac{M_{3_o}}{(R-Rm)_o}(R-Rm)$$

The instantaneous cross-traverse orientation of the guidance transmitter is related to its original orientation by the following relationship:

$$\underline{l}=\underline{1}\cos(\Delta Zms)-\underline{3}\sin(\Delta Zms)$$

$$\underline{v}=\underline{1}\sin(\Delta Zms)+\underline{3}\cos(\Delta Zms)$$

When the above equations are combined there results the following scalar control equations:

$$\Delta_1=(M_1-A_1)-\frac{M_{3_o}}{(R-Rm)_o}(R-Rm)\sin(\Delta Zms)-\frac{M_{1_o}}{(R-Rm)_o}(R-RM)\cos(\Delta Zms) \tag{9a}$$

$$\Delta_3=(M_3-A_3)-\frac{M_{3_o}}{(R-Rm)_o}(R-Rm)\cos(\Delta Zms)+\frac{M_{1_o}}{(R-Rm)_o}(R-Rm)\sin(\Delta Zms) \tag{9b}$$

The remaining operations in the guidance loop are identical to that of the type B program.

The traverse and elevation components of the vector separation $(\underline{M}-\underline{2})$ FIG. 7 between the two beams is established by the input computations. The component development is based on a knowledge of the deck-referenced angles of the tracking and guidance radars. The coordinate transformation required for this development appears in FIG. 9. The unit vector $\underline{r}$ along the target line-of slight has components r_1, r_2, and r_3 along the three axes of the guidance transmitter coordinate system. The $\underline{M}$ vector is an extension of the unit vector $\underline{r}$ out to the boresight plane. The component of $\underline{M}$ along the unit vector $\underline{2}$ is equal to unity by definition and it follows from the geometry that:

$$M_1=\frac{r_1}{r_2}=mMbd$$

$$M_3=\frac{r_3}{r_2}=mMe'$$

Referring now more particularly to FIG. 10 there is shown an embodiment of the present invention comprising five basic elements: input computer **31**, function generator **33**, beam sensitivity computer **32**, cross-traverse rate circuit **34**, and smoothing circuit **35**. The embodiment shown in FIG. 10 is analogous to the second order smoothing circuit of FIG. 5 with the exception that FIG. 5 shows second stage integration. However, as previously pointed out second stage integration is provided by the guidance radar closed loop response illustrated in FIG.

6. Therefore, the output of summation circuits **51** and **54** are first stage integration quantities which are used to continuously position the guidance beam of the guidance radar wherein the second integration is inherently performed. For the type B trajectory switches S_1 and S_2 are in the position shown in FIG. 10. In other words, function generator **33** is disconnected from smoothing circuit **35**.

Input computer **31** provides smoothing circuit **35** with the traverse and elevation components of the vector separation $\underline{M}-\underline{2}$ between the two beams, that is, between the actual line-of-sight of the radar guidance beam and the target line-of-sight. The traverse component M_1 of the vector separation is fed to summation network **36** while the elevation component M_3 of the vector separation is fed to summation network **37** of smoothing circuit **35** as well as to function generator **33** discussed hereinbelow. The traverse component A_1 and the elevation component A_3 of the separation in the boresight plane (as discussed in reference to FIGS. 7 and 8) between the programmed and actual positions of the guidance transmitter are respectively fed into summation circuits **36** and **37** of smoothing circuit **35**. Summation circuits provide the traverse and elevation separation quantities, Δ_1 and Δ_3, as inputs to multiplier circuits **39** and **49**, respectively. Δ_1 and Δ_3 are the scalar components of $\underline{\Delta}$, the tangent of the space angle between the target and missile lines of sights as shown in FIG. 7. The guidance radar servo **40** feeds back to summation circuits **37** and **36** inputs proportional to the guidance elevation error A_3 and guidance traverse error A_1, respectively.

The beam sensitivity parameters $2\zeta\omega n$ and $(\omega n^2-2\dot{\zeta}\omega n)$ are used to control the rate of closure of the beam separation angle in a manner readily seen in the preceding mathematics. These parameters are computed in the beam sensitivity computer **32** in the following manner. Divider circuit **41** receives inputs from the guidance radar **50** proportional to missile-target range difference rate and another input proportional to missile-target range difference which are divided to provide an output proportional to time-to-intercept. This output is added to a constant K*b* in summation network **42** and is provided as an input to divider circuit **43**. Divider circuit **43** is provided with a second input K*a* which is a nondimensional constant. The angular output of divider circuit **43** ωn of the inverse of time-to-intercept is applied as an input to multiplier circuit **44** and squaring circuit **45**. The second input to multiplier circuit **44** is the damping constant 2ζ and the output from multiplier circuit **44** is one of the desired quantities $2\zeta\omega n$ which is applied as an input to multiplier circuit **38** of smoothing circuit **35**.

