GUNFIRE CONTROL SYSTEM FOR SUPPLYING AIMING INFORMATION FOR GUNS HAVING DIFFERENT BALLISTIC CHARACTERISTICS

Filed Feb. 27, 1946

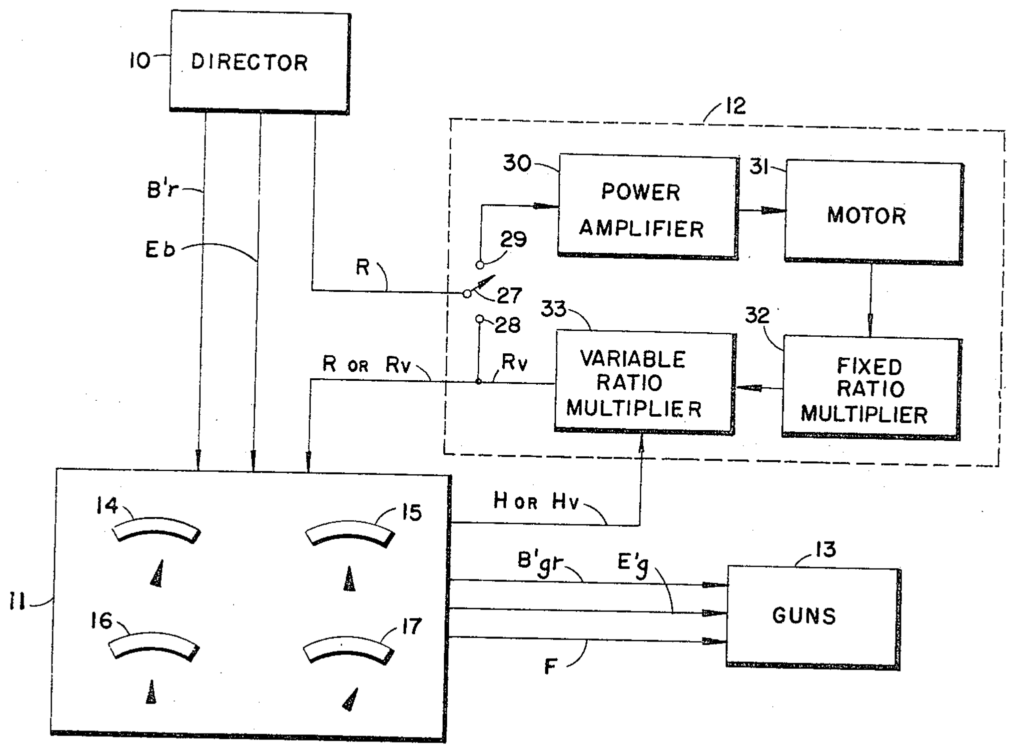

FIG. 1

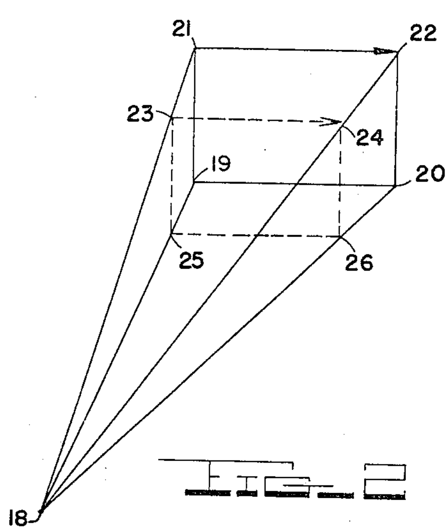

FIG. 2

INVENTORS
DENSIL M. COOPER
CHARLES F. WYSONG
THOMAS W. CHAPPELLE
M. C. Hayes
ATTORNEY

3,373,263

GUNFIRE CONTROL SYSTEM FOR SUPPLYING AIMING INFORMATION FOR GUNS HAVING DIFFERENT BALLISTIC CHARACTERISTICS

Densil M. Cooper, Washington, D.C., Charles F. Wysong, Atlanta, Ga., and Thomas W. Chappelle, U.S. Navy, assignors to the United States of America as represented by the Secretary of the Navy

Filed Feb. 27, 1946, Ser. No. 650,584
2 Claims. (Cl. 235—61.5)

This invention relates to gunfire control systems and in particular to fire control direction and computer systems which may be employed to provide gun pointing data for guns of various sizes.

