March 12, 1963 E. F. LAPHAM, JR 3,081,048

DIRECTIONAL ANTENNA

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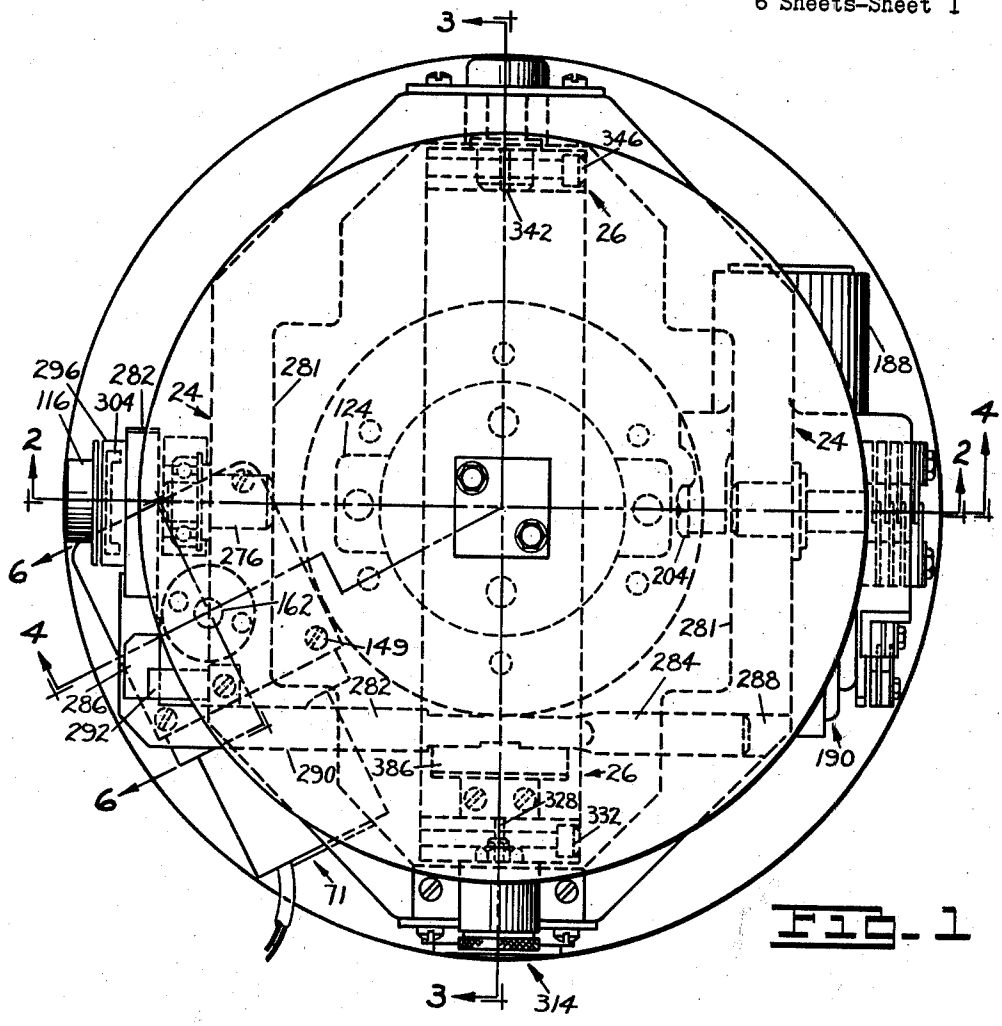


FIG. 1

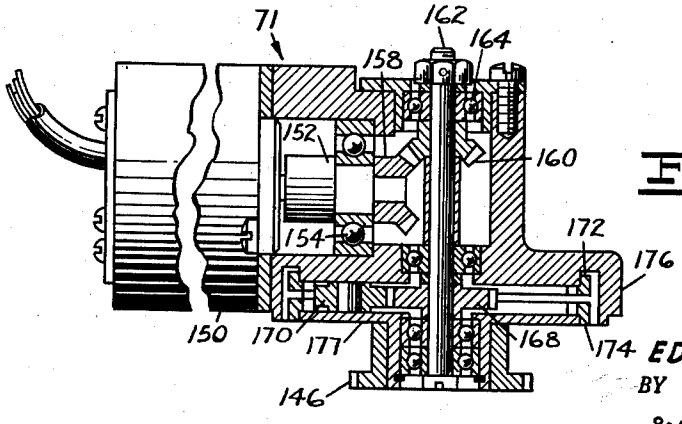


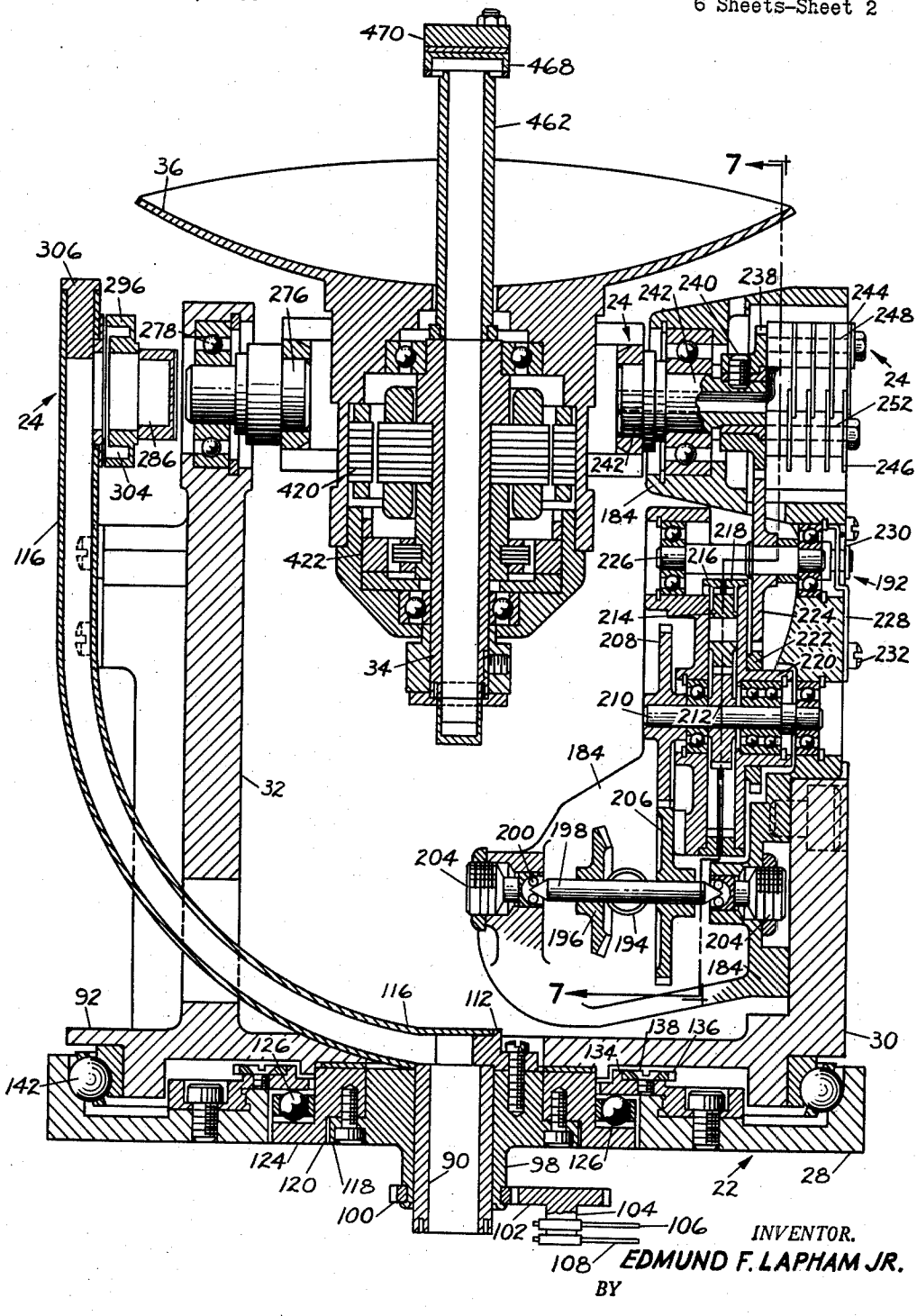
FIG. 6

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DIRECTIONAL ANTENNA

Filed Oct. 7, 1950 6 Sheets-Sheet 2



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Fig. 2

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DIRECTIONAL ANTENNA

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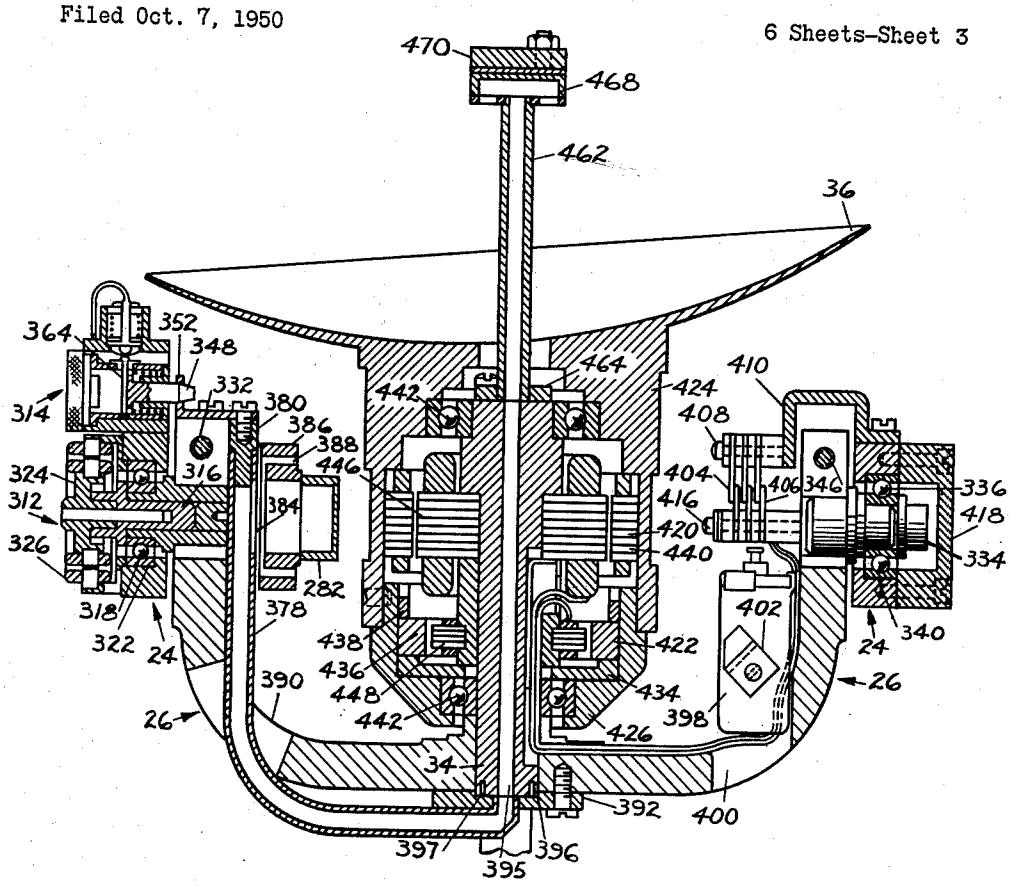