The output from squaring circuit **45** is fed as an input to multiplier circuit **46**. The nondimensional constant K*a* which is fed as an input to divider circuit **43** is changed into a function of ζ or $1-2\zeta/Ka$ by means of function generator **47** and applied as the second input to multiplier circuit **46**. The output

$$\omega n^2\frac{(1-2\zeta)}{Ka}$$

which is equivalent to the desired quantity $\omega n^2-2\dot{\zeta}\omega n$ is provided as an input to multiplier circuit **39** of smoothing circuit **35**.

The output from multiplier circuit **49** of beam sensitivity circuit **32** is also fed as an input to multiplier circuit **48** of smoothing circuit **35**. The output from multiplier circuit **46** of beam sensitivity circuit **32** is also fed as an input to multiplier circuit **49** of smoothing circuit **35**. Multiplier circuits **38** and **48** receive inputs from summation circuits **36** and **37**, respectively, and therefore have outputs proportional to $2\zeta\omega n\Delta 1$ and $2\zeta\omega n\Delta 3$, respectively.

The output of multiplier circuit **38** is fed as one input to summation network **51** while the output from multiplier **39** is fed as one input to the summation network **52**. The output from multiplier circuit **49** is fed as one input to summation circuit **53** while the output from multiplier circuit **48** is fed as one input to summation circuit **54**.

A measure of the cross-traverse rate (angular rate about the guidance beam axis) is required to compensate for coriolis accelerations and to compute the incremental cross-traverse angle ΔZms for the type A beam program. A computation of ΔZms requires extremely accurate rate data and for this reason cross-traverse rate circuit **34** which utilizes a high gain second order loop around the cross-traverse gyro is required. The cross-traverse rate circuit **34** also computes the correction terms required for the gyro cross feed in the smoothing circuit **35**. The correction terms appear in Equations 8*a* and 8*f*. Therefore, cross-traverse rate circuit **34** provides the measure of the input $(DZms)s$ or ω_2 as an input to each of multipliers **56** and **57** as well as to function generator **33**. The input from summation circuit **52** is integrated in integrator **58**, the output of which provides one input to multiplier **57**. The output of summation circuit **53** is integrated in integrator circuit **59**, the output of which serves as one input to multiplier circuit **56**. The outputs of integrator circuits **58**, **59** are also connected to summation circuits **51** and **54**, respectively. The output of summation circuit **51** is the traverse gyro order which is fed to the gyro of the antenna mount of the guidance radar. The output from summation circuit **54** is the elevation gyro order which is fed to the gyro of the guidance radar. The outputs from summation circuits **51** and **54**, respectively, position the guidance beam in the proper traverse and elevation poitions.

Function generator **33** provides the elevation and traverse components of the forcing function in the guidance beam coordinate system for the type A program. As previously explained no forcing function is required in the type B program. This operation consists of storing and locking, at the time of capture, the elevation and traverse components of the $(\underline{M}-\underline{A})$ vector shown in FIG. 8 and the cross-traverse orientation of the guidance beam. The locked elevation and traverse components are varied in accordance with the type A closure by means of the input representative of range difference between missile and target and resolved through a change in cross-traverse to produe the desired output for the smoothing circuit. The incremental change in the roll angle ΔZms of the guidance antenna is obtained by direct integration of the cross-traverse rate $(Dzms)s$.

In other words, the function generator **33** when switches S1 and S2 are in the position opposite from that shown inserts into summation circuits **36** and **37** and the additional desired traverse separation and the desired elevation separation, respectively, necessary to provide in the system the up and over trajectory of type A. In either case, the guidance beam from the guidance radar is positioned by the gyros to reduced separation angle as a function of change in range between the missile and target which range becomes zero when the tracking and guidance beam coincide in three dimensional coordinate system.