In numerous circumstances, typically aboard warcraft, it is desirable to employ guns of various sizes and control their fire by means of a single director and computer system. Computer systems as presently employed are usually designed for a particular size and caliber gun because of the complexities involved were a single computer system to be set-up for the aiming of guns of a plurality of sizes.

It is therefore an object of the present invention to provide means whereby a fire control computer system designed for one size gun may be employed to give substantially accurate gun aiming data for guns of a plurality of sizes.

Another object of the present invention is to provide in a gunfire control system, a method of altering the information supplied to the computer by the director so that the gunfire control system can be made to provide substantially accurate aiming information for any one of a plurality of guns having different ballistic characteristics.

Another object of the present invention is to provide a gunfire control system capable of supplying substantially accurate aiming information for a plurality of guns having different ballistic characteristics.

Other and further objects and features of the present invention will become apparent upon a careful consideration of the following detailed description when taken together with the accompanying drawings which illustrate a typical embodiment of the invention and the manner in which this embodiment may be considered to operate.

In the drawing:

FIG. 1 shows one embodiment of the features of the present invention;

FIG. 2 shows a simplified fire control problem as encountered and solved with the apparatus of FIG. 1 for guns having different ballistic characteristics.

In accordance with the general features of the present invention, a system of gunfire control is provided which is capable of accurate gun aiming information for a first gun having certain ballistic characteristics and of substantially accurate aiming information for a second gun having different ballistic characteristics. A standard fire control computer of conventional design having information or signal inputs and designed to provide aiming information for the first gun employed. When calculation for the second gun is desired, certain of the input signals are modified by new apparatus according to the teachings of the present invention to cause the computer to solve a fictitious problem for the first gun which will cause the production of substantially accurate aiming information for the second gun.

For convenience, the following symbols for shipboard fire control as employed in the specification, are defined.

B'gr (gun train order): The angle between the fore and aft axis of own ship and the plane through the gun perpendicular to the deck (plus parrallax correction if made), measured in the deck plane clockwise from the bow. (Gun train is the ordered gun train as transmitted to the gun.)

B'*r* (director train): The angle between the fore and aft axis of own ship and the vertical plane through the line of sight from the director, measured in the deck plane clockwise from the bow.

*d*H (rate of climb): The time rate of change of height of target.

D*j*: Spot correction in gun deflection angle made in the slant plane to the target.

E*b* (director elevation): The elevation angle of the director line of sight above the deck (plus parallax correction if made) measured in the vertical plane through the line of sight to the target.

E'*g* (gun elevation): The elevation angle of the gun above the deck (plus parallax correction, if made) measured in the plane through the gun perpendicular to the deck. (Gun elevation order is the gun elevation transmitted to the gun.)

F (fuse setting): Fuse setting in seconds.

R (range): The distance from the director to the target (measured along the line of sight).

R_v (virtual target range): Approximately equal to target range R multiplied by factor equal to the reciprocal of the ratio of the time of flight of the projectile for the gun for which the control system gives accurate solution T_{f1} to the time of flight of the projectile for the gun for which the control system gives substantially accurate solution T_{f2}, both flight times taken for the same range. The value of virtual target range R_v is approximately related to the actual target range R according to the equation below.

$$R_v = R \times \frac{T_{f2}}{T_{f1}}$$

This relationship is a first approximation and should subsequently be modified empirically in accordance with the height H_v to become more accurate. Such modification is provided by apparatus combination in accordance with the teachings of the present invention.

R_{2v} (predicted virtual target range): Predicted virtual range of target at instant a projectile, fired at the present time, reaches the target vicinity.

H (height): The vertical distance of the target above the horizontal plane through the director.

