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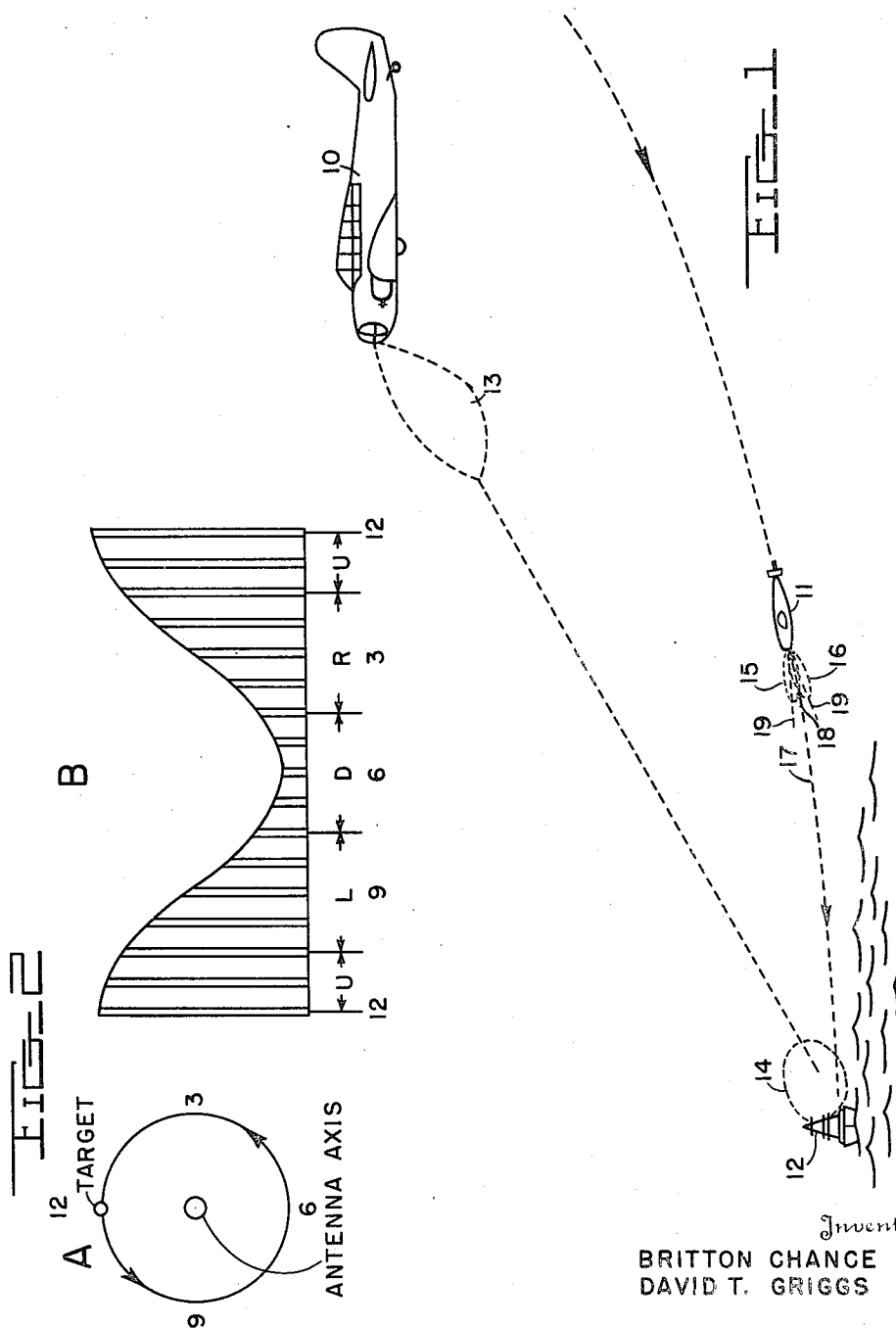
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METHOD OF AND MEANS FOR GUIDING MISSILES

Filed Jan. 18, 1945

6 Sheets-Sheet 1



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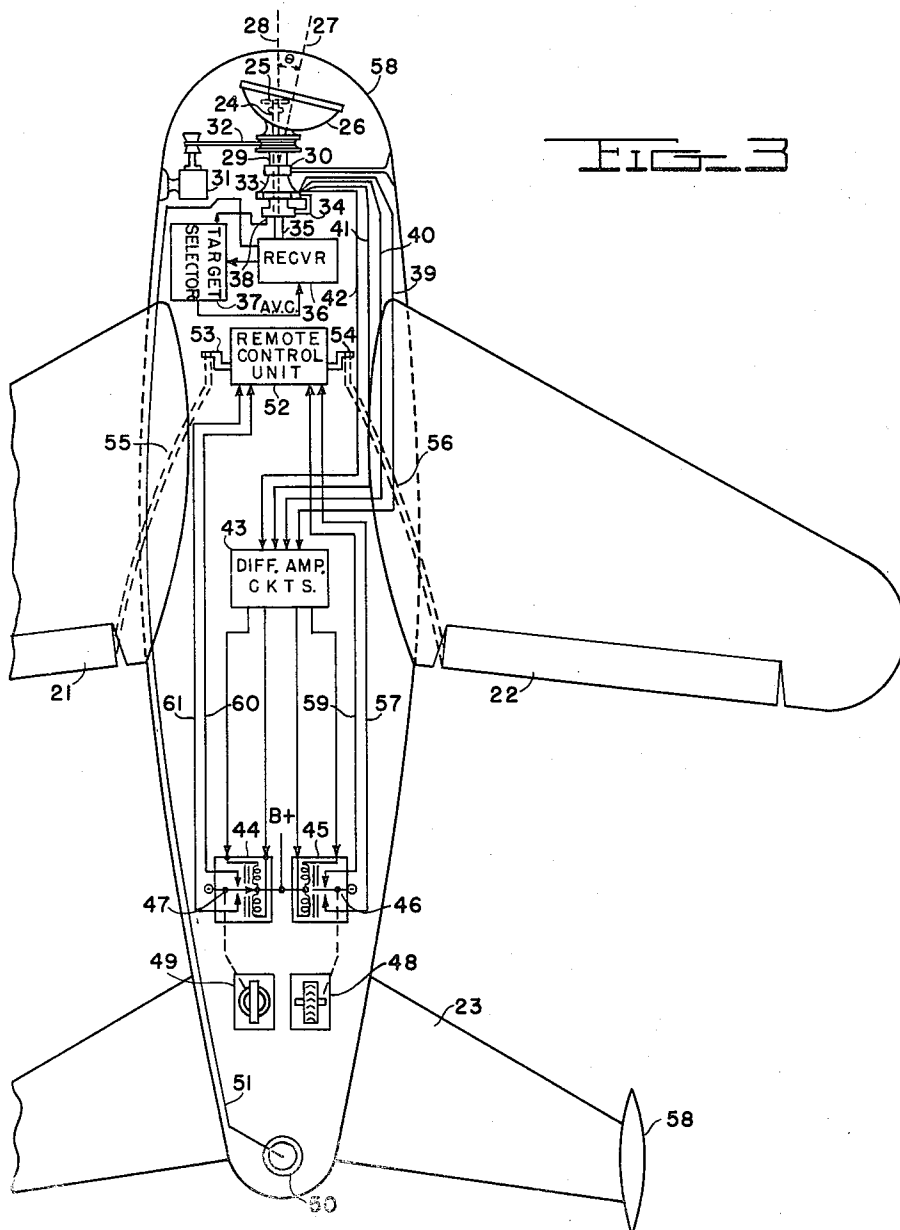
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# METHOD OF AND MEANS FOR GUIDING MISSILES