The outputs from summation circuits **51** and **54** are proportional to the designated true target bearing and guidance elevation gyro order, respectively. These outputs up to but before insertion into the guidance radar servo **40** are the solutions of Equations 8*e* and 8*f* for the general case where ω_1 (angular rate about the elevation axis) and ω_3 (cross-traverse rate about the traverse axis) are not equal to zero. Upon insertion into the guidance radar servo **40** the second integration is performed upon the quantities expressed in Equations 8*e* and 8*f* making the solution complete.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within

the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A computer system for programming the flight of a beam riding missile subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

computer circuit means,

first means providing said computer circuit means with inputs representative of the traverse and elevation components of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said computer circuit means with inputs representative of the traverse and elevation components of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

beam sensitivity computer means providing inputs representative of beam sensitivity parameters to said computer circuit for controlling the rate of closure of the angle separating actual and desired guidance beams as a function of the remaining time of flight of the missile,

cross-traverse rate circuit means connected to said computer circuit means providing said computer circuit means with an input representative of the cross-traverse rate about the beam axis,

guidance radar servo means connected to the output of said computer circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

2. A computer system according to claim 1 wherein said beam sensitivity computer comprises:

divider circuit means having inputs representative of range between a missile and target and rate of change of said range between a missile and target having an output representative of time-to-intercept between the missile and target,

first circuit means connected to said divider circuit for converting said output representative of time-to-intercept into a linear angular function of said time-to-intercept,

second circuit means connected to said first circuit means converting said linear angular function into a nonlinear angular function of said time-to-intercept.

3. A computer system for programming the flight of a beam riding missile subsequent to lauch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

first means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam and to said second summation circuit means with an input representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and an input to said second summation circuit means and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first computer means connected to said first summation circuit means,

second computer means connected to said second summation circuit means,

beam sensitivity computer means providing an input to said first and second computer means of the angular function of the remaining time of flight of the missile,

cross-traverse rate circuit means connected to said first and second computer means providing said first and second computer means with inputs proportional to the cross-traverse rate about the beam axis.

guidance radar servo means connected to the output of said first and second computer circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders from said first and second computer means respectively for positioning the guidance transmitter in accordance with beam program.

4. A computer system according to claim 3 wherein said beam sensitivity computer comprises:

divider circuit means having inputs representative of range between a missile and target and rate of change of said range between a missile and target having an output representative of time-to-intercept between the missile and target,

first circuit means connected to said divider circuit for converting said output representative of time-to-intercept into a linear angular function of said time-to-intercept,

second circuit means connected to said first circuit means converting said linear angular function into a nonlinear angular function of said time-to-intercept.

5. A computer system for programming the flight of a beam riding missile subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

input computer means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam and said second summation circuit means with an input representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

guidance radar servo means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first, second, third and fourth multiplier circuit means,

means connecting the output of said first summation circuit means to said first and second multiplier circuit means,

means connecting the output of said second summation circuit means to said third and fourth multiplier circuit means,

beam sensitivity computer means providing an input representative of a first beam sensitivity parameter to said first and fourth multiplier circuit means and an input representative of a second beam sensitivity parameter to said second and third multiplier circuit means for controlling the rate of closure of the angle separating actual and desired guidance beam as a function of the remaining time of flight of the missile,

first computer means connected to said second multiplier circuit means,

second computer means connected to said third multiplier circuit means,

third summation circuit means connected to said first multiplier circuit means and said first computer means,

fourth summation circuit means connected to said fourth multiplier circuit means and said second computer means,

cross-traverse rate circuit means connected to said first and second computer means and said third and fourth summation circuit means providing said first and second computer means with an input proportional to the cross-traverse rate about the beam axis,

said cross-traverse rate circuit providing said third summation circuit means with an input representative of said cross-traverse rate multiplied by the traverse component of the vector separation between the programmed and actual positions of the guidance transmitter and said fourth summation circuit means with an input representative of said cross-traverse rate multiplied by the elevation component of the vector separation between the programmed and actual position of the guidance transmitter,

guidance radar servo means connected to the output of said third and fourth summation circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

6. A computer system according to claim 5 wherein said beam sensitivity computer comprises:

divided circuit means having inputs representative of range between a missile and target and rate of change of said range between a missile and target having an output representative of time-to-intercept between the missile and target,

first circuit means connected to said divider circuit for converting said output representative of time-to-intercept into a linear angular function of said time-to-intercept,

second circuit means connected to said first circuit means converting said linear angular function into a nonlinear angular function of said time-to-intercept.