H_v (virtual target height): The value of the virtual target height H_v is that value of H obtained from the computer when it is provided with R_v as input in place of the conventional R input. It can be shown that this virtual target height is approximately equal to target height H multiplied by a factor equal to the reciprocal of the ratio of the time of flight of the projectile for the gun for which the control system gives accurate solution T_{f1} to the time of flight of the projectile for the gun for which the control system gives substantially accurate solution T_{f2}, both flight times taken for the same range. By way of example, from the above definitions we know that,

$$\sin (E_b) = \frac{H}{R} = \frac{H_v}{R_v}$$

which can be rewritten as

$$H_v = R_v \sin (E_b)$$

substituting for

$$R_v,\ H_v = \left(R \times \frac{T_{f2}}{R_{f1}}\right) \sin (E_b)$$

but

$$R \sin (E_b) = H$$

therefore

$$H_v = R \sin (E_b) \times \frac{T_{f2}}{T_{f1}} = H \times \frac{T_{f2}}{T_{f1}}$$

Sa (air target air speed): Speed of air target along the line of flight with respect to the earth. (May or may not be for horizontal flight.)

V_j: Spot correction in gun elevation angle made in a plane perpendicular to the horizontal plane.

With reference to FIG. 1, a gunfire control system is shown in which a director **10** is employed to secure positional data regarding the instantaneous range, elevational angle and bearing of a distant target. This data is supplied to a computer system in the form of signals which may be of mechanical movement or electrical variation such as shaft displacement or rotation, fluid pressure variations, or amplitude, frequency, or phase electrical variations. The computer system includes a main computer unit **11** and an auxiliary unit **12**. Aiming information is supplied to the guns **13** from the computer **11** which permit orientation of the guns so that the path of a shell leaving any of them at one instant will intersect the path of the target at the instant in time at which the target is at the point of intersection.

The computer **11** is of any suitable conventional type designed primarily for the control of a gun having certain ballistic characteristics. As an example of a typical computer, reference is made to the U.S. patent to Chaffee et al., 2,340,865 wherein is described a computer which requires a separate height finder. For the purposes of the present invention, a set-up may be considered wherein the computer of Chaffee et al., together with a height finder, both responsive to input signals from the director **10** of FIG. 1 are included as components of block **11**. Where the complete system is mounted aboard ship it is preferably adapted to receive three primary input signals from the director B'*r*, E*b*, and R. To this information is ordinarily added but not shown in FIG. 1, conventional input signals relative to the motion of the structure or ship carrying the fire control system and of the air conditions. With some types of computers it is necessary to supply additional input signals which may in many instances be done manually. The exact manner of supplying the additional information is of no real significance to the present invention, the only important thing being that the computer **11** be of the type suitable to receive target position information from a director **10** and supply control information to accurately direct the fire of guns of block **13**. To assist in this operation, certain types of computers may require additional information inputs such as information regarding estimated target motion S*a* and *d*H which can be introduced manually for example through controls **14** and **15**, and "spot" corrections introduced manually in response to observations of accuracy of the shell hits. Such spot corrections may be introduced as D_j and V_j through the typical controls **16**, **17**. The principles of the present invention are equally applicable where the computer **11** is adapted to make further conventional corrections such as trunnion tilt, parallax, gun erosion, and others.

The principal output quantities of the computer **11** are B'*gr*, E'*g*, and F, which are supplied to the guns, and H or H_v obtained in the course of calculation of the particular fire control problem.

Unit **12** is employed where it is desired to obtain aiming data for guns having ballistic characteristics dissimilar to those for which the original computer system **11** was designed. A primary function of the adapter unit **12** is to alter the range signal R delivered to the computer **11** from the director **10** whenever computation is desired for a second gun having characteristics different from those of a first gun for which the computer **11** was designed. This range signal alteration is made to cause the computer **11** set-up to provide accurate solution of a problem for the first gun to solve a fictitious problem which will supply substantially accurate firing information for the second gun.

Referring now to FIG. 2, the method by which the fictitious problem is set up and solved is shown. For this part of the discussion, straight line shell paths without