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6 Sheets-Sheet 2



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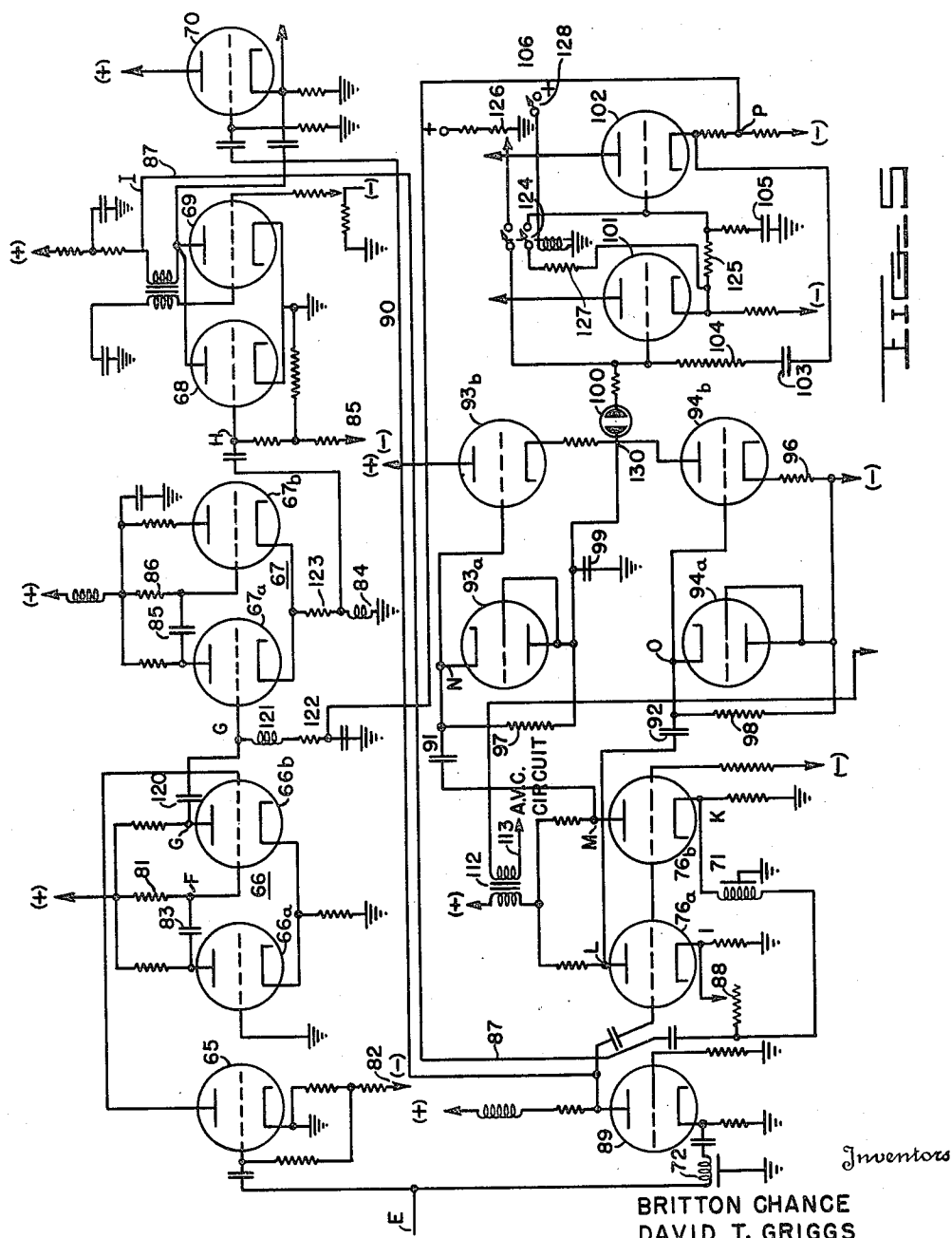
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## METHOD OF AND MEANS FOR GUIDING MISSILES

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6 Sheets-Sheet 4



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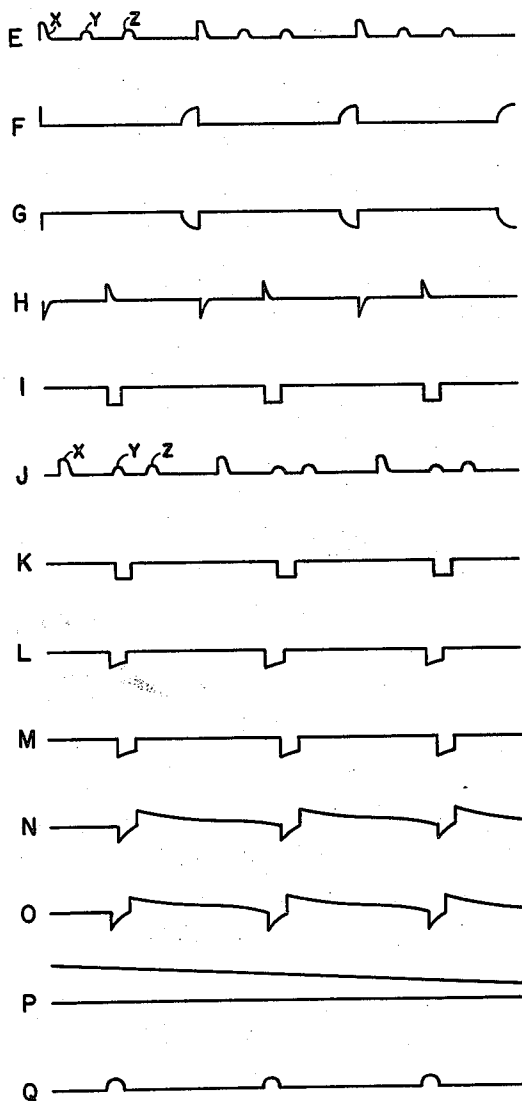
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METHOD OF AND MEANS FOR GUIDING MISSILES