7. A computer system for programming the flight of a beam riding missile subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

first means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam and said second summation circuit means with an input representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and an input to said second summation circuit means and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first, second, third and fourth multiplier circuit means,

means connecting the output of said first summation circuit means to said first and second multiplier circuit means,

means connecting the output of said second summation circuit means to said third and fourth multiplier circuit means,

beam sensitivity computer means providing an input representative of a first beam sensitivity parameter to said first and fourth multiplier circuit means and an input representative of a second beam sensitivity parameter to said second and third multiplier circuit means for controlling the rate of closure of the angle separating actual and desired guidance beams as a function of the remaining time of flight of the missile,

third summation circuit means connected to said second multiplier circuit means,

fourth summation circuit means connected to said first multiplier circuit means,

fifth summation circuit means connected to said third multiplier circuit means,

sixth summation circuit means connected to said fourth multiplier circuit means,

fifth multiplier circuit means having an output connected to said third summation circuit means,

sixth multiplier circuit means having an output connected to said fifth summation circuit means,

cross-traverse rate circuit means connected to said fifth and sixth multiplier circuit means and providing said fifth and sixth multiplier circuit means with an input proportional to the cross-traverse rate about the beam axis,

said cross-traverse rate circuit providing said fourth summation circuit means with an input representative of a first modified cross-traverse rate and said sixth summation circuit means with an input representative of a second modified cross-traverse rate,

first integrator circuit means having an input connected to said third summation circuit means and an output connected to said fourth summation circuit means and said sixth multiplier circuit means,

second integrator circuit means having its input connected to said fifth summation circuit means and its output connected to said sixth summation circuit means and said fifth multiplier circuit means,

guidance radar servo means connected to the output of said fourth and sixth summation circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

8. A computer system according to claim 7 wherein said beam sensitivity computer comprises:

divider circuit means having inputs representative of range between a missile and target and rate of change of said range between a missile and target having an output representative of time-to-intercept between the missile and target,

first circuit means connected to said divider circuit for converting said output representative of time-to-intercept into a linear angular function of said time-to-intercept,

second circuit means connected to said first circuit means converting said linear angular function into a nonlinear angular function of said time-to-intercept.

9. A computer system for programming the flight of a beam riding missile in one of two modes subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

computer circuit means,

function generator means for developing traverse and elevation components of desired angle separation between the radar tracking and guidance beams as a function of range,

switch means for selectively coupling said function generator means to provide said computer circuit means with said traverse and elevation components, respectively, as inputs thereto,

first means providing said computer circuit means with inputs representative of the traverse and elevation components of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said computer circuit means with inputs representative of the traverse and elevation components of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

beam sensitivity computer means providing inputs representative beam sensitivity parameters to said computer circuit for controlling the rate of closure of the angle separating actual and desired guidance beams as a function of the remaining time of flight of the missile,

cross-traverse rate circuit means connected to said computer circuit means providing said computer circuit means with an input representative of the cross-traverse rate about the beam axis,

guidance radar servo means connected to the output of said computer circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

10. A computer system according to claim **9** wherein said beam sensitivity computer means comprises:

divider circuit means having inputs representative of range between a missile and target and rate of change of said range between a missile and target having an output representative of time-to-intercept between the missile and target,

first circuit means connected to said divider circuit for converting said output representative of time-to-intercept into a linear angular function of said time-to-intercept,

second circuit means connected to said first circuit means converting said linear angular function into a nonlinear angular function of said time-to-intercept.

11. A computer system for programming the flight of a beam riding missile in one of two modes subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

function generator means for developing traverse and elevation components of desired angle separation between the radar tracking and guidance beams as a function of range,

switch means for selectively coupling said function generator means to provide said first and second summation circuit means with said traverse and elevation components, respectively, as inputs thereto,

first means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam and to said second summation circuit means with an input representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and an input to said second summation circuit means and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first computer means connected to said first summation circuit means,

second computer means connected to said second summation circuit means,

beam sensitivity computer means providing an input to said first and second computer means of the angular function of the remaining time of flight of the missile,

cross-traverse rate circuit means connected to said first and second computer means providing said first and second computer means with inputs proportional to the cross-traverse rate about the beam axis,

guidance radar servo means connected to the output of said first and second computer circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders from said first and second computer means respectively for positioning the guidance transmitter in accordance with the beam program.