FIG. 3

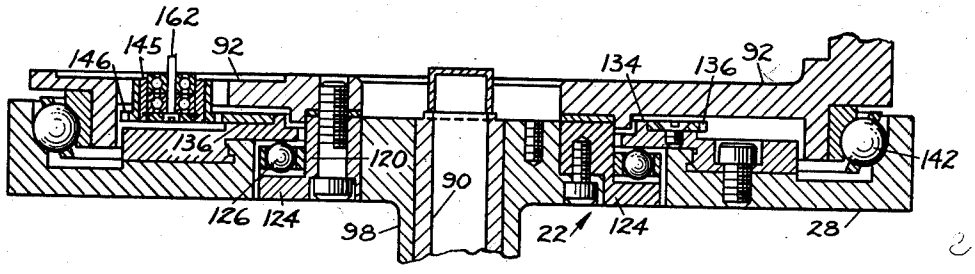


FIG. 4

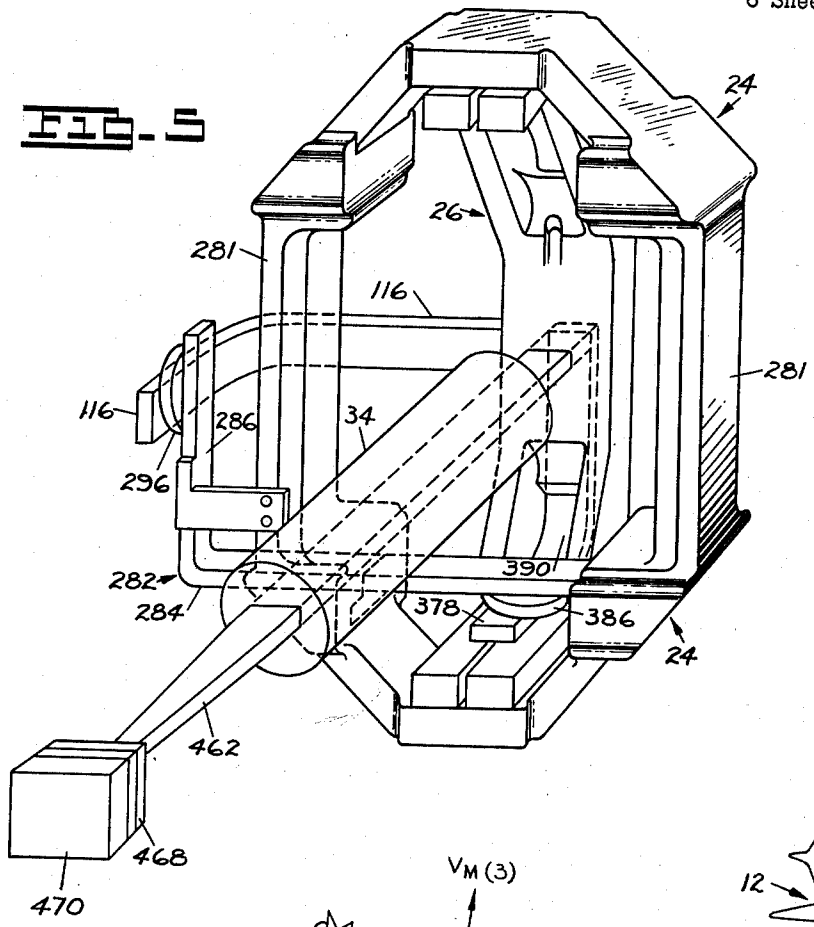
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DIRECTIONAL ANTENNA

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Fig. 5



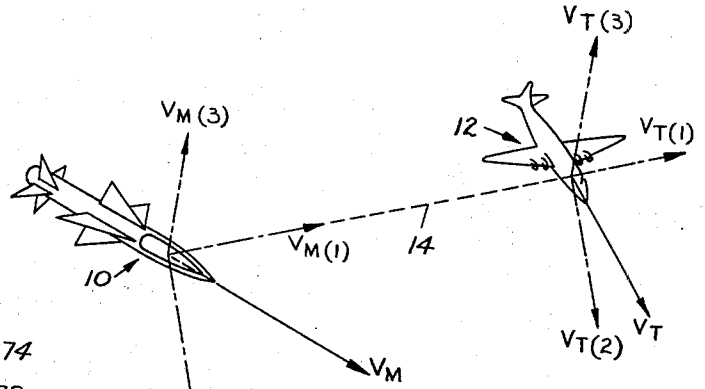


Fig. 14

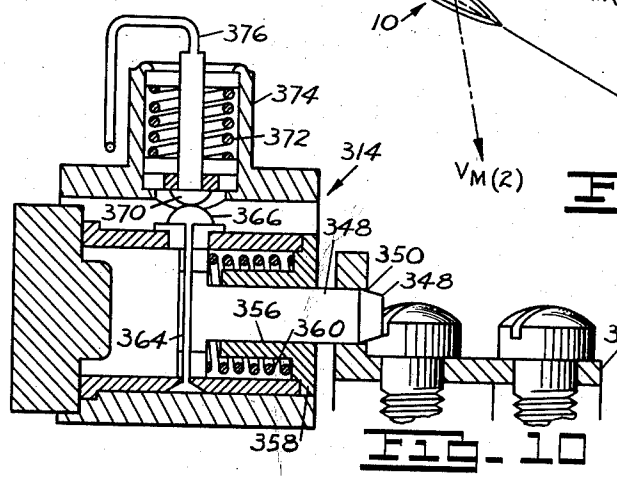


Fig. 10

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DIRECTIONAL ANTENNA

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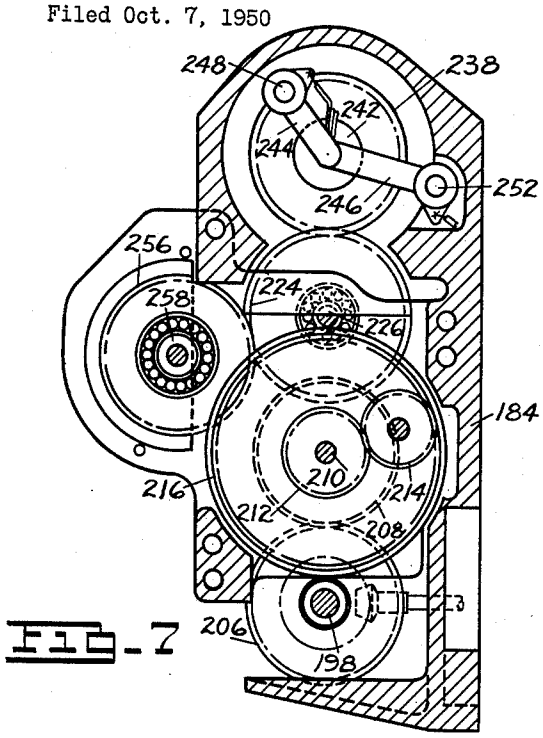