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6 Sheets-Sheet 5

FIG. 6



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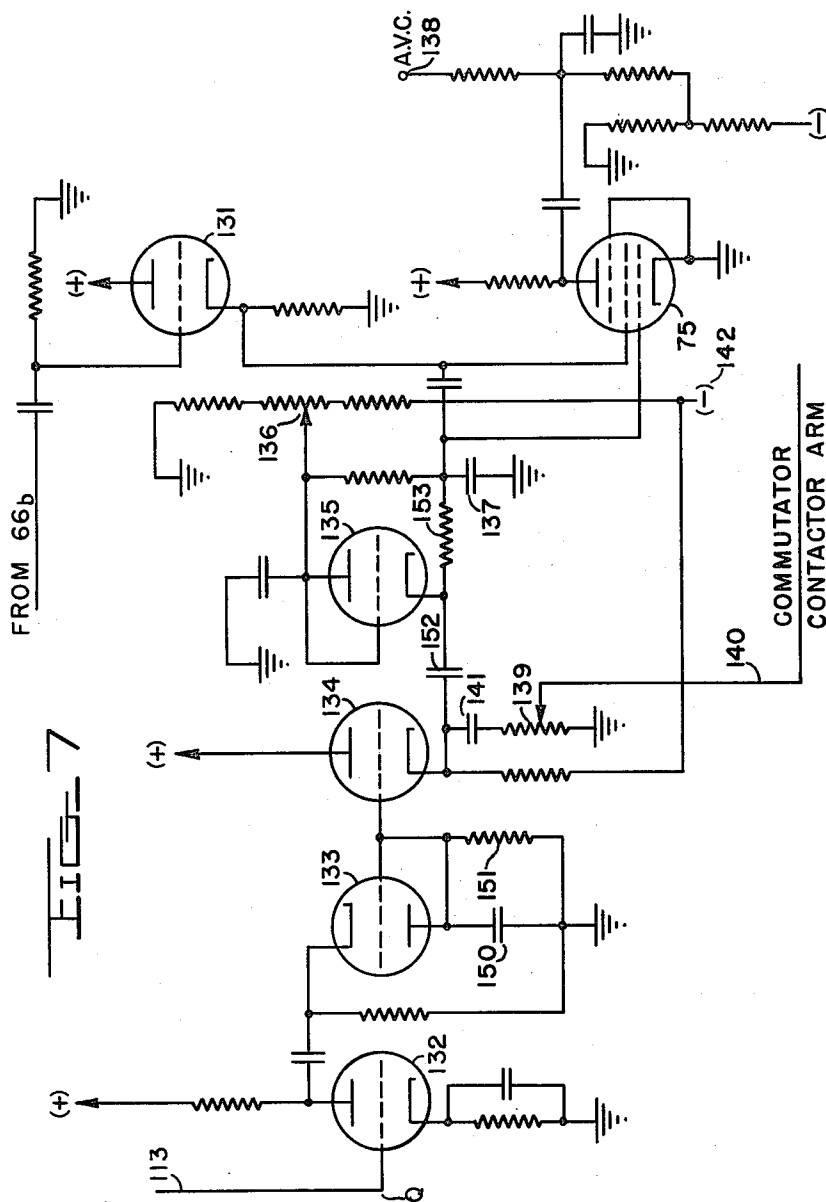
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METHOD OF AND MEANS FOR GUIDING MISSILES

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6 Sheets-Sheet 6



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## METHOD OF AND MEANS FOR GUIDING MISSILES

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Filed Jan. 18, 1945, Ser. No. 574,438

10 Claims. (Cl. 244—14)

This invention relates to automatic guiding of missiles such as glider bombs, torpedo carrying craft and the like, through the use of directed electromagnetic energy. In the preferred case the guided missile is caused to home on a course leading to a collision with a target by means receiving at the missile waves reflected from the target.

The apparatus herein described is best employed in connection with a radio echo detection system for bombing unfriendly craft at night or through overcast when the visibility is limited. In one use an airplane which contains a radio echo transmitter carries a guided missile constructed in accordance with the teachings of this invention slung underneath it in a manner adapted for instant release. When a suitable target is located such as an unfriendly ship the operator stops the scanning of the antenna of the radio echo transmitter and directs its radiation at the target. Whereupon a large amount of reflection will occur at the target and the re-radiated energy will propagate back to the carrier plane to thus permeate the vicinity thereof with reflected energy. Then at the proper instant which usually is not at all critical the guided missile is released and under control of its own apparatus takes up a course leading to a collision with the target.

Since electromagnetic waves propagate in a straight line fashion it is apparent that the guided missile may be made to home along one or another reflected ray until it ultimately collides with the apparent source, in this case the target. Such is the operating principle of the invention.

It should be noted however that the source of radiation used to illuminate the target may be stationed at points other than on the carrier plane, such as on a nearby ship or even in the missile itself. Furthermore the guided missile may contain a propelling force, but for purposes of illustration the invention will be described on the basis of a glider bomb.

It is an object of this invention to provide a guided missile adapted automatically to seek a course toward a target by means in said missile which is responsive to the reception of electromagnetic energy reflected from the target.

It is another object of this invention to provide a guided missile which is responsive solely to electromagnetic echo energy reflected from a selected target.

It is another object of this invention to provide a guided missile adapted to home on a selected target through the use of reflected electromagnetic waves in such a manner that any deviation of the guided missile from its homing course or any evasive motion of the target itself, will automatically cause the missile flight controls to correct the direction of flight and thus keep the missile aimed at the target.

Other 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.

Fig. 1 is an illustration of one possible use of the

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invention; Fig. 2 is a graphical analysis of the variation in echo signal strength which occurs during the time that the flight of the missile has deviated from the correct homing course; Fig. 3 is a schematic diagram showing in part the organization of apparatus used in controlling the flight of the missile; Fig. 4 is a block diagram showing integrally the various components of the "Target Selector Circuit" shown in Fig. 3; Fig. 5 is a circuit diagram illustrating in greater detail the target selector circuit; Fig. 6 is a series of diagrams representing certain variations in voltages which occur at correspondingly designated points in the target selector circuit during a normal cycle of operation thereof, and Fig. 7 is a circuit diagram illustrating in greater detail the automatic volume control and detector circuits shown in Fig. 4.

Reference is now had more particularly to Fig. 1 wherein there is illustrated one possible use of the invention including a controlled glider 11 which is arranged to be released from a carrier plane 10. In this case, the plane 10 serves as a carrier for both the glider 11 and a radio echo system, the energy distribution pattern of which is indicated generally at 13. While the reflected energy occurring at ship 12, which is here illustrated as a target, may appear approximately as shown at 14. Actually, the re-radiated energy 14 will be much more complex but is here shown in such a manner as to simplify the illustration. Once a target such as ship 12 has been located the beam of the radio echo transmitter is trained thereon either through the efforts of the operator or by use of any one of a number of suitable automatic antenna training means now known to the art. Thereafter the carrier plane takes up a course toward the target 12 and at the proper instant, after a few preliminary adjustments have been made on the control apparatus in the glider, the glider 11 is released and immediately starts to home on the target under control of its own apparatus. Following the release of the glider the attitude of the carrier plane is not critical so long as it maintains both the glider and the target in the field of illumination. For example it may fly in a circle behind the glider or at a tangent to the target.