arched trajectory have been chosen. The position of the platform or ship mounting the gunfire system is at point **18**. The horizontal plane is that of **18**, **19**, **20**. The problem is to secure firing information for a target presently located at point **21** and traveling in the direction **21–22** such that a shell fired at the instant the target is at position **21** will strike the target when it reaches position **22**. Estimates of the target speed S*a* and rate of climb *d*H can be supplied manually to the computer **11** of FIG. 1 by means of controls **14**, **15**, respectively. Accurate firing information is readily obtained from the computer **11** for the gun for which the computation system was designed. For a gun having different ballistic characteristics, for example, one firing a larger diameter and larger weight shell which will have different characteristics such as initial velocity, rate of change of velocity with distance traveled, and drift per unit distance of travel, the firing information supplied for the first gun would not suffice. To obtain substantially accurate information for the second gun, the target range signal R which is represented by the line **18**, **21** is multiplied by a factor to obtain a virtual target range signal R_v which is represented by the line **18**, **23**. This virtual range signal is then transmitted to the computer **11** and employed as a basis for calculation of firing data to obtain a predicted virtual target position **24**, which, when fired upon by the second gun will cause simultaneous occupation of point **22** by the projectile and the target. The factor by which the range signal R is multiplied to obtain the virtual range signal R_v is equal to the reciprocal of the ratio of the time of flight of a projectile from the first gun to point **22** to the time of flight of a projectile from the second gun to point **22**. This ratio is substantially constant regardless of the actual distance **18–22** or **18–21** and for practical purposes may be considered constant for any reasonable combination of guns. It is to be noted that the vector **23**, **24**, is in the same direction as vector **21**, **22**, but that its length bears the same relationship to vector **21**, **22** as the distance **18**, **23** does to distance **18**, **21**. Thus the S*a* and *d*H estimates must be altered (manually) by the same factor as the range R. All angular measurements such as lead angle **21**, **18**, **22** and predicted elevation angle **22**, **18**, **20** are unaffected by the change in range.

In practical fire control situations wherein the projectiles do not travel in straight lines but rather have arched trajectories, the simple range alteration as given above is not entirely satisfactory. A first correction that is made is that of altering the virtual target range signal R_v by another factor depending upon H_v (distance **23**, **25**) as obtained from the computer **11** of FIG. 1 in solving the triangle **23**, **18**, **25**.

The above correction for shell trajectory is not altogether sufficient for all target ranges, hence a second correction must be made. Furthermore, the windage and drift while in flight are generally different for different size projectiles. The supplemental corrections, for drift, windage, and trajectory are small and are best grouped into an indefinite classification called "spot corrections signals," which are made manually while firing is in progress. These "spot corrections signals" are designated V_j and D_j and are introduced by controls **16** and **17**, respectively, of the computer system **11** in FIG. 1. They are conveniently made by resetting controls **16**, **17** by known, substantially fixed amounts depending upon target range when computation for different guns is desired. To this end, a plurality of scales, in this case two, is provided for each of controls **16**, **17**, with the appropriate change in scale employed when operation is changed from calculation for one gun to calculation for another.

Referring again to FIG. 1, the range input signal from the director **10** to the adapter **12** is applied to a two position switch **27**. With switch **27** connected to contact **28**, the target range signal as obtained by the director **10** is supplied direct to the computer **11** for operation with the gun for which the computer **11** was designed. With switch

27 connected to contact 29, the range signal obtained from the director 10 is applied to a power amplifier 30 which supplies controlled power for imparting motion to the armature of an electric motor 31. Motion of the shaft of motor 31 is applied to a fixed ratio multiplier 32. The ratio of the multiplier 32 is chosen such that true target range represented by the distance 18–21 in FIG. 2 will be multiplied by a constant value to obtain the virtual target range 18–23 which will drive the computer 11 to solution for the second size gun for the actual target at range 18, 21.

In conventional remote signal conveying systems for this type of application it is common practice to employ selsyn or synchro systems wherein the position of a movable mechanical member or shaft located at one point is converted into electrical signals which cause corresponding mechanical motion of a shaft at a distant point. Such remote indicators are familiar to those skilled in various electrical arts, and in particular are widely used in radar where the orientation of a rotatable directional antenna located at one point must be repeated or analyzed at another point. This selsyn or synchro system is ideal where the indicating point does not require much power because any power required for the rotation of the indicator, as well as frictional losses and certain resistance losses must be provided by the distantly located movable system. In certain instances this power loss is negligible, in others it is undesirable because of the greater possibility of introduction of erroneous indication. To provide power where the indicating system requires it and hence to improve accuracy, a servo type system may be employed in which the indicating device is driven by a separate power source which is merely synchronized with the remote device through the selsyn or synchro system. In such a layout, therefore, error signals are derived in dependency on positional differences between the internal indicating system and the remote member. These error signals are amplified by the power amplifier 30 and then employed to drive an electric motor 31 which positions the indicating shaft directly. It should be remembered, however, that the electrical system herein indicated, although highly desirable, is not essential to the performance of the invention, it being entirely possible for the principles of the present invention to be realized satisfactorily by employing mechanical linkage in which case the switch 27 would become a gear shifting mechanism.