FIG. 7

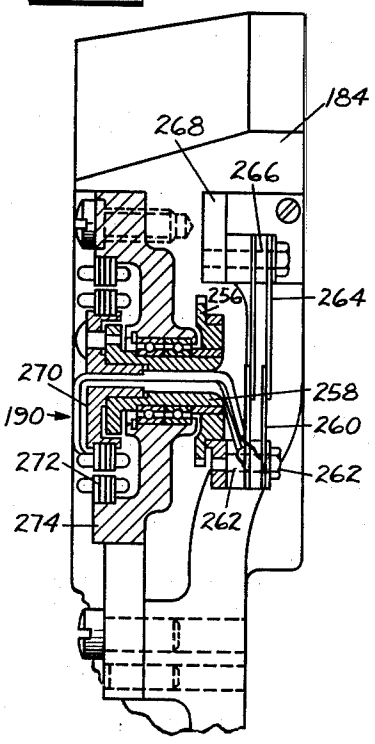


FIG. 9

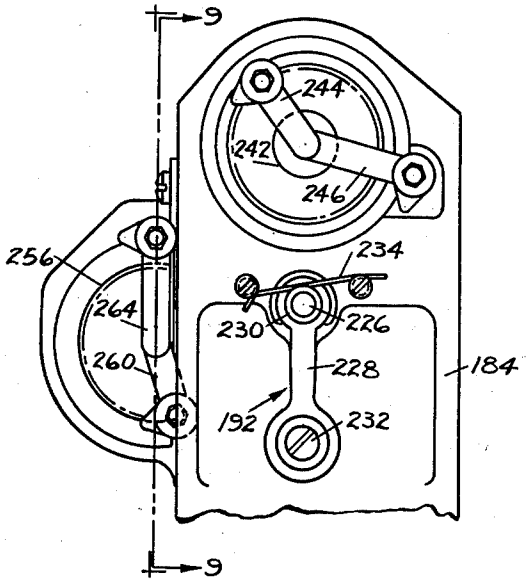


FIG. 8

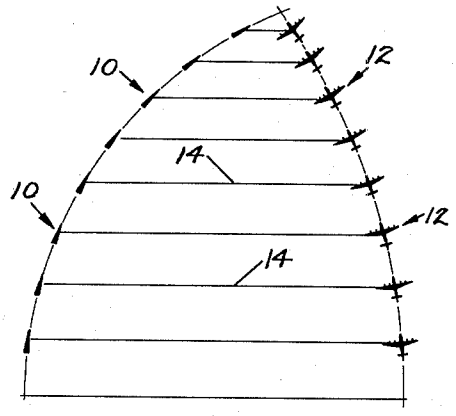


FIG. 15

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DIRECTIONAL ANTENNA

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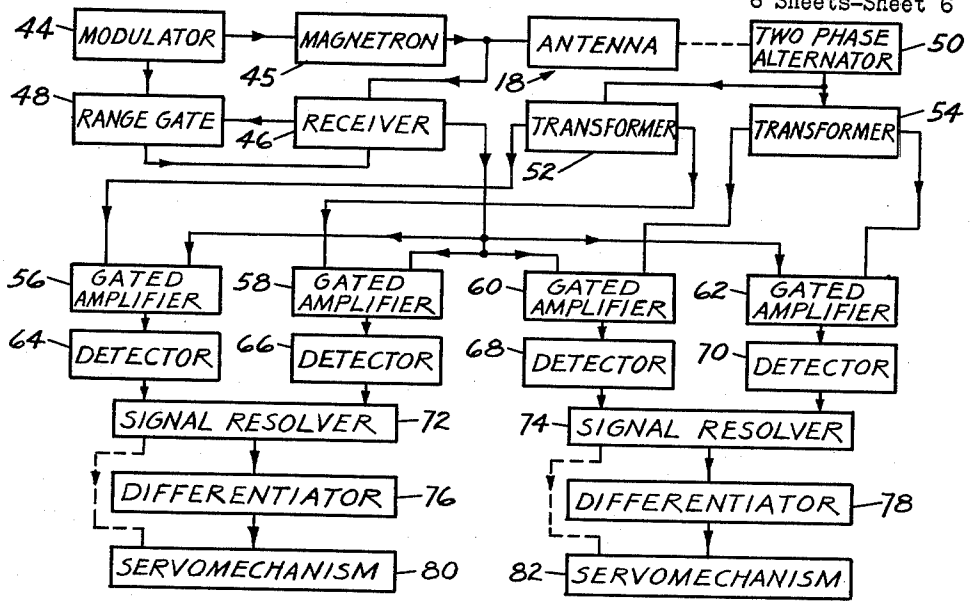


FIG. 12

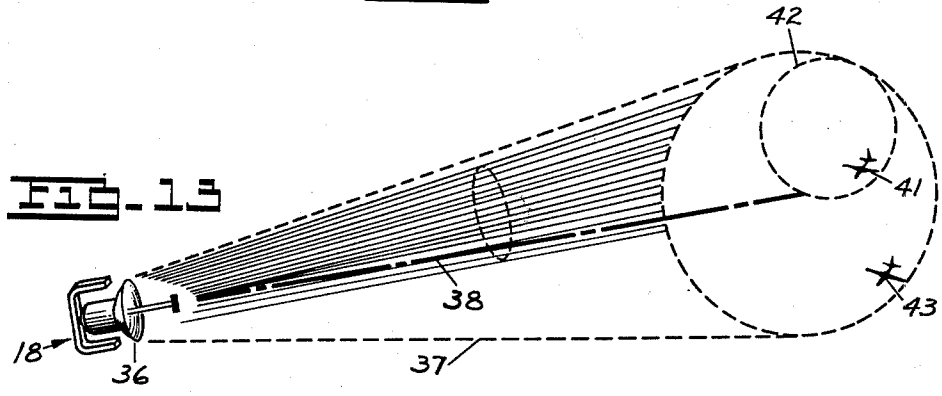


FIG. 13

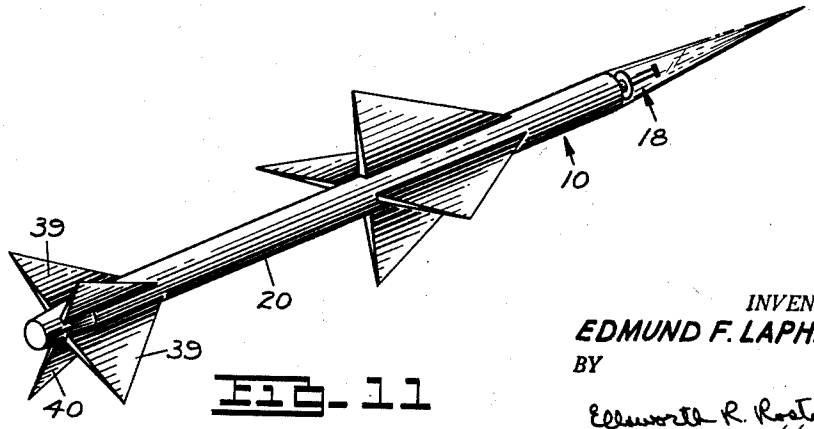


FIG. 11

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United States Patent Office 3,081,048 Patented Mar. 12, 1963

3,081,048

DIRECTIONAL ANTENNA

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Filed Oct. 7, 1950, Ser. No. 188,943
37 Claims. (Cl. 244—14)

This invention relates to a radar antenna and more particularly to a directional antenna adapted to project a beam over a wide angle in any plane. The antenna is especially adapted for use in directing a missile to intercept a distant target.

Missile systems may in general be divided into two categories, passive and active. In the passive missile system, the missile is launched by a friendly aircraft against an enemy target and is then guided by the launching aircraft to intercept the target. A directional antenna is mounted on the launching aircraft for the transmission of directional signals to the target and for the reception of echoes from the target. On the basis of the echo signals received, the launching aircraft directs the course of the missile toward the target. Since the direction of missile flight is determined by the launching aircraft, the missile may employ a non-directional antenna.

Passive missile systems have several disadvantages. They require the launching aircraft to remain within range of the target until the missile intercepts the target. Furthermore, they require the launching aircraft to transmit signals to and receive echoes from the target before directing the missile in its flight. This prevents the flight of the missile from being immediately corrected in case the missile deviates from its correct path.

In active missile systems, the missile transmits its own signals toward the target and adjusts its direction of flight on the basis of the signals reflected by the target. This causes any deviations in the flight of the missile to be corrected in a minimum amount of time. It also allows the launching aircraft to withdraw from the vicinity of the target immediately after the missile is launched. However, it requires the missile to have a directional antenna.

With the missile guiding itself, there are various courses which it may follow in approaching a target. As one possibility, the missile may follow a homing course. This requires the missile and its antenna to point continuously at the target. Since the missile and its antenna are always pointed in the same direction, the missile may be rigidly coupled to the antenna. Although this rigid coupling is desirable, homing systems have several disadvantages. Probably the most serious disadvantage is that excessive lateral accelerations are required of the missile when the missile is fairly close to the target. Since the missile cannot meet the large lateral accelerations which may be demanded, it often misses the target by a considerable distance.

The missile may also proceed on a path substantially perpendicular to the wake of the target until it crosses the wake and it may then follow the wake to intercept the target. Here, too, the missile may be rigidly coupled to the antenna since both always point in the same direction. But a missile following this course also has several disadvantages. The missile has to travel through an unnecessarily long path to reach the target. It has to turn sharply when it reaches the wake of the target, thus incurring excessive lateral accelerations, and it is provided with a minimum amount of control as it is approaching the wake of the target. Because of this, it may intercept the wrong target.

The missile may also follow a constant lead angle course in which it points ahead of the target by a predetermined amount. This will cause the missile to intercept the target if the target proceeds on a straight line at a constant speed. Errors result if the target changes its speed or follows a curved path.

A variable lead angle course, more familiarly known as a collision course, is probably the most desirable. In this course, the antenna is pointed at the target by a conventional radar system before the missile is released. A line of sight is accordingly formed between the antenna and the target. After the missile is released, its antenna continues to point at the target, but the missile pivots about the antenna to maintain a correct movement toward the target. By such pivoting, the missile follows the movement of the target in directions perpendicular to the line of sight, but gradually moves along the line of sight relative to the target. Since the only movement of the missile relative to the target is along the line of sight, the missile will intercept the target regardless of the flight path which the target adopts.

Conventional radar systems employ directional antennas which can be pivoted to point in any direction. These antennas generally have a dish or reflector which is adapted to spin about a shaft as an axis and simultaneously pivot with the shaft so as to scan a wide area for a particular object, such as an enemy airplane. However, these directional antennas are not suitable for use with active missiles following a collision course. They are not suitable because the missiles travel at a high rate of speed in a path that may be constantly changing in direction. Furthermore, the antennas occupy more space than is available in most missiles.

An object of this invention is to provide an antenna for guiding a missile to intercept a distant target.

Another object of the invention is to provide a directional antenna of the above indicated character which can swing relative to the missile through a wide angle in any plane so as to correct any deviations in the flight of the missile towards the target.

A further object is to provide an antenna of the above indicated character which can adopt any angle relative to the missile so that it can adjust the course of the missile in accordance with any changes in the flight path of a distant object.

Still another object is to provide an antenna of the above indicated character which is constructed simply, sturdily and compactly and which operates efficiently and reliably.

Other objects and advantages of the invention will be apparent from a detailed description of the invention and from the appended drawings and claims.

In the drawings:

FIGURE 1 is a top plan view of the antenna;

FIGURE 2 is a sectional view substantially on the line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary sectional view substantially on the line 3—3 of FIGURE 1;

FIGURE 4 is a fragmentary sectional view of the mount gimbal assembly taken substantially on the line 4—4 of FIGURE 1;

FIGURE 5 is a perspective view of the ring and horseshoe gimbals and the wave guide assembly as seen from a position above and to the right of the antenna;

FIGURE 6 is a fragmentary sectional view substantially on the line 6—6 of FIGURE 1 and shows the motor assembly for operating the mount gimbal;

FIGURE 7 is a fragmentary sectional view substantially on the line 7—7 of FIGURE 2, showing particularly the gear assembly for rotating the ring gimbal;

FIGURE 8 is a fragmentary elepational view from the right side of the antenna as seen in FIGURE 1;

FIGURE 9 is a sectional view of the motor assembly for the ring gimbal when taken substantially on the line 9—9 of FIGURE 8;

FIGURE 10 is an enlarged detail view of structure shown in FIGURE 3 for uncaging the horseshoe gimbal when the missile is released;

FIGURE 11 is a perspective view of the missile and its antenna;

FIGURE 12 is a block diagram of the electrical system for guiding the missile toward the target;

FIGURE 13 is a schematic diagram of the beam scanned by the antenna;

FIGURE 14 is a schematic diagram illustrating the flight paths of the missile and target at any instant, and

FIGURE 15 is a schematic diagram which illustrates the course of the missile for a particular flight path of the target.