In accomplishing its purpose, the glider control apparatus must perform two rather basic functions. First it must use the variation in echo signal strength caused by a deviation in its flight path with respect to its proper homing course to operate suitable control surfaces which in turn maintain the glider aimed directly at the target. Second it must be able to discriminate between echo signals returned by a selected target and those returned by a nearby object in order that the above flight corrections will only take place with respect to the desired target, otherwise confusion would certainly result.

The first of the above functions is relatively the simpler of the two, capable of being performed by the use of a rotating off-set parabolic reflector in connection with the glider antenna assembly. The reflector is arranged with its axis of maximum directivity 19, which is the axis of the paraboloid, tilted at an angle to the axis of rotation 17. The latter axis may, for example, coincide with the axis of the glider. Patterns 15 and 16 represent respectively the uppermost and lowermost positions of the antenna scan which traces out a sort of a heart shaped figure of revolution having a sharp dip 18 near the antenna rotation axis 17. Thus if the target is dead ahead, that is in line with the antenna rotation axis, then the axis of maximum directivity 19 will exactly circumscribe the target during rotation to thus cause the same amount of echo energy to be received throughout the cycle of antenna scan. If however the target is off the antenna rotation axis 17, then the antenna will obviously receive a stronger signal during that portion of the scan when the axis of

maximum directivity is closer to the line of sight of the target. For example in Fig. 2, plot A represents a case where the target is dead ahead but above the antenna axis at 12 o'clock thus resulting in the reception of the strongest signal at the uppermost portion of the antenna scan and the weakest signal at 6 o'clock in the antenna scan as graphically illustrated in plot B Fig. 2. Energy received at 9 and 3 o'clock in the cycle of antenna scan will be equal since the axis of antenna rotation is only disposed below the target and not to the right or left. Deviations in the alignment of the axis of antenna rotation from the line of sight of the target will thus result in modulation of the received signals, such modulation occurring at the frequency of antenna rotation (which has been set at 35 c.p.s. in some instances) while the phase and amplitude of the same will depend respectively upon the angular position of the target and the degree of displacement thereof relative to the antenna rotation axis. This modulated signal is then detected and by means hereinafter to be described is employed to operate suitable control surfaces on the glider 11 so as to cause it to seek alignment with the target.

No special type of radio echo transmitter is needed for illuminating the target, one producing one micro-second (or less) pulses at a rate of 700 pulses per second has been used to a favorable advantage. Although no particular point of glider release from the carrier is required, it has been found advantageous to release it at a point, say 8 to 10 miles from the target, such that the angle of glider approach to the target does not exceed 50° or 60°, since angles in excess of these often cause the reception of large and confusing sea echos. Furthermore by following this method of glider release the carrier plane may stay well out of range of enemy gun fire.

Reference is now had more particularly to Fig. 3 wherein there is shown in part the organization of equipment used in controlling the flight of the glider. Here a glider is shown having suitable control surfaces or flaps 21 and 22 inserted in the trailing edge of the main wing and a horizontal tail surface 23 to which there are attached port and starboard vertical rudders 58. The tail surface 23 is located at such a distance from the main wing as to be in the down wash therefrom. Therefore downward movement of flaps 21 and 22 increase the lift while upward movement thereof decreases the lift. Turns are effected by simultaneously moving the flaps in opposite directions.

Disposed in the nose of the glider is its antenna system including a one-half wave dipole 24, a parasitic reflector 25 which is disposed in front of the dipole at such a distance to reinforce the radiation therefrom, and the off-set parabolic reflector 26. The latter having an axis of directivity 27 tilted at an angle  $\theta$  with respect to the axis of rotation 28. In general the tilt angle is not critical but is preferably kept within 5 or 6 degrees. Maximum effectiveness of the flight control system is obtainable when the antenna directive axis 27 is rotated as previously suggested for which purpose a drive motor 31 is provided, coupled to the hub of the paraboloid through a suitable belt and pulley arrangement 32. Secured to the paraboloid and adapted to rotate therewith is a hollow sleeve 29 which carries at its opposite end a suitable contactor brush 34 arranged to rotate in electrical contact with a mechanical distributor 33 and in angular correspondence with the paraboloid axis 27. Shaft 29 is supported at any convenient point by a bracket and bearing member 30 which fixedly carries the mechanical distributor 33 which comprises a commutator having four segments arranged in space quadrature corresponding to right-left and up-down positions of the axis 27 of the paraboloid 26.

The output of the antenna is coupled to a superheterodyne receiver 36 through a coaxial transmission line 35 which in turn is held fast and passes coaxially through the hollow sleeve 29 thereby allowing only the parabolic reflector and the sleeve 29 to rotate. The video signals

obtained from the output of the receiver are then fed to the target selector circuit 37 the function of which is to permit only those echo signals which are reflected from a selected target to reach the flight control circuits. As the glider approaches the target the intensity of the echo signals will increase to a point where they may saturate the receiver to thus render the same incapable of responding to variations in signal strength caused by deviations in the glider flight path with respect to its proper homing course. To avoid receiver saturation an automatic volume control signal obtained from the target selector circuit is fed back into the receiver 36, as indicated, to control the sensitivity of the same in the usual manner. From the target selector circuit the selected video signal is applied to the contactor arm 34 through a suitable brush and slip ring arrangement 38 from whence it is applied to a commutator segment corresponding to that sector of the antenna scan from which it was obtained. From the commutator segments the signals are fed through respective leads to separate energy comparing circuits and differential amplifiers indicated generally at 43, where the energy obtained from opposed commutator segments and hence sectors of antenna scan are compared. For example leads 39 and 40 may connect the right-left commutator segments to one energy comparing circuit, while leads 41 and 42 connect the up and down commutator segments to another energy comparing circuit. Thus as the flight of the glider deviates from its proper homing course, for example, to the left then the intensity of signals received from the right side of the cycle of antenna scan will exceed those received during the left side, thus causing an unbalance in energy to occur in the corresponding energy comparing circuit. This unbalance in energy as will be described hereinafter will then cause more current to flow through one coil of the differential relay 45 then the other, thus closing the contact 46 onto lead 57, for example, to thereby complete a power circuit (not shown) to the remote control unit 52 or other suitable and known apparatus for controlling the position of the flaps 21 and 22. A preferred type of control unit may, for example, consist of an electrical motor, four solenoid operated clutches and suitable mechanical interlinkages adapted to operate the crank like extensions 53 and 54 which in turn actuate rods 55 and 56 to control the position of flaps 21 and 22. This device is capable of moving rods 55 and 56 in the same direction, in opposite directions or to hold one still while moving the other in response to the operation of the solenoid controlled clutches.