With range signals thus delivered to the device 12 by any suitable or convenient means, they are acted upon by the fixed ratio multiplier to obtain the virtual range signals R_v. By way of example the fixed ratio multiplier 32 is a fixed ratio gear train operative to receive input at one angularity and change it to a second angularity.

The simple R_v signal from the multiplier 32 is modified additionally in variable ratio multiplier 33 in dependency on the H_v of the target as obtained from the computer 11. Although height of target information is not made use of in some computers, it is a relatively simple expedient to provide a height computer which furnishes the desired height information in response to elevation and range inputs. This is typically accomplished by mechanically solving the equation

$$\sin(E_b)=\frac{H}{R}$$

Such height computers are well known in the art. Therefore, since the director 10 provides range R and elevation E_b signals directly, computer 11 may conveniently include or be modified to include a height computer which supplies a height signal to multiplier 33 in response to and in dependency on the target elevation E_b and range input signals provided by director 10 and supplied to the computer 11. The linkage supplying H_v to the variable ratio multiplier 33 may be mechanical, electric, or manual as preferred. A variable ratio device such as the variable

speed devices 13, 74, etc. of the U.S. patent to Chaffee et al. 2,340,865 would be suitable. Should a cylinder, ball and disc type device, such as shown in Chaffee et al. be used, the signal from the fixed ratio multiplier 32 could be applied to the disc, the virtual height signal H_v from computer 11 would position the balls and the output signal R_v would then be taken from the cylinder. Of course, the invention is not intended to be limited to the above described variable speed device and other variable ratio multipliers, such as a screw type multiplier, could also be satisfactorily used.

In operation, the fire control system may be quickly changed to give solution for a plurality of gun ballistic characteristics by operation of switch 27 and the resetting of controls 14, 15, 16, 17.

From the foregoing discussion it is apparent that considerable modification of the features of the present invention are possible and while the device herein described and the form of apparatus for the operation thereof constitutes a preferred embodiment of the invention, it is to be understood that the invention is not limited to this precise device and form of apparatus, and that change may be made therein without departing from the scope of the invention as defined in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A gunfire control system for controlling the fire of any one of a plurality of guns having dissimilar ballistic characteristics, comprising; a director and a computer system for supplying accurate firing information for a first gun having certain ballistic characteristics, said director supplying signals including target range to said computer system, means altering the target range signal supplied to the computer when a second gun having different ballistic characteristics is employed, said last named means altering the target range signal in accordance with the relationship of the ballistic characteristics of the first gun to those of the second gun to generate a range signal in accordance with a fictitious target, and means further altering the target range signal supplied to the computer system by a variable amount dependent upon the product of target height multiplied by said relationship to partially compensate for any difference in trajectory ballistic characteristics of the two guns.

2. A fire control system for selectively controlling a plurality of guns having dissimilar ballistic characteristics, comprising a director for providing target bearing, elevation and range signals, a computer responsive to signals derived by the director for positioning a first gun of selected characteristics, and a signal alteration apparatus interposed in the path of range signals from the director to the computer when the system is to be used for positioning a second gun of characteristics different from the first, said apparatus comprising a means for altering director derived range signals in proportion to the ratio of the time of flight of a projectile for the second gun to the time of flight of a projectile for the first gun, said signal alteration apparatus also comprising a means for altering additionally the range signals by a variable amount which is dependent upon the product of target height multiplied by said ratio.

References Cited

UNITED STATES PATENTS

2,340,865	2/1944	Chafee et al.	235—61.5
2,397,783	4/1946	Ford	235—61.5
2,409,648	10/1946	Van Auken.	

MALCOLM A. MORRISON, *Primary Examiner.*

MAX L. LEVY, B. H. CARPENTER, J. B. LEWIS, *Examiners.*