GENERAL

In the ideal collision course, the direction of the line of sight from the missile to the target remains fixed in space during flight. FIGURE 14 illustrates the course which a missile, generally indicated at **10**, follows at any instant to intercept a target, generally indicated at **12**. The missile has at any instant a velocity V_M and the target a velocity V_T. The velocity V_M may be resolved into components $V_{M(1)}$, $V_{M(2)}$ and $V_{M(3)}$ along the axes of a coordinate system in which the axis $V_{M(1)}$ coincides with a line of sight **14** between the missile and the target. Similarly, the velocity V_T of the target may be resolved into components $V_{T(1)}$, $V_{T(2)}$ and $V_{T(3)}$ which are parallel to the above coordinates. In a collision course,

$$V_{M(1)} > V_{T(1)}$$
$$V_{M(2)} = V_{T(2)}$$
$$V_{M(3)} = V_{T(3)}$$

Since the only relative motion is along the line of sight **14**, the missile will move toward the target with a velocity $V_{M(1)} - V_{T(1)}$ and will ultimately intercept the target.

The course of the missile **10** for a particular flight path of the target **12** is illustrated in FIGURE 15. The direction of the line of sight **14** remains constant and the length of this line of sight gradually decreases as the missile overtakes the target. The line of sight may be formed, before the release of the missile, by the action of a conventional radar set. The radar set is coupled to the missile and varies the position of a missile antenna, generally indicated at **18** (FIGURE 11), as it scans the sky. When the radar set sights a target, it trains the antenna **18** on the target and the missile is then released. After the release of the missile, its antenna **18** continues to point at the target along the line of sight **14**, and the body **20** of the missile pivots about the antenna to maintain the missile on a correct course. The pivoting action causes the missile to follow a curved path, as shown in FIGURE 15, when the target **12** is following a curved path or when the speed of the target varies.

A mount gimbal, indicated generally at **22** (FIGURES 2 and 4); a ring gimbal, indicated generally at **24** (FIGURES 1 and 2); and a horseshoe gimbal, indicated generally at **26** (FIGURES 1 and 3), permit the body **20** of the missile to pivot about the antenna **18**. The mount gimbal **22** is mounted for rotation on a stationary base **28** (FIGURES 2 and 4). The ring gimbal is pivotably mounted between a pair of uprights, **30** and **32** (FIGURE 2) extended from the mount gimbal **22**. The horseshoe gimbal **26** is mounted on the ring gimbal **24** to pivot in a plane substantially perpendicular to the plane of the ring gimbal. A shaft **34** (FIGURES 2 and 3) is attached to the horseshoe gimbal **26** and a parabolic reflector **36** is mounted for rotation on the shaft with its axis slightly offset with respect to the shaft. As a result, the shaft **34** and reflector **36** follow the pivoting movements of both the ring and horseshoe gimbals. The rotation of the mount gimbal **22** and the pivotal movements of the ring gimbal **24** and horseshoe gimbal **26** cause the missile to maintain a proper course toward the target **12** while the reflector **36** points constantly at the target.

Since the axis of the reflector **36** is slightly offset with respect to the shaft **34**, the beam transmitted by the reflector describes a cone **37** (FIGURE 13) in space for each complete revolution of the reflector. If the target is on the axis **38** of the cone **37**, the missile is proceeding in the proper direction. If the target is not on the axis of the cone, the missile is pivoted about the antenna to change its direction of flight. The pivoting action is accomplished by varying the position of a first pair of fins **39** (FIGURE 11) diametrically disposed at the rear of the missile and a second pair of diametrically disposed fins **40** having a quadrant relationship with the fins **39**.

When the target **12** is not on the axis **38** (FIGURE 13) of the cone **37**, the strength of the signals reflected by the target varies as the reflector **36** rotates through a complete revolution. For example, with the target in a position 41 off the axis **38** and with the antenna transmitting a beam **42** at any instant, the strength of the pulses impinging on the target increases as the beam approaches the target and decreases as the beam moves away from the target. As a result, the pulses reflected by the target have a sinusoidal envelope for a complete revolution of the reflector **36**. The amplitude of the sinusoidal envelope is determined by the distance between the target **12** and the axis **38** in relation to the distance between the missile **10** and the target **12**. The phase of the sinusoidal envelope depends upon the direction of the target from the axis. Thus, the sinusoidal envelopes have different amplitudes and phases when the target is in positions 41 and 43. The phase and amplitude of the sinusoidal envelopes respectively determine the direction in which the missile **10** is pivoted about the antenna **18** and the amount of such pivoting.

The system for pivoting the body **20** of the missile relative to the antenna **18** is shown in block form in FIGURE 12 and is fully disclosed in co-pending application Serial No. 175,442 filed July 22, 1950 by Ian H. McLaren and me and now abandoned. Pulses at a predetermined frequency are provided by a modulator **44**. These pulses modulate carrier signals which are produced by a magnetron **45** having a very high frequency. The modulated carrier signals are transmitted by the antenna **18** to the target **12**, from which they are reflected and subsequently received by the antenna **18**. The signals are then demodulated by a receiver **46** so that only the pulses remain. The receiver **46** is operated only when the reflected signals are expected from the target **12**, thereby eliminating from consideration signals reflected by other objects. This gating of the receiver is provided by a range gate unit **48**, which is synchronized by signals from the modulator **44** and the receiver **46**.

A two-phase alternator **50** is coupled to the antenna **18** so as to produce a pair of signals having the same frequency as the conical scan of the antenna. These signals are 90° out of phase with each other. One of the signals is subdivided by a transformer **52** into two signals having a 180° phase relationship with each other and the other signal is similarly subdivided by a transformer **54**. Four signals in quadrature phase with one another are accordingly produced. These signals are individually introduced to gated amplifiers **56**, **58**, **60** and **62**, respectively, where they are mixed with the signals from the receiver **46**.

The peak outputs from the gated amplifiers **56**, **58**, **60** and **62** are detected by detectors **64**, **66**, **68** and **70**, respectively. The peak outputs from the detectors **64** and **66** are combined and the resultant signal is used to determine whether the missile should turn upwardly or downwardly. If the peak output from the detector **64** exceeds the peak output from the detector **66**, the missile is pivoted upwardly. If the peak output from the detector **66** is greater than the output from the detector **64**, the missile is turned downwardly. Likewise, the peak outputs from the detectors **68** and **70** are combined and the resultant signal is used to determine whether the missile should turn in a right or a left direction.

The peak outputs from each of the gated amplifiers is

determined by the position of the target 12 relative to the conical axis 38 (FIGURE 13). With the target on the axis, the peak output from each of the amplifiers is the same. With the target in the position 41, however, the peak output from the amplifier 56 exceeds the peak output from the amplifier 58 and the peak output from the amplifier 60 exceeds the output from the amplifier 62. As a result, the missile turns upwardly and to the right.

The error signals from the gated amplifiers are translated into a pivoting movement of the ring gimbal 24 and the horseshoe gimbal 26. However, when the horseshoe gimbal 26 starts to turn, it causes a signal to be generated and this signal is introduced to a motor assembly, generally indicated at 71 (FIGURES 1 and 6). The motor assembly 71 then rotates the mount gimbal 22 until the generated signal becomes zero, as will be explained in detail hereinafter. The ring gimbal 24 also pivots in a motion complementary to the rotation of the mount gimbal. As a result, any movement of the horseshoe gimbal 26 is translated into complementary movements of the mount gimbal 22 and the ring gimbal 24, causing the horseshoe gimbal to remain constantly perpendicular to the ring gimbal 24.

When the mount gimbal 22 rotates, the shaft 34 and reflector 36 rotate with it. This causes the vertical and horizontal axes of the antenna to become displaced with respect to the corresponding axes of the missile. Therefore, before the error signals from the gated amplifiers 56, 58, 60 and 62 can be utilized to pivot the missile, they must be shifted in phase by an angle which corresponds to the rotation of the mount gimbal 22 relative to the missile. A signal resolver 72 (FIGURE 12) is coupled to the mount gimbal 22 to provide a proper phase shift in the output of the amplifiers 56 and 58. A second signal resolver 74 similarly shifts the phase of the output from the amplifiers 60 and 62.

Differentiators 76 and 78 are connected to the signal resolvers 72 and 74, respectively, to differentiate the output of the signal resolvers. Such differentiation is required to maintain the missile in a proper collision course. The output from the differentiator 76 may be introduced directly to a servomechanism 80 or it may be combined with the output from the signal resolver 72, as indicated by the broken lines in FIGURE 12, before being introduced to the servomechanism. Likewise the output from the differentiator 78 may be introduced directly to a servomechanism 82 or it may be combined with the output from the signal resolver 74 before being introduced to the servomechanism. The servomechanisms 80 and 82 position the fins 39 and 40, respectively, so that the missile pivots about the antenna in a direction to correct any deviations in its flight.

Mount Gimbal Assembly

The mount gimbal assembly includes a hollow spindle 90 (FIGURES 2 and 4) which rotates with a plate 92 about the stationary base 28, the rotation being provided by the motor assembly 71 (FIGURES 1 and 6). A sleeve 98 (FIGURES 2 and 4) mounted on the spindle 90 carries a gear 100 in mesh with a second gear 102 mounted on a shaft 104. Arms 106 and 108 of a pair of sine potentiometers (not shown) are carried by the shaft 104. The sine potentiometers may serve as the signal resolvers 72 and 74 shown in FIGURE 12 to compensate for any rotation of the spindle 90 and plate 92.

A plug 112 (FIGURE 2) suitably attached to the sleeve 98 closes the end of a wave guide 116. The sleeve has diametrally opposed flanges 118 fastened to an annular member 120 as by screws. The member 120 is in turn provided with an annular flange 124 and ball bearings 126 rotate on the flange 124. Screws extend through the member 120 and the plate 92, causing the member 120 and the spindle 90 to rotate with the plate. The bearings 126 support a ring 134 (FIGURES 2 and 4) which in turn suitably supports a gear 136. The ring 134 is attached to the base 28 as by screws, and bearings 142 are supported in a retainer between the base 28 and the plate 92.

The plate 92, the spindle 90 and the member 120 are rotated by the motor assembly 71 (FIGURES 1 and 6), which extends through an opening 145 (FIGURE 4) in the plate 92 and which has a drive gear 146 engaging the stationary gear 136. The motor assembly 71 is mounted on a bracket suitably fastened to the plate 92. The assembly includes an electrical motor 150 (FIGURE 6) having its armature 152 mounted for rotation on suitable bearings 154. A gear 158 is mounted on the shaft 152 in mesh with a miter gear 160 on a shaft 162 journaled on suitable bearings 164. A sun gear 168 mounted on the shaft 162 drives a planet pinion 170 in mesh with a pair of ring gears 172 and 174. The ring gear 172 is fixed to the housing 176 of the motor assembly and the ring gear 174 is free to rotate. The ring gear 174 has one tooth less than the ring gear 172. This causes the gear 174 to advance slightly each time the planet gear 170 rotates about the gear. The sun gear 168, the planet pinion 170 and the ring gears 172 and 174 constitute an epicyclic gear train which produces a considerable and accurate reduction in the speed of the motor 150. By using such a gear train, the speed reduction is accomplished in a minimum amount of space.