Thus in the case chosen, the unbalance in energy may cause the energization of one such solenoid operated clutch of unit 52 so as to raise flap 22 and lower flap 21, for example, to change the azimuthal course of the glider until equal amounts of energy are received at the right and left commutator segments, at which time the contact 46 will open to permit flaps 21 and 22 to return to their normal position. Up and down control may be achieved through the operation of the differential relay 44 in response to a unbalance of energy in the up and down energy comparing circuits.

To stabilize the flight of the glider a pair of gyroscopes 48 and 49 are provided, mounted for example in the after part of the glider fuselage. On gyroscope 48 is mounted with its spin axis horizontal and normal to the horizontal flight path and responsive therefore to yawing movements of the glider. The other gyroscope 49 is mounted with its spin axis vertical and normal to the horizontal flight path and responsive therefore to pitching movements of the glider. The gimbals in which the gyroscope wheels rotate are pivoted in planes parallel to the longitudinal axis of the glider but are inclined to the horizontal plane of the glider in order to render the gyroscope responsive to roll as well as pitch and yaw.

These gyroscopes are then so mechanically connected to the respective armatures 46 and 47 of the differential

relays 44 and 45 that movements of the glider in excess of predetermined amounts will bring about a precession of the gyroscope spin axis which in turn closes the armatures 46 or 47 onto leads, 57, 59, or 60, 61 to again complete a power circuit to one of solenoid clutches of control unit 52. Conventional gyroscopic stabilizers suitable for this purpose are known to the art.

More frequently than not the glider will be faced with the task of discerning between echo signals returned by the selected target and those returned by a nearby object, in which case it would be difficult if not almost impossible for the glider to home on a particular target. For this reason the "Target Selector Circuit" 37 is provided, an invention of William J. Tull, et al. covered under a separate patent application entitled "Automatic Range Tracking and Memory Circuit" filed October 13, 1944, Ser. No. 558,576, issued as U.S. Patent No. 2,516,356, July 25, 1950. The object of the target selector circuit is to admit only the echo signals from the selected target to the commutator while rejecting all those which come from objects of different range. A detailed description of this circuit will follow with reference to Figs. 4, 5, and 6. The circuit consists in part of a double gated amplifier, that is a pair of amplifier tubes which are held normally at cut-off except for the duration of a pair of applied overlapping gating pulses.

In gating such an amplifier two conditions must be satisfied, first the gates must be made adjustable in time so that the operator may set them to accurately center the echo signal from the desired target before the glider is released from the plane and second the gates must track, that is keep themselves automatically "locked on" the selected target signal as the glider approaches the target.

Before proceeding with the manner in which target tracking is accomplished it is thought desirable to describe in connection with Fig. 4 the manner in which the gates are controlled in time with respect to the reception of the main pulse from the transmitter. The direct signal from the transmitter triggers, in manner to be described hereinafter, the delay multivibrator 67 which in turn produces a variable time duration pulse the trailing edge of which keys off a gate generating blocking oscillator 69. The time duration of the pulse from the delay multivibrator 67 depends upon the D.C. bias applied to the grid of one of the multivibrator tubes. Adjustments of the bias from approximately +10 volts to +35 volts phases the production of the delayed blocking oscillator gate from 1 to 160 microseconds after the reception of the direct pulse which corresponds to ranges of 1 to 15 miles. For tracking purposes a memory circuit 74 is provided, which functions as a long time linear voltage generator arranged to control the D.C. bias on the phase adjusting tube of the delay multivibrator.

Thus if the glider upon release from the carrier plane travels toward the target with uniform velocity and the circuits were perfect the memory circuit alone would suffice for tracking the echo with the blocking oscillator gate. Unfortunately neither of these conditions exists in actual practice so that an additional circuit (an integrator) is needed in order to "trim" the memory circuit one way or another as the delayed gate begins to lag or lead the echo signal. Such a circuit will now be described in detail together with the memory circuit.

Reference is now had more particularly to Fig. 5. The receiver output or the input to the target selector circuit is shown in plot E of Fig. 6, comprising the transmitted signal X, the reflected signal Y from the selected target and another echo signal Z which is to be excluded but nevertheless occurs in the output of the receiver. These signals are applied to the control grid of the blocking amplifier 65, which has a plate load resistance 81 which also serves as a grid resistance for tube 66b in the wide gate generating circuit 66. This latter circuit is a two tube arrangement known as a positive grid multi-

vibrator adapted to respond to output from tube 65 and arranged to produce a pulse say of 200 microsecond duration which is slightly less than the interval of time elapsing between transmitted pulses. The blocking amplifier is biased normally non-conducting by means of a negative grid voltage such as that indicated at 82 so that it will respond only to signals of say 25 volts amplitude or more. Thus when the transmitted pulse X is applied to this tube the cut-off bias is overcome and the tube conducts thereby initiating the generation of the wide gate pulse from 66 by driving the grid of tube 66b sharply negative. Whereupon current commences to flow through resistance 81 to charge condenser 83 to thus hold the grid of tube 66b negative and hence the plate of tube 65 negative thereby rendering the latter incapable of responding to signals following the reception of the transmitted pulse.

The output from the wide gate circuit 66 as taken from the plate of tube 66b is a positive rectangular gate as shown at G in Fig. 6 is differentiated by the condenser 120, resistance 122 and inductance 121 and is applied as a trigger pulse to the grid of tube 67a of the delayed multivibrator 67. This multivibrator immediately generates a pulse in response to the leading edge of G and in the same manner as 66 but of a time length determined by the bias on the grid of tube 67a. Production of the variable delay gate pulse and triggering pulse for the blocking oscillator is as follows: tube 67b is normally conducting so that when tube 67a is triggered by the positive trigger from 66b the grid of 67b drives negative and renders this tube non-conducting. Since the grids of tube 67b and 67a are connected respectively to B+ and ground approximately the multivibrator cathode current is greater when 67b is conducting than when 67a is conducting. Consequently when the multivibrator is triggered by the leading edge of G the net cathode current will decrease and a negative pulse will appear across the inductance. The time length required for the multivibrator to recover to its quiescent state is governed by resistance 86, capacitor 85 and the D.C. bias on the grid of 67a. The higher the bias on the tube the greater the voltage drop across the cathode resistance 123 when tube 67a is conducting and hence the longer it takes for condenser 85 to charge to a value sufficient for restoring conduction to tube 67b. As will be described hereinafter the memory or tracking circuit supplies tube 67a with a linearly decreasing bias which shortens correspondingly the length of the pulse generated by the multivibrator 67. As indicated the trailing edge of this pulse produces a positive trigger voltage across inductance 84 which renders tube 68 conducting and hence keys the blocking oscillator 69 into operation. Blocking oscillator 69 in turn produces a .6 microsecond negative pulse of about 50 volts amplitude as shown in plot I which in turn is fed through lead 87, and attenuator 88 to the cathode of 76a of the gated amplifier 76 and after being delayed .4 microseconds by the delay line 71 is applied to the cathode of tube 76b. In this manner the gated amplifier will be properly opened to receive a 1. microsecond pulse, i.e. taking the time from the instant that the delayed blocking oscillator pulse is applied to the gated amplifier, tube 76a is opened from 0 to .6 microseconds, while tube 76b is opened from .4 microseconds to 1 microsecond. The attenuator 88 is provided so as to equalize the amplitude of the gates applied to the cathodes of the amplifier 76 by compensating for the inherent attenuation in delay line 71. The output of the receiver is simultaneously applied to both grids of amplifier 76 through delay line 72 and amplifier 89. The latter delay line compensates for the inherent delay in the foregoing pulse generating circuits as shown in plot j of Fig. 6 and also enables the gates to follow the echo signal down further in range since the width of the gates would limit the lowest tracking range without this line.