12. A computer system for programming the flight of a beam riding missile in one of two modes subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

function generator means for developing traverse and elevation components of desired angle separation between the radar tracking and guidance beams as a function of range, switch means for selectively coupling said function generator means to provide said first and second summation circuit means with said traverse and elevation components, respectively, as inputs thereto,

input computer means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the the actual direction of the guidance beam and the desired direction of the guidance beam and said second summation circuit means representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

guidance radar servo means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and an input to said second summation circuit means and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first, second, third and fourth mulitplier circuit means,

means connecting the output of said first summation circuit means to said first and second multiplier circuit means,

means connecting the output of said second summation circuit means to said third and fourth multiplier circuit means,

beam sensitivity computer means providing an input representative of a first beam sensitivity parameter to said first and fourth multiplier circuit means and an input representative of a second beam sensitivity parameter to said second and third multiplier circuit means for controlling the rate of closure of the angle separating actual and desired guidance beam as a function of the remaining time of flight of the missile,

first computer means connected to said second multiplier circuit means,

second computer means connected to said third multiplier circuit means,

third summation circuit means connected to said first multiplier circuit means and said first computer means,

fourth summation circuit means connected to said fourth multiplier circuit means and said second computer means,

cross-traverse rate circuit means connected to said first and second computer means and said third and fourth summation circuit means providing said first and second computer means with an input proportional to the cross-traverse rate about the beam axis,

said cross-traverse rate circuit providing said third summation circuit means with an input representative of said cross-traverse rate multiplied by the traverse component of the vector separation between the programmed and actual positions of the guidance transmitter and said fourth summation circuit means with an input representative of said cross-traverse rate multiplied by the elevation component of the vector separation between the programmed and actual position of the guidance transmitter,

guidance radar servo means connected to the output of said third and fourth summation circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

13. A computer system for programming the flight of a beam riding missile in one of two modes subsequent to launch by positioning the guidance beam of a guidance transmitter, comprising in combination:

first summation circuit means,

second summation circuit means,

function generator means for developing traverse and elevation components of desired angle separation between the radar tracking and guidance beams as a function of range,

switch means for selectively coupling said function generator means to provide said first and second summation circuit means with said traverse and elevation components, respectively, as inputs thereto,

first means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam and said second summation circuit means with an input representative of the elevation component of the vector separation between the actual direction of the guidance beam and the desired direction of the guidance beam,

second means providing said first summation circuit means with an input representative of the traverse component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter and an input to said second summation circuit means and providing said second summation circuit means with an input representative of the elevation component of the vector separation between the programmed position of the guidance transmitter and the actual position of the guidance transmitter,

first, second, third and fourth multiplier circuit means,

means connecting the output of said first summation circuit means to said first and second multiplier circuit means,

means connecting the output of said second summation circuit means to said third and fourth multiplier circuit means,

beam sensitivity computer means providing an input representative of a first beam sensitivity parameter to said first and fourth multiplier circuit means and an input representative of a second beam sensitivity parameter to said second and third multiplier circuit means for controlling the rate of closure of the angle separating actual and desired guidance beams as a function of the remaining time of flight of the missile,

third summation circuit means connected to said second multiplier circuit means,

fourth summation circuit means connected to said first multiplier circuit means,

fifth summation circuit means connected to said third multiplier circuit means,

sixth summation circuit means connected to said fourth multiplier circuit means,

fifth multiplier circuit means having an output connected to said third summation circuit means,

sixth multiplier circuit means having an output connected to said fifth summation circuit means,

cross-traverse rate circuit means connected to said fifth and sixth multiplier circuit means and providing said fifth and sixth multiplier circuit means with an input proportional to the cross-traverse rate about the beam axis,

said cross-traverse rate circuit providing said fourth summation circuit means with an input representative of a first modified cross-traverse rate and said sixth summation circuit means with an input representative of a second modified cross-traverse rate,

first integrator circuit means having an input connected to said third summation circuit means and an output connected to said fourth summation circuit means and said sixth multiplier circuit means,

second integrator circuit means having its input connected to said fifth summation circuit means and its output connected to said sixth summation circuit means and said fifth multiplier circuit means,

guidance radar servo means connected to the output of said fourth and sixth summation circuit means whereby said guidance radar servo means is provided with traverse and elevation gyro orders for positioning the guidance transmitter in accordance with the beam program.

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