A flange 177 on the drive gear 146 is attached to the ring gear 174, and, as above described, the drive gear 146 meshes with the stationary gear 136 (FIGURE 4). This causes the motor assembly 71 and plate 92 to rotate about the stationary gear 136 as the motor 150 operates.

Ring Gimbal Assembly

The ring gimbal assembly is attached to the oppositely disposed uprights 30 and 32 (FIGURE 2), extended from the rotatable plate 92. The operative parts of the ring gimbal assembly are carried by a frame 184 attached to the upright 30 as by screws. The assembly includes a motor 188 (FIGURE 1), an epicyclic gear train similar to that described above, a synchro, generally indicated at 190 (FIGURES 1 and 9), and an uncaging mechanism, indicated generally at 192 (FIGURES 2 and 8).

The motor 188 drives a pinion gear 194 (FIGURE 2) which meshes with a bevel gear 196 mounted on a shaft 198 (FIGURES 2 and 7). The shaft 198 rotates on bearings 200 properly positioned with respect to each other as by screws 204. The shaft carries a driver gear 206 in mesh with an idler gear 208 on a shaft 210.

The shaft 210 carries a sun gear 212, which drives a planet gear 214 about the inner peripheries of a pair of ring gears 216 and 218. The ring gear 216 is fixed to the frame 184 and has one tooth more than the gear 218, which is free for rotation. Thus, the gear 218 advances one tooth every time the planet gear 214 revolves completely around the inner perimeter of the gears 216 and 218. A flanged sleeve 220 is attached to the ring gear 218, and a pinion gear 222 is mounted on the sleeve. The pinion gear 222 meshes with an idler gear 224 on a shaft 226.

A leaf spring 228 (FIGURES 2 and 8) fitted on the shaft 226 presses against a collar 230 at one end of the shaft. The leaf spring pivots about a pin 232 which secures the spring to the frame 184. Before the release of the missile, the leaf spring is compressed by a wire 234 (FIGURE 8) secured to the frame as by screws.

The idler gear 224 (FIGURES 2 and 7) drives a gear 238 mounted as by a set screw 240 on a shaft 242. The shaft is hollow so that electrical leads may extend through the shaft from a movable set of contacts 244 (FIGURES 2 and 8) and a stationary set of contacts 246. The movable contacts 244 are carried on a shaft 248 fastened to a face of the gear 238 and are suitably insulated from one another. The stationary contacts 246 are insulated from one another on a shaft 252. The contacts 244 wipe

the contacts 246 as they pivot with the shaft 248 so as to maintain proper electrical connections at all times.

In addition to driving the gear 238, the gear 224 also drives a gear 256 (FIGURES 7 and 9) mounted on a hollow shaft 258. The gear 256 has a 1:1 ratio with the gear 238 so that the shafts 258 and 242 will be rotated through the same angle by the motor 188. A set of movable contacts 260 (FIGURES 8 and 9) are carried by a shaft 262 which is fastened to a face of the gear 256. The contacts engage a set of stationary contacts 264 as they pivot with the shaft 262, the stationary contacts being mounted on a shaft 266 which is fastened to a bracket 268 suitably secured to the frame 184. Electrical leads extend from the contacts through the hollow shaft 258 to the synchro 190, which has a rotor 270 mounted on the shaft 258 and a stator 272 secured to the synchro housing 274. The housing 274 is in turn fastened to the frame 184 as by screws. Signals from the synchro 190 are used to control the operation of the motor 188 (FIGURE 1) before the release of the missile.

One side of the ring gimbal 24 is mounted on the shaft 242 (FIGURE 2) for rotation with the shaft. The other side of the ring gimbal is mounted on a shaft 276 which rotates on bearings 278 housed within the upright 32. The ring gimbal has in general, an octagonal shape (FIGURES 1 and 5) with two sides 281 of the octagon being longer than the other sides and being reinforced at the corners to increase the strength of the gimbal. The ring gimbal supports a wave guide 282 (FIGURES 1 and 5) having two substantially perpendicular portions 284 and 286. At one end, the portion 284 is supported within a hole 288 in the ring gimbal and at its other end the portion 284 extends through a hole 290 in the gimbal. Support for the portion 286 is provided by a bracket 292 which is suitably attached to the ring gimbal 192. A rotating joint 296 (FIGURES 1, 2 and 5) is attached to the wave guide portion 286 adjacent the shaft 276 and is slightly separated from the wave guide 116, attached to the upright 32 as by screws (FIGURE 2). The rotating joint has a choke joint 304 which causes the waves reflected as a result of the separation between the rotating joint 296 and the wave guide 116 to be in phase with the waves passing directly between the rotating joint and the wave guide. The wave guide 116 extends downwardly and to the right (FIGURE 2) in a curvilinear path to meet the hollow spindle 90. The wave guide 116 is closed at one end by a plug 306 and at the other end by the plug 112 previously mentioned.

Before the missile is released, the synchro 190 is connected to a similar generator in the radar set which is carried by the launching airplane, as previously explained. As the radar set scans the sky for a distant target, such as the target 12, its synchro is rotated. This produces an angular displacement between the field of the radar synchro and the field of the synchro 190 and causes a voltage to be generated in the synchro 190. The magnitude of this voltage is determined by the angular displacement between the fields of the two synchros.

Since the motor 188 is controlled by signals from the synchro 190, the motor operates when an error voltage is produced by the synchro. The motor drives the epicyclic gear train associated with it, causing the synchro to rotate in a direction to reduce the strength of the generated voltage. The motor stops rotating when the angular position of the synchro 190 corresponds to that of the synchro in the radar set. Because of the 1:1 ratio between the gear 238 (FIGURE 2) and the gear 256 (FIGURE 9), the ring gimbal 24 rotates through an angle corresponding to that of the synchro 190 and accordingly adopts a position which corresponds to the position in which the radar set is pointing. The reflector 36 in turn follows the movement of the ring gimbal 24, as will be explained in detail hereinafter, and therefore is trained by the radar set on the target 12 before the missile is released.

As the missile is being released, a predetermined current is passed through the wire 234 (FIGURE 8) to rupture the wire. This releases the spring 228 for movement to the right in FIGURE 2 and the spring carries the shaft 226 to the right by pressing against the collar 230. Movement of the spring causes the idler gear 224 to move out of engagement with the gears 238 (FIGURE 2) and 256 (FIGURE 9) and prevents the motor 188 from rotating the ring gimbal 24 and the synchro 190. Furthermore, the synchro 190 becomes disconnected from the synchro in the radar set as the missile leaves the launching aircraft. As a result, the missile is free to pivot about the ring gimbal 24 during its flight. This pivoting action is provided by the servomechanism 80 (FIGURE 12) and is instrumental in maintaining the missile on a proper interception course.

Horseshoe Gimbal Assembly

The horseshoe gimbal assembly is mounted for rotation on the ring gimbal 24 and includes the horseshoe gimbal 26, a synchro, indicated generally at 312 (FIGURE 3), and an uncaging mechanism, indicated generally at 314. One side of the horseshoe gimbal 26 is mounted on a shaft 316 journaled on bearings 318 housed in a socket 322 in the ring gimbal 24. The rotor 324 of the synchro 312 is also mounted on the shaft and the stator 326 is fixed to the ring gimbal. The synchro 312 may be similar to the synchro 190 (FIGURE 9) in the ring gimbal assembly and is electrically connected to the motor 150 (FIGURE 6) in the mount gimbal assembly. A slot 328 (FIGURE 1) is provided in the horseshoe gimbal axially with the shaft 316. The slot communicates with a threaded tap in the horseshoe gimbal 26 and a screw 332 extends through the tap.

The other side of the horseshoe gimbal is mounted on a shaft 334 (FIGURES 1 and 3) which rotates on bearings 336 housed within a socket 340 in the ring gimbal. A slot 342, similar to the slot 328, communicates with a threaded tap in the horseshoe gimbal and a screw 346 fits into the tap. The screws 332 and 346 are loosened before the horseshoe gimbal is mounted on the shafts 316 and 334 and are tightened after the gimbal is positioned on the shafts.

The uncaging mechanism 314 (FIGURES 3 and 10) prevents the horseshoe gimbal 26 from rotating before the missile is released. The caging is provided by a pivot pin 348 which extends through an opening 350 in a bracket 352 suitably secured to the horseshoe gimbal 26. The pin is positioned within a sleeve 356 having a flange 358. A spring 360 fits on the sleeve 356 in compression between the flange 358 and a wire 364. The wire 364 is connected to a suitably insulated contact 366, and a second contact 370 is pressed against the contact 366 by a spring 372 housed within a member 374. An electrical lead 376 is connected to the contact 370.

The horseshoe gimbal 26 supports a wave guide 378 (FIGURES 3 and 5). The wave guide is closed at one end by a plug 380 suitably secured to the bracket 352. At the same end, the wave guide 378 has an opening 384 adjacent a wave guide joint 386 which is connected to the wave guide 282 (FIGURES 1 and 3). The joint 386 (FIGURE 3) has a choke joint 388 which compensates for the opening between it and the wave guide 378 by maintaining the reflected waves in phase with the waves passing directly between it and the wave guide. The wave guide 378 passes through an opening 390 in the horseshoe gimbal and has a flange portion 392 which is attached to the gimbal as by screws. The wave guide communicates with a hole 395 which extends axially through the shaft 34, the hole being broached so that its dimensions correspond to the inner dimensions of the wave guide 378. The shaft in turn fits in an opening 396 in the horseshoe gimbal and has a choke joint 397 to compensate for any separation between it and the wave guide 378.

A condenser 398 fits in a second opening 400 in the horseshoe gimbal. The condenser is secured to the gimbal as by a bracket 402. Connections to the condenser are made from a set of stationary contacts 404 and a set of movable contacts 406, which engage the stationary contacts as they rotate. The stationary contacts 404 are suitably insulated from each other on a shaft 408 connected to a bracket 410, which is in turn suitably fastened to the ring gimbal. The movable contacts are carried on a shaft 416 which is connected to the shaft 334. A bracket 418 is secured to the ring gimbal as by screws to cover the shaft 334 and to provide a balance for the horseshoe gimbal assembly.