The amplifier tubes 76a and 76b have their grids both

biased to cut-off say -60 volts as indicated so that no video signal (maximum of about 30 volts will pass through this circuit except during the application of the overlapping negative 50 volt signals and applied to their cathodes. If the timing of the .6 microsecond blocking oscillator pulse and its .4 microsecond delayed mate is correctly centered with respect to the selected echo signal then equal amounts of the echo signal will pass through both sections of the amplifier 76. This being the case equal voltages will be developed across the respective plate resistances of 76a and 76b. Should the blocking oscillator pulse occur later than the instant required the tube 76a will conduct more energy than 76b since more video energy will lie in the early gate. The outputs from the two channels of amplifier 76 are taken from the respective plate circuits and applied through condenser 91 and 92 to the integrator circuit 74. The function of the integrating circuits is one of comparing the relative amounts of video signal passed by each section of the gated amplifier 76 and for providing a corrective signal to the delay multivibrator 67 to control the pulse length thereof such that the overlapping gates produced by the blocking oscillator will be correctly timed to properly center the video signal.

The integrating circuit consists of a pair of "pulse stretchers" comprising diode 93a and 94a, capacitances 91 and 92 and the condenser 99 connected to the mid-point a pair of serially connected amplifiers 93b and 94b. Diodes 93a and 94a are connected across the two inputs to the two series amplifiers with the cathode of the diodes connected to the respective grids. The input to these two amplifiers are a pair of negative overlapping pulses as shown in L and M in Fig. 6 which short circuit the diodes 93a and 94a to first charge condenser 91 and then 92 during the initial period of the respective pulses L and M. Consider for instance the upper half of this circuit including condenser 91 and point N. During each negative pulse diode 93 conducts to charge condenser 91. The amplitude of this pulse which is dependent upon the amount of video signal embraced by the respective gate determines the charge which condenser 91 will accrue, and at the termination of which point N will jump positive as indicated at N of Fig. 6 by the voltage on 91 to cause tube 93b to conduct. Condenser 91 then begins an exponential discharge through resistance 97, thus holding 93b conducting which in turn tends to charge condenser 99 more positive. In a similar fashion tube 76a charges condenser 92 to hold point O as indicated in Fig. 6 and tube 94b conducting which in turn tends to discharge the condenser 99. As a result condenser 99 assumes an average or integrated charge when the output signals from the gated amplifier 76 are equal. If, however, the overlapping gates appear later than that required then the gates are not tracking fast enough, in which case the output from 76a will exceed that from 76b so that condenser 99 or the mid-point 130 between the series tube 93b and 94b will go negative with respect to its normal voltage which drop in voltage is applied to the memory circuit in a manner herein-after described to correct the rate of the automatic tracking voltage applied to the delay multivibrator 67.

As previously mentioned it is the function of the "memory" circuit to provide the delay multivibrator 67 with a linearly decreasing bias so that the time interval elapsing between the reception of the transmitter pulse and the generation of the output pulse from the blocking oscillator will be automatically decreasing at approximately the same rate as the rate of approach of the glider to the target. This circuit consists of a pair of cathode followers 101 and 102 which applies the output of 102 as taken from point P in the cathode circuit thereof to the control grid of 67a. The cathode of 101 is connected to the grid of 102 through resistance 125 while the cathode of 102 is connected through condenser 103 and resistance 104 to the grid of 101. In operation before

the glider is released from the carrier plane the operator adjusts the bias of the delay multivibrator 67 to properly center the gates with respect to the video signal. This adjustment is performed by closing the switch 128 which is located in the carrier plane together with certain other controls which may be brought into the carrier plane through a pull away connector and umbilical cord arrangement. Closing of this switch operates relay 124 to short out resistance 125 with resistance 127 and connect the grid of 101 to a "Slewing" potentiometer 126. This latter potentiometer has a positive voltage connected thereacross and is adjusted until condenser 105 and consequently point P of tube 102 is raised to a potential to provide multivibrator 67 with the proper bias to center the video signal. The propriety of this adjustment may best be observed by applying the delayed output of the receiver as taken from the plate of tube 89 and the output of the blocking oscillator 69 through a cathode follower mixer stage 70 to a cathode ray indicator tube also situated in the carrier airplane. Once this adjustment has been made the switch 128 can be opened to start operation of the memory circuit. Condenser 105 starts to discharge through resistance 125 to thus reduce the potential on the grid of 102 and consequently cathode of 101. The reduction in potential on the grid of 102 causes a corresponding reduction in potential on its cathode which in turn reduces the potential on the grid of 101. The circuit is so arranged that the potential on the cathode and grid of 101 decrease in a like manner and amount so that a constant potential drop across resistance 125 is observed which thus causes a slow uniform discharge of condenser 105 with point P as indicated in the corresponding plot of Fig. 6 decreasing slowly from its quiescent or static value. In the event the memory circuit does not cause proper tracking of the video signal the mid-point 130 of the series amplifiers 93b and 94b will rise or fall to thus ignite the neon lamp 100 and thereby provide an error signal to the grid of tube 101 in the memory circuit. Such an error signal appears instantaneously at point P and hence at the delay multivibrator 67. For example in the previous case it was assumed that the gating pulses were late thus causing the plate potential drop of 76a to exceed that of 76b. In this condition 94b will be more strongly conducting than 93b so the potential at point 130 will go negative to thus ignite the neon bulb 100 and hence insert a small negative discontinuity in the slope of the voltage at point P. If this lumped correction does not remedy the error in tracking, the neon bulb 100 will continue to fire to thus provide a series of discontinuities in the tracking voltage until an effective change in the slope of the tracking voltage has been established. After the error in tracking has been amply corrected then the tracking voltage will proceed in accordance with the neutral decay of the circuit. The neon bulb serves as a means for isolating small and insignificant variations at point 130 from the memory circuit in that it requires about a 30 volt difference across it for breakdown. The circuits however, are so designed as to provide a 30 volt signal at small errors.

From the analysis of the foregoing circuits it is seen that the target selector circuit utilizes the direct pulse from the radio echo transmitter to initiate its cycle of operation, that is to render tube 65 blocked and thus start the generation of the blocking oscillator 69 pulse. In the early stages of the glider flight the forward looking rotating antenna will receive ample power for this purpose from the direct pulse until a certain distance separates the glider from the carrier plane after which this antenna will no longer suffice. For this reason a beacon type antenna 50 is provided, located in the tail of the glider as shown in Fig. 3. Such an antenna provides a circular pattern that is adapted to receive energy from all angles. Also provided but not shown is a delay switch interposed between the beacon antenna and its

connection to the receiver through lead 51 which shorts out antenna 50 for the first 3 or 4 seconds of the glider's flight in order to prevent unattenuated reception of the high power direct pulse at close range and hence damage to the receiver.

Reference is now had more particularly to Fig. 7 wherein there is shown a gated automatic volume control circuit for the receiver. The purpose of this circuit is to first permit the direct pulse from the transmitter to pass through the receiver during the absence of an A.V.C. voltage to thus provide an adequate trigger pulse for the blocking amplifier 65, after which the A.V.C. voltage is applied to the receiver to reduce the sensitivity of the same to about 50% to thus enable the echo signal to pass undistorted therethrough. In practice the A.V.C. output tube 75 is set into operation in response to the output from the cathode follower 131 which in turn is under control of the wide gate generating circuit 66. The transmitted pulse is first received and then used to trigger the wide gate generating circuit 66 to produce a positive pulse G which is applied to the grid of the cathode follower 131 which in turn provides an operative bias for the screen grid of the A.V.C. output tube 75. In generating the A.V.C. voltage a pure video signal as indicated at Q in Fig. 6 is obtained from the plate circuit of the gated amplifier 76 by means of the transformer 112 and applied through lead 113 to the grid of the buffer amplifier 132 of the A.V.C. circuit. In this manner the video signal from the selected target alone and not those produced by nearby objects will effect the generation of the A.V.C. voltage.

From the amplifier tube 132 the video signal is fed to the cathode of the detector tube 133 so that as the plate of the amplifier swings negative the detector conducts to thus charge the condenser 150 disposed in the plate circuit thereof sharply negative after which the condenser is allowed to render a slow discharge through resistance 151. In this manner the voltage developed across the resistance 151 represents a saw-tooth wave having a leading edge which sharply drops to a value depending upon the magnitude of the video signal and trailing edge which slowly decays to zero in a time approximately equal to the interval elapsing between transmitted pulses. This saw-tooth voltage is then coupled to the contactor arm of the commutator through amplifier 134, condenser 141, potentiometer 139 and lead 140. As the cathode of the amplifier 134 swings negative in response to the saw-tooth input the cathode of diode 135 also swings negative thus rendering the latter conducting and hence providing condensers 137 and 152 disposed in the cathode circuit of the diode with a charge. The amount of charge condensers 137 and 152 will accrue depends upon the amplitude of the video signal. Before proceeding further with the description of the method employed to generate the A.V.C. voltage it is to be noted that the adjustment of the potentiometer 136 controls the static charge (negative since the potentiometer is connected between ground and a negative source indicated at 142) on condenser 137 and therefore the grid bias of the A.V.C. output tube. Hence as the cathode of the diode 135 is driven negative from the output of the amplifier 134 the cathode loses electrons and hence condensers 137 and 152 tend to charge in a positive direction to decrease the negative bias on the control grid of the A.V.C. output tube 75 and therefore increase the gain of this tube and hence the amplitude of the pulse gate output therefrom which is available at point 138. The time constant of the condensers 137 and 152 and resistance 153 is large compared to the interval between pulses so that the condenser 137 will assume an integrated charge and will not vary between pulses. Thus the A.V.C. signal is a wide gate pulse equal in time length to the pulse G and adjusted in amplitude in accordance with the setting of the potentiometer 136 and the intensity of the video signal.

Turning now to Fig. 4 wherein there is shown in

greater detail the relationship between the target selector circuit 37 and the remaining portion of the flight control circuits including the differential amplifiers indicated at 43 in Fig. 3 and relays 44 and 45. The output of the target selector circuit is taken from the movable tap of potentiometer 139 shown in Fig. 7 and consists, whenever the orientation of the antenna axis deviates from the line-of-sight of the target, of a sinusoidal modulated video saw-tooth wave. For example let it be assumed that the target lies below the antenna axis then the contactor arm 34 of the commutator 33 will distribute a voltage wave to the grids of the differential amplifiers 43a and 43b having an A.C. component due to the sine wave modulation envelope and a D.C. component coming from the rectifier action of the commutator itself. That is as the commutator contactor arm rotates the intensity of the signals received by the antenna when in a down position will exceed those received during the up portion of the scan. In which case the charge applied to the side of the condenser 143 attached to the grid of 43b by the negative saw-tooth voltage obtained from the detector circuit will predominate over that applied to the side attached to the grid of 43a. In this event more D.C. current will pass through 43a than 43b. The A.C. component (or the saw-tooth wave itself) distributed by the commutator is applied in parallel through condenser 143 to the grids of both amplifiers so that this component will cancel out in the plate condenser 146.

The output of the differential amplifier is direct coupled into a pair of respective power amplifiers 145a and 145b which are in turn plate loaded by the respective coils of the differential relay 44, for instance. Thus since 43a is passing more current than 43b its plate voltage will be lower than 43b so that the grid bias of 145a will be more negative than that on 145b. In this case more current will pass through the lower coil than the upper to thus close the armature 47 onto contactor 61 and thereby complete a power circuit, the negative end of which is indicated at 148 to the proper solenoid operated clutch contained in control unit 52. A similar differential amplifier and power amplifier circuit is used to connect the right and left commutator segments to the differential relay 45.

When equal amounts of energy are passing through each coil of one differential relay the armature 47 or 43 should lie in a neutral position, for which purpose the potentiometer 147 is provided. This potentiometer is disposed in the cathode circuit of the power amplifier and is adjusted in a no signal condition to balance the current flow through the relay coils.

Although we have indicated a preferred type of gyroscope stabilizer and remote control unit it must be understood that other systems now known to the art may be employed, if desired, for example, one very suitable arrangement is disclosed in U.S. Patent No. 1,896,805. We are also fully aware of many other modifications possible in our invention. Therefore this invention is not to be limited except insofar as is necessitated by the prior art and the spirit of the appended claims.