Before the missile is released, the horseshoe gimbal 26 is prevented from rotating by the uncaging mechanism 314. As the missile is being released, however, a predetermined current is passed through the wire 364 (FIGURE 10) to rupture the wire, causing the pivot pin 348 to be released by the spring 360 from the hole 350 in the bracket 352. The horseshoe gimbal is then free for pivotal movement relative to the ring gimbal 24 in case the direction of the missile has to be corrected during its flight. However, the horseshoe gimbal 26 can rotate through only a limited angle in either direction before it strikes the ring gimbal 24. Thus, it is desirable to limit the rotation of the horseshoe gimbal 26 by providing compensatory movements of the mount gimbal 22 and the ring gimbal 24. This is in accordance with a fundamental law of servomechanism operation that an object can be made to point in any direction by rotating it through proper angles in each of two substantially perpendicular directions.

When the missile starts to pivot relative to the horseshoe gimbal 26, an error voltage is generated in the synchro 312 (FIGURE 3) and this voltage is introduced to the motor 150 (FIGURE 6) in the mount gimbal assembly, causing the motor to rotate the plate 92 in a direction to reduce the voltage to zero. At the same time, the ring gimbal 24 pivots relative to the missile to compensate for the rotation of the mount gimbal and to maintain the horseshoe gimbal 26 in a plane substantially perpendicular to the plane of the ring gimbal 24.

Flywheel Assembly

The flywheel assembly includes the parabolic reflector 36, a motor 420 for rotating the reflector, and a generator 422 mechanically coupled to the motor and electrically connected to the condenser 398. The reflector 36 has a cylindrical extension 424 (FIGURE 3) which is suitably connected to a retainer 426. The retainer 426 has an annular shoulder which supports a ring 434. The rotor 436 of the generator 422 is supported by the retainer 426 and is positioned between the ring 434 and a second ring 438. The rotor 440 of the motor is connected to the cylindrical extension 424 of the reflector 36. The reflector 36, retainer 426, and rotors 436 and 440 rotate on suitable bearings 442.

The stators 446 and 448 of the motor 420 and generator 422, respectively, are supported by the shaft 34, which is slightly offset with respect to the reflector 36, as previously explained. The shaft 34 also supports a wave guide 462 which has at one end a flange 464 connected to the shaft as by screws. The wave guide is tapered to provide matched impedances between the shaft 34 and a cavity 468 connected to the outer end of the wave guide. The cavity 468 is resonant at the frequency of the magnetron 45 (FIGURE 12) and is instrumental in transmitting large pulse of energy towards the target. A plate 470 may be connected to the cavity 468 to provide a balance for the antenna.

The motor 420 drives the reflector at a predetermined speed, such as 180 revolutions per second. As the reflector rotates through each complete revolution, its transmitted beam describes a cone in space. This conical beam is produced as a result of a slight angle between the axis of the reflector 36 and the axes of the shaft 34 and the wave guide 462.

The motor 420 also drives the generator 422, causing the generator 422 and the condenser 398 to produce two signals having the frequency of the conical scan and a 90° phase relationship with each other. The generator 422 and the condenser may serve as the two-phase alternator 50 shown in FIGURE 12.

Summary of Operation

The radar set in the launching aircraft has a synchro similar to the synchro 190 (FIGURE 9) and a signal resolver similar to the sine potentiometer having the rotatable arm 106 (FIGURE 2). As the radar set searches for a distant object, it causes the angular position of its synchro to shift with respect to the angular position of the synchro 190. This causes a voltage to be generated in the synchro 190, the amplitude of which is proportional to the angular displacement between the two synchros. As a result, the motor 188 (FIGURE 1) operates to rotate the synchro so that its generated voltage is reduced to zero. Since the ring gimbal 24 is coupled to the synchro in a 1:1 ratio and the reflector 36 follows the ring gimbal, the reflector 36 follows the movement of the radar antenna in the plane of the ring gimbal.

Likewise, rotation of the radar set in the plane of the mount gimbal 22 (FIGURE 2) causes a voltage to be produced across the sine potentiometer having the rotatable arm 108, which is connected to a similar sine potentiometer in the radar set before the release of the missile. This causes the motor 150 (FIGURE 6) to operate until the voltage across the sine potentiometer has been reduced to zero. With zero voltage, the position of the mount gimbal corresponds to the position of the radar antenna in a similar plane.

As previously explained, the system shown in FIGURE 12 is located in the missile. This system may operate before the release of the missile to adjust the position of the missile fins 39 and 40. Thus, although the body 20 is maintained in a fixed position by the launching aircraft, its fins may be adjusted so that, immediately after it is released, it will start to turn in the proper direction to intercept the target. The missile will not be launched if it has to turn through an excessive angle when it is released, such as an angle greater than 30°. A suitable locking mechanism may be employed to prevent the missile from being launched when the turning angle is excessive.

As the missile is being launched, the uncaging mechanism 192 (FIGURE 2) is operated. The uncaging mechanism moves the gear 224 (FIGURES 2 and 7) out of engagement wtih the gears 238 (FIGURE 2) and 256 (FIGURE 9). At the same time, the synchro 190 (FIGURE 9) becomes disconnected from the synchro in the radar set. This causes the rotation of the ring gimbal 24 to become independent of the radar set and of the motor 188 (FIGURE 1). As a result, the missile pivots about the ring gimbal in accordance with the position of the fins 39, which are controlled by the servomechanism 80.

The uncaging mechanism 314 (FIGURES 3 and 10) is also operated as the missile is being launched, thereby releasing the horseshoe gimbal 26 for pivotal movement about the ring gimbal 24. As the missile starts to pivot about the horseshoe gimbal to correct a deviation in its flight, a voltage is generated in the synchro 312 (FIGURE 3). This voltage is introduced to the motor 150 (FIGURES 1 and 6) to rotate the mount gimbal 22 in a direction to reduce the amplitude of the generated voltage. At the same time, the missile pivots on the ring gimbal 24 to compensate for the movement of the mount gimbal 22. By adjusting the angle of the missile with respect to the antenna in two substantially perpendicular planes, the angle between the missile and the antenna can be maintained constant in a third plane substantially perpendicular to the first two planes. This third plane

corresponds to the plane of the horseshoe gimbal, which remains substantially perpendicular to the ring gimbal 24.

To correct for any deviations in the course of the missile, the axis of the parabolic reflector 36 is slightly offset with respect to the axis of the shaft 34. Thus, as the reflector is rotated through each complete revolution by the motor 420 (FIGURES 2 and 3), the beam which it transmits describes a cone 37 (FIGURE 13) in space. If the missile is following a proper course to intercept the target 12, the target will appear on the axis 38 of the conical beam. If the missile is straying from its proper course, the target will appear to one side of the axis. The pulses reflected by the target back to the missile antenna will therefore have a sinusoidal pattern, the phase of which is determined by the angular position of the target on the conical beam and the amplitude of which is determined by the ratio of the distance from the target to the axis 38 and the distance from the missile to the target. The phase and amplitude of the sinusoidal envelope are then shifted by the signal resolvers 72 and 74 (FIGURE 12) through an angle corresponding to the rotation of the mount gimbal 22 so that the axes of the antenna will correspond to the axes of the missile. The fins 39 and 40 on the missile are adjusted by the servomechanisms 80 and 82 (FIGURE 11), respectively, in accordance with the phase and amplitude of the resolved signals, and the course of the missile is accordingly varied to center the target on the axis of the conical beam.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

What is claimed is:

1. In an antenna for directing the flight of a missile towards a target, a reflector, means for rotating the reflector in a first plane, means for pivoting the reflector in a second plane substantially perpendicular to the first plane, means for pivoting the reflector in a third plane substantially perpendicular to the first and second planes of reflector movement, and means for rotating the reflector in the first plane and pivoting the reflector in the second plane to maintain the reflector movement in the third plane within predetermined limits.

2. In an antenna for directing the flight of a missile towards a target, a reflector, a base adapted to rotate the reflector in a first plane, a gimbal mounted on the base to pivot the reflector in a second plane substantially perpendicular to the first plane, a second gimbal mounted on the first gimbal to provide a pivotal movement of the reflector in a third plane substantially perpendicular to the first and second planes, and means for rotating the base and for providing a complementary pivotal movement of the first gimbal to maintain the pivotal movement of the second gimbal within predetermined limits.

3. In an antenna for directing the flight of a missile towards a target, a reflector, a gimbal mounted for rotation relative to the missile in a first plane, means associated with the gimbal for providing a pivotal movement of the missile relative to the gimbal in the first plane upon a deviation in the course of the missile from a course causing the reflector to point at the target, and means for providing complementary pivotal movements of the missile in planes substantially perpendicular to the first plane to maintain the pivotal movement of the missile in the first plane within predetermined limits and to cause the reflector to point at the target.

4. In an antenna for directing the flight of a missile towards a target, a reflector, a first gimbal mounted for rotation relative to the missile in a first plane, a second gimbal mounted on the first gimbal for rotation relaive to the missile in a second plane substantially perpendicular to the first plane, means operative upon the signals received by the reflector from the target to provide a pivotal movement of the missile in the first plane to correct the course of the missile in one direction, means operative upon the signals received by the reflector from the target to provide a pivotal movement of the missile in the second plane to correct the course of the missile in a second direction substantially perpendicular to the first direction, a synchro pivotable in accordance with the movements of the missile in the second plane to produce an error signal having an amplitude dependent upon such movements, and a motor operative by the error signal from the synchro to provide a complementary rotational movement of the missile relative to the antenna in the first plane and a free pivotal movement of the missile relative to the antenna in a plane substantially perpendicular to the first and second planes to maintain the pivotal movement of the missile in the second plane within predetermined limits.

5. In an antenna for directing the flight of a missile towards a target, a first gimbal operative to rotate in a first plane, a second gimbal mounted on the first gimbal for pivotal movement in a second plane substantially perpendicular to the first plane, means for pivoting the second gimbal to correct the course of the missile in one direction, and means for rotating the first gimbal and providing a complementary pivotal movement of the second gimbal to correct the course of the missile in a second direction substantially perpendicular to the first direction.