What is claimed is:

1. Means for automatically piloting a controlled missile, comprising means for transmitting a series of pulses of electromagnetic energy to a preselected remote object, means on said missile for receiving reflections of said transmitted pulses, said receiving means including means for amplitude modulating received signals in accordance with the direction of reception of said signals with respect to the course line of said missile, means responsive to said transmitted pulses and to echo pulses from said remote object adapted to pass only signals reflected from said remote object, means for comparing the amplitude of alternate quarter cycles of the signal passed by said last-mentioned means and means responsive to said comparing means adapted to operate first control means in

response to differences in the relative amplitudes of odd quarter cycles of the signal applied to said comparing means and adapted to operate second control means in response to differences in the relative amplitudes of even quarter cycles of the signal applied to said comparing means.

2. Means for automatically piloting a controlled missile comprising means for transmitting a series of pulses of electromagnetic energy to a remote object, means on said missile for receiving reflections of said transmitted pulses, said receiving means including an antenna array comprising a parabolic reflector and an eccentrically mounted rotatable dipole wherein rotation of said dipole causes the axis of directivity of said array to rotate about the course line of said missile, pulse receiver means coupled to said antenna array, means on said missile for comparing the amplitude of signals received in opposed positions of said axis of directivity, range tracking means intermediate said receiving means and said comparing means adapted to block signals from objects at ranges substantially different from the range to a preselected object, and means operating control surfaces on said missile in response to the difference in amplitude of signals in said opposed positions.

3. Means for automatically piloting a controllable missile, comprising means for transmitting a series of pulses of electromagnetic energy in a pattern illuminating said missile and a preselected remote object, means on said missile for receiving said transmitted pulses directly and after reflection from said remote object, said receiving means including means for amplitude modulating received signals in accordance with the direction of reception of said signals with respect to the course line of said missile, means responsive to said transmitted pulses and to echo pulses from said remote object adapted to pass only signals reflected from said remote object, means for comparing the amplitude of alternate quarter cycles of the signal passed by said last-mentioned means and means responsive to said comparing means adapted to operate first control means in response to differences in the relative amplitudes of odd quarter cycles of the signal applied to said comparing means and adapted to operate second control means in response to differences in the relative amplitudes of even quarter cycles of the signal applied to said comparing means.

4. Means for automatically piloting a controllable missile, comprising means for transmitting a series of pulses of electromagnetic energy in a pattern illuminating said missile and a preselected remote object, means on said missile for receiving said transmitted pulses directly and after reflection from said remote object, said receiving means including an antenna array comprising a parabolic reflector and an eccentrically mounted rotatable dipole wherein rotation of said dipole causes the axis of directivity of said array to rotate about the course line of said missile and an auxiliary antenna having a receiving pattern including said transmitting means irrespective of the orientation of said missile, pulse receiver means coupled to said antenna array and said auxiliary antenna, means on said missile for comparing the amplitude of signals received in opposed positions of said axis of directivity, range tracking means intermediate said receiving means and said comparing means adapted to block signals from objects at ranges substantially different from the range to said preselected object, and means for operating control surfaces on said missile in response to the difference in amplitude of signals in said opposed positions.

5. Automatic piloting means in claim 4, said means further comprising means for disconnecting said auxiliary antenna from said pulse receiver means, said last-mentioned means being adapted to automatically reconnect said auxiliary antenna to said pulse receiver means after the passage of a preselected interval of time.

6. Means for automatically piloting a controllable aerial craft to a target comprising, a radiant energy pulse system for illuminating said target and said craft with radiant energy pulses from a point remote from said craft, means on said craft for orienting said craft in elevation and azimuth, respectively, a reflector disposed with the axis thereof at a small angle with the craft axis, means for rotating said reflector about the craft axis whereby a solid conical angle of space is scanned, means for receiving energy pulses reflected from objects located within said conical angle, auxiliary antenna means for receiving energy pulses directly from said illuminating system, and means responsive to said received reflected energy pulses and to the signals received by said auxiliary antenna for interpreting the phase and amplitude of the variations in intensity of pulses reflected from said target and for producing elevation and azimuth signal voltages corresponding to the elevational and azimuthal components, respectively, of the angular displacement of the line of sight to the target with respect to the craft axis, and servo control means for actuating said orientation means in response to said azimuth signal voltage and said elevation signal voltage, whereby the orientation of said craft is continuously maintained coincident with the line of sight to said target.

7. Apparatus for striking a target comprising, a target seeking aerial craft, generating means for producing periodic pulses of electromagnetic energy, directive radiating means for projecting said energy pulses into space in a direction to illuminate said target and said craft, directive receiving means mounted on said craft for receiving target reflected energy from a solid conical angle of space, the axis of said conical angle coinciding with the axis of said craft, auxiliary receiving means mounted on said craft for directly receiving pulses from said directive radiating means, means responsive to signals received by said directive receiving means and said auxiliary receiving means for blocking signals from objects at ranges substantially different from said target, means for interpreting the variations of intensity of said target reflected energy and producing voltage signals proportional to the angular deviation of the line of sight to said target from the axis of said craft, automatic positioning means responsive to said voltage signals for continuously maintaining the axis of said craft coincident with the line of sight to the target after release of said craft, and an indicator means responsive to said target reflected energy for indicating the relative position of said target and said aerial craft prior to the release of said craft.

8. Apparatus for striking a target comprising, a target seeking aerial craft, generating means for producing periodic pulses of electromagnetic energy, directive radiating means for projecting said energy pulses into space in a direction to illuminate said target and said craft, directive receiving means mounted on said craft for receiving target reflected energy from a solid conical angle of space, the axis of said conical angle coinciding with the axis of said craft, auxiliary receiving means mounting on said craft for directly receiving pulses from said directive radiating means, means responsive to signals received by said directive receiving means and said auxiliary receiving means for blocking signals from objects at ranges substantially different from said target, means for interpreting the variations of intensity of said target reflected energy and producing voltage signals proportional to the angular deviation of the line of sight to said target from the axis of said craft, said aerial craft being provided with first and second wing members, first and second control areas disposed on said first and second wing members, respectively, said control areas when operated in the same direction acting to change the direction of said craft in elevation, said control areas when operated in opposite directions acting

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to control the direction of said craft in azimuth, automatic positioning means responsive to said voltage signals for actuating said control areas to maintain the axis of said craft coincident with the line of sight to the target after release of said craft.

9. Apparatus as in claim 8, wherein said automatic positioning means includes gyrostabilizing elements for stabilizing the flight of said aerial craft.

10. Means for automatically piloting a controlled missile comprising, means for transmitting electromagnetic energy to a remote object, means for receiving energy reflected from said object, said energy receiving means including means impressing a substantially sinusoidal modulation on said received energy, the phase of said modulation being indicative of the position of said target with respect to a transverse axis of said missile, and the amplitude of said modulation being a function of the angular displacement of said object from the flight axis of said missile, means for comparing the amplitude of energy at alternate quarter cycles of said modulation, means responsive to said comparing means for operat-

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ing control surfaces on said missile, and means interposed between said receiving means and said comparing means for blocking signals from objects at ranges substantially different from the range to said remote object.

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