6. In an antenna for directing the flight of a missile towards a target, a first gimbal adapted to rotate in a first plane, a second gimbal adapted to rotate in anoher plane substantially perpendicular to the first plane, a directional reflector adapted to follow the movement of the first and second gimbals, means for guiding the rotation of the first and second gimbals before the release of the missile to point the reflector at the target, and means for releasing the guiding means for the second gimbal after the launching of the missile to provide a free movement of the missile in the second plane.

7. In an antenna for directing the flight of a missile towards a target, a gimbal adapted to be pivoted, relative to the missile, in a first plane, a directional reflector, means for pivoting the reflector with the gimbal, means for caging the gimbal before release of the missile and for uncaging the gimbal upon the release of the missile, means operative to pivot the gimbal after the release of the missile to point the reflector at the target, and means for complementarily rotating the gimbal and reflector in planes substantially perpendicular to the first plane to maintain the pivotal movement of the gimbal in the first plane within predetermined limits.

8. In an antenna for directing the flight of a missile towards a target, a gimbal adapted to be pivoted, relative to the missile, in a first plane, a directional reflector, means for pivoting the reflector with the gimbal, means for pivoting the gimbal before the release of the missile to point the reflector at the target, means for releasing the pivoting means after the launching of the missile to permit a free movement of the gimbal in the first plane, and means for utilizing the free movement of the gimbal in the first plane to maintain within predetermined limits the movement of the reflector in a second plane substantially perpendicular to the first plane.

9. In an antenna for directing the flight of a missile towards a target, a gimbal adapted to be rotated, relative to the missile, in a first plane, a directional reflector, means for rotating the reflector with the gimbal, means for rotating the gimbal before the release of the missile to point the reflector at the target, and means for rotating the gimbal after the release of the missile to maintain within predetermined limits the pivotal movement of the reflector in a second plane substantially perpendicular to the first plane.

10. In an antenna for directing the flight of a missile towards a target, a first gimbal adapted to rotate in a first

plane, a second gimbal mounted on the first gimbal for rotation in a second plane substantially a perpendicular to the first plane, a third gimbal mounted on the second gimbal for rotation in a third plane substantially perpendicular to the first and second planes, a reflector adapted to follow the movements of the first, second and third gimbals, the reflector being adapted to spin in a plane substantially constant with respect to the third gimbal, means operative in accordance with the signals received by the reflector from the target to pivot the missile in the second plane to correct the course of the missile in a first direction, means operative in accordance with the signals received by the reflector from the target to pivot the missile in the third plane to correct the course of the missile in a second direction substantially perpendicular to the first direction, a synchro associated with the third gimbal to produce an error signal having an amplitude dependent upon the movement of the missile relative to the gimbal, and a motor operative in accordance with the error signal from the synchro to provide missile rotation in the first plane and a complementary pivotal movement of the missile in the second plane to maintain the pivotal movement of the missile in the third plane within predetermined limits.

11. In an antenna for directing the flight of a missile towards a target, a first gimbal adapted to rotate in a first plane, a second gimbal adapted to pivot in a second plane substantially perpendicular to the first plane, a third gimbal adapted to pivot in a third plane substantially perpendicular to the first and second planes, a directional reflector adapted to follow the movements of the first, second and third gimbals, means for directing the rotation of the first gimbal before the release of the missile to point the reflector at the target, means for directing the pivotal movement of the second gimbal before the release of the missile to point the reflector at the target, means for pivoting the missile in the third plane after the release of the missile, means associated with the first directing means for translating the missile movement in the third plane into a rotational movement in the first plane, and means for releasing the second directing means after the release of the missile to permit a free movement of the second gimbal so as to complement the rotational movement of the missile in the first plane with a pivotal movement in the second plane.

12. In an antenna for directing the flight of a missile towards a target, a first gimbal adapted to rotate in a first plane, a second gimbal adapted to pivot in a second plane substantially perpendicular to the first plane, a directional reflector adapted to follow the movements of t e first and second gimbals, a motor for rotating the first gimbal before the release of the missile to point the reflector at the target, means for caging the second gimbal before release of the missile and for uncaging the gimbal upon the release of the missile, means for pivoting the second gimbal after the release of the missile to maintain the missile on a proper course towards the target, and means associated with the second gimbal and the motor for providing a compensatory rotation of the first gimbal so as to maintain the pivotal movement of the second gimbal within predetermined limits.

13. In an antenna for directing the flight of a missile towards a target, a base rotatable in a first plane, a motor for rotating the base, a reflector, a first gimbal mounted on the base for pivotal movement in a second plane substantially perpendicular to the first plane, a second gimbal mounted on the first gimbal for pivotal movement in a third plane substantially perpendicular to the first and second planes, means attaching the reflector to the second gimbal, a second motor for pivoting the first gimbal before release of the missile to train the reflector on the target, means for uncaging the second motor upon the release of the missile, and means for actuating the first motor after a predetermined movement of the missile in the third plane to maintain the movement of the missile in the third plane within predetermined limits.

14. In an antenna for directing the flight of a missile towards a target, a base adapted to rotate in a first plane, a motor for rotating the base, a gimbal adapted to pivot in a second plane substantially perpendicular to the first plane, a reflector adapted to spin in a plane substantially parallel to the gimbal, the reflector being connected to the gimbal to follow the movements of the base and the gimbal, means for determining the pivotal movement of the gimbal, and means for operating the motor in accordance with these determinations to maintain the pivotal movement of the gimbal within predetermined limits.

15. In an antenna for directing the flight of a missile towards a target, a base adapted to rotate in a first plane, a motor for rotating the base, a gimbal, means for mounting the gimbal on the base for pivotal movement in a second plane substantially perpendicular to the first plane, a second gimbal, means for mounting the second gimbal on the first gimbal for pivotal movement after the release of the missile in a third plane substantially perpendicular to the first and second planes, a reflector adapted to spin in a fixed plane with respect to the second gimbal, the reflector being connected to the second gimbal to follow the movement of the base and of the first and second gimbals, a second motor for pivoting the first gimbal before release of the missile to train the antenna on the target, means for disengaging the second motor from the first gimbal, upon the release of the missile, to permit a free pivotal movement of the missile on the gimbal, means for determining the pivotal movement of the missile on the second gimbal after the release of the missile, and means for operating the first motor in accordance with these determinations to maintain the pivotal movement of the missile on the second gimbal within predetermined limits.

16. In an antenna for directing the flight of a missile towards a target, a mount gimbal adapted to provide a pivotal movement of the missile relative to the antenna about a first axis, a ring gimbal mounted on the mount gimbal to provide a pivotal movement of the missile relative to the antenna about a second axis substantially perpendicular to the first axis, a horseshoe gimbal mounted on the ring gimbal to provide a pivotal movement of the missile relative to the antenna about a third axis substantially perpendicular to the first and second axes, means for pivoting the antenna on the gimbals relative to the missile before the release of the missile to point the antenna at the target, means operative after the release of the missile to provide signals indicative of any deviation of the missile from its proper course, and means for pivoting the missile on the gimbals relative to the antenna to maintain the antenna pointed at the target so as to correct any deviations of the missile from its proper course.

17. In an antenna for directing the flight of a missile towards a target, a mount gimbal adapted to provide a rotational movement of the missile about a first axis relative to the antenna, a ring gimbal mounted on the mount gimbal to provide a pivotal movement of the missile relative to the antenna about a second axis substantially perpendicular to the first axis, a horseshoe gimbal mounted on the ring gimbal to provide a pivotal movement of the missile relative to the antenna about a third axis substantially perpendicular to the first and second axes, a reflector mounted on the horseshoe gimbal to spin at a predetermined speed and to transmit signals towards the target and receive signals reflected from the target, means operative in accordance with the pattern of the signals reflected towards the reflector by the target to rotate the missile in a predetermined manner about the first axis relative to the antenna and to pivot the missile in a predetermined manner about the second and third axes relative to the antenna so as to correct the

flight of the missile and to maintain the reflector pointed at the target.

18. In an antenna for directing the flight of a missile towards a target, a reflector, a gimbal supporting the reflector and adapted to provide a pivotal movement of the missile relative to the antenna about a first axis, means for pivoting the missile on the gimbal relative to the antenna to maintain the reflector pointed at the target, a synchro associated with the gimbal for providing an error signal having an amplitude dependent upon the pivotal movement of the missile on the gimbal, and a motor operative in accordance with the error signal from the synchro to convert the pivotal movement of the missile on the gimbal into complementary movements of the missile relative to the antenna about axes substantially perpendicular to the first axis so as to maintain the movement of the missile on the gimbal within predetermined limits.

19. In an antenna for directing the flight of a missile towards a target, a gimbal for providing a pivotal movement of the missile relative to the antenna about a first axis, a reflector supported by the gimbal and adapted to spin in a substantially fixed plane relative to the gimbal, means for providing signals for transmission from the reflector towards the target and for receiving signals reflected from the target towards the reflector, means operative in accordance with the received signals to pivot the missile on the gimbal relative to the antenna to maintain the reflector pointed at the target, a synchro coupled to the gimbal to provide an error signal having an amplitude substantially proportionate to the relative movement between the missile and the gimbal, and a motor operative in accordance with the error signal from the synchro to convert the pivotal movement of the missile about the first axis into complementary movements of the missile relative to the antenna about axes substantially perpendicular to the first axis so as to maintain the movement of the missile relative to the antenna about the first axis within the predetermined limits.

20. In an antenna for directing the flight of a missile towards a target, a first gimbal for providing a rotational movement of the missile relative to the antenna about a first axis, a second gimbal for providing a pivotal movement of the missile relative to the antenna about a second axis substantially perpendicular to the first axis, means for pivoting the missile on the second gimbal relative to the antenna to maintain the antenna pointed at the target, and means for converting the pivotal movement of the missile on the second gimbal relative to the antenna into a rotational movement of the missile on the first gimbal relative to the antenna to maintain the movement of the missile on the second gimbal within predetermined limits.

21. In an antenna for directing the flight of a missile towards a target, a base adapted to provide a rotational movement of the missile relative to the antenna about a first axis, a gimbal mounted on the base to provide a pivotal movement of the missile relative to the antenna about a second axis, a reflector mounted on the gimbal to spin in a substantially constant plane with respect to the gimbal, means for providing signals for transmission towards the target and for receiving signals reflected from the target, means operative in accordance with the pattern of the received signals to pivot the missile on the gimbal relative to the antenna so as to maintain the reflector pointed at the target, a synchro coupled to the gimbal to provide an error signal having an amplitude substantially proportionate to the relative movement between the missile and the gimbal, and a motor coupled to the missile and to the base and operative in accordance with the error signal from the synchro to convert the pivotal movement of the missile on the gimbal into a rotational movement of the missile on the base to maintain the movement of the missile on the gimbal within predetermined limits and to maintain the reflector pointed at the target.

22. In an antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile relative to the antenna about a first axis, a first gimbal mounted on the base to provide a pivotal movement of the missile relative to the antenna about a second axis substantially perpendicular to the first axis, a second gimbal mounted on the first gimbal to provide a pivotal movement of the missile relative to the antenna about a third axis substantially perpendicular to the first and second axes, means for pivoting the missile on the first gimbal relative to the antenna to maintain the antenna pointed at the target in case the missile deviates from its proper course in a first direction, means for pivoting the missile on the second gimbal relative to the antenna to maintain the antenna pointed at the target in case the missile deviates from its proper course in a second direction substantially perpendicular to the first direction, and means for converting the pivotal movement of the missile on the second gimbal into a rotational movement of the missile on the base and a complementary pivotal movement of the missile on the first gimbal to maintain the reflector pointed at the target and the pivotal movement of the missile on the second gimbal within predetermined limits.

23. In an antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile relative to the antenna about a first axis, a gimbal for pivoting the antenna relative to the missile about a second axis substantially perpendicular to the first axis, means for pivoting the missile on the gimbal relative to the antenna upon a deviation of the missile in a first direction from its proper course so as to maintain the antenna pointed at the target, means for pivoting the missile relative to the antenna about a third axis substantially perpendicular to the first and second axes upon a deviation of the missile in a second direction substantially perpendicular to the first direction so as to maintain the antenna pointed at the target, and means for converting the pivotal movement of the missile about the third axis relative to the antenna into a rotation of the missile on the base relative to the antenna and a pivotal movement of the antenna on the gimbal relative to the antenna to maintain the movement of the missile about the third axis relative to the antenna within predetermined limits.

24. In an antenna for directing the flight of a missile towards a target, a gimbal for providing a relative pivotal motion between the missile and the antenna about a first axis, a reflector mounted on the gimbal, means operative before the release of the missile to lock the gimbal against relative movement between the missile and the antenna about the first axis, means operative before the release of the missile to pivot the antenna relative to the missile about axes substantially perpendicular to the first axis to point the reflector at the target, means operative upon the release of the missile to free the gimbal for pivotal movement of the missile relative to the antenna about the first axis, means operative upon a deviation of the missile from its proper course to pivot the missile relative to the antenna about the first axis so as to maintain the reflector pointed at the target, and means for converting the pivotal movement of the missile relative to the antenna about the first axis into compensating movements of the missile relative to the antenna about the axes substantially perpendicular to the first axis so as to maintain the movement of the missile about the first axis within predetermined limits.

25. In an antenna for directing the flight of a missile towards a target, a first gimbal for providing a relative pivotal motion between the missile and the antenna in a first plane, a second gimbal for providing a relative pivotal motion between the missile and the antenna in a second plane substantially perpendicular to the first plane, a reflector mounted on the second gimbal, means operative before the release of the missile to provide a controlled pivotal movement of the antenna relative to the missile

in the first plane to point the reflector at the target, means operative before the release of the missile to lock the antenna against movement relative to the missile in the second plane, means operative upon the release of the missile to free the missile for movement relative to the antenna in the first and second planes, means operative, upon a deviation of the missile from its proper course in a first direction, to pivot the missile relative to the antenna in the first plane so as to maintain the reflector pointed at the target, means operative, upon a deviation of the missile from its proper course in a second direction substantially perpendicular to the first direction, to pivot the missile relative to the antenna in the second plane to maintain the reflector pointed at the target, and means for converting the pivotal movement of the missile relative to the antenna in the second plane into compensating movements of the missile relative to the antenna in the first plane and in a third plane substantially perpendicular to the first and second planes to maintain the pivotal movement of the missile relative to the antenna in the second plane within predetermined limits.

26. In an antenna for directing the flight of a missile towards a target, a base adapted to rotate the missile relative to the antenna in a first plane, a first gimbal mounted on the base and adapted to pivot the missile relative to the antenna in a second plane substantially perpendicular to the first plane, a second gimbal mounted on the first gimbal and adapted to pivot the missile relative to the antenna in a third plane substantially perpendicular to the first and second planes, means operative upon a deviation in the course of the missile in a first direction to pivot the missile on the first gimbal relative to the antenna so as to maintain the antenna pointed at the target, means operative upon a deviation in the course of the missile in a second direction substantially perpendicular to the first direction to pivot the missile on the second gimbal relative to the antenna so as to maintain the antenna pointed at the target, and means for converting the pivotal movement of the missile on the second gimbal relative to the antenna into a rotational movement of the missile on the base relative to the antenna and a pivotal movement of the missile on the first gimbal relative to the antenna so as to maintain the movement of the missile on the second gimbal relative to the antenna within predetermined limits.

27. In an antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile about a first axis relative to the antenna, a motor for rotating the missile on the base relative to the antenna, a gimbal mounted on the base for pivoting the missile relative to the antenna about a second axis substantially perpendicular to the first axis, means operative upon a deviation in the course of the missile to produce a pivotal movement of the missile on the gimbal relative to the antenna so as to maintain the missile pointed at the target, means associated with the gimbal for producing an error signal having an amplitude dependent upon the pivotal movement of the missile on the gimbal relative to the antenna, and means for introducing the error signal to the motor to produce a compensatory rotation of the missile on the base relative to the antenna so as to maintain the motion of the missile on the gimbal relative to the antenna within predetermined limits.

28. In an antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile in a first plane relative to the antenna, a motor for rotating the missile on the base, a first gimbal mounted on the base for pivoting the missile relative to the antenna in a second plane substantially perpendicular to the first plane, a second gimbal mounted on the first gimbal for pivoting the missile relative to the antenna in a third plane substantially perpendicular to the first and second planes, means operative upon a deviation in the course of the missile in a first direction to produce a pivotal movement of the missile on the first gimbal relative to the antenna so as to maintain the antenna pointed at the target, means operative upon a deviation in the course of the missile in a second direction substantially perpendicular to the first direction to produce a pivotal movement of the missile on the second gimbal relative to the antenna so as to maintain the antenna pointed at the target means associated with the second gimbal for producing an error signal having an amplitude dependent upon the displacement of the missile on the second gimbal relative to the antenna, and means for introducing the error signal to the motor to produce a compensatory rotation of the missile on the base relative to the antenna and a complementary pivotal movement of the missile on the first gimbal relative to the antenna so as to maintain the pivotal movement of the missile on the second gimbal relative to the antenna within predetermined limits.

29. An antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile about a first axis relative to the antenna, a motor for rotating the missile on the base, a first gimbal mounted on the base for pivoting the missile relative to the antenna about a second axis substantially perpendicular to the first axis, means operative before the release of the missile to provide a controlled movement of the antenna on the gimbal to maintain the antenna pointed at the target, means operative upon the release of the missile to disengage the control means so as to provide a free movement of the missile relative to the antenna about the second axis, means operative upon a deviation of the missile in a first direction to pivot the missile on the gimbal relative to the antenna so as to maintain the antenna pointed at the target, a second gimbal mounted on the base for pivoting the missile relative to the antenna in a third plane substantially perpendicular to the first and second planes, means operative upon a deviation of the missile in a second direction substantially perpendicular to the first direction to pivot the missile on the second gimbal relative to the antenna so as to maintain the antenna pointed at the target, means for producing an error signal having an amplitude dependent upon the displacement of the missile on the second gimbal, and means for introducing the error signal to the motor for producing a compensatory rotation of the missile on the base and a complementary pivotal movement of the missile on the first gimbal so as to maintain the pivotal movement of the missile on the second gimbal within predetermined limits.

30. In an antenna for directing the flight of a missile towards a target, a gimbal, a reflector, a shaft supported by the gimbal, means for mounting the reflector at a slightly skewed angle on the shaft, means for spinning the reflector on the shaft so that the reflector will face in slightly different directions as it spins, means for providing signals for transmission from the reflector towards the target and for receiving signals reflected from the target, means operative in accordance with the pattern of the received signals to pivot the missile on the gimbal so as to maintain the reflector pointed at the target in case the missile deviates from its proper course, a synchro coupled to the gimbal to produce an error signal having an amplitude dependent upon the relative movements between the missile and the gimbal, and a motor operative in accordance with the error signal from the synchro to convert the pivotal movement of the missile on the gimbal into compensatory movements of the missile relative to the reflector in directions substantially perpendicular to the relative movement between the missile and the gimbal.

31. In an antenna for directing the flight of a missile towards a target, a gimbal, a reflector shaped to beam signals towards a target, a shaft supported by the gimbal, means for mounting the reflector at a slightly skewed angle on the shaft, means for spinning the reflector on the shaft at a predetermined speed so that the reflector will transmit a conical beam in space as it spins, means

for providing signals for transmission from the reflector towards the target and for receiving signals reflected from the target, means operative in accordance with the pattern of the reflected signals resulting from the spin of the reflector to pivot the missile on the gimbal so as to maintain the reflector pointed at the target in case the missile deviates from its proper course, a synchro coupled to the gimbal to produce an error signal in accordance with the pivotal movement of the missile on the gimbal, and a motor operative in accordance with the error signal to convert the pivotal movement of the missile on the gimbal into compensatory movements of the missile relative to the reflector in directions substantially perpendicular to the direction of relative movement between the missile and the gimbal.

32. An antenna for directing the flight of a missile towards a target, a base adapted to provide a rotation of the missile about a first axis relative to the antenna, a gimbal mounted on the base for pivoting the missile relative to the antenna about a second axis substantially perpendicular to the first axis, means operative before the release of the missile to provide a controlled movement of the antenna on the gimbal to maintain the antenna pointed at the target, means operative upon the release of the missile to disengage the control means so as to provide a free movement of the missile relative to the antenna about the second axis, means operative upon a deviation of the missile in a first direction to pivot the missile on the gimbal relative to the antenna so as to maintain the antenna pointed at the target, and means operative upon a deviation of the missile in a second direction substantially perpendicular to the first direction to rotate the missile on the base relative to the antenna and to provide a complementary pivotal movement of the missile on the gimbal relative to the antenna.

33. In an antenna for directing the flight of a missile towards a target, a first gimbal adapted to provide a pivotal movement of the missile relative to the antenna about a first axis, a second gimbal mounted on the first gimbal to provide a pivotal movement of the missile relative to the antenna about a second axis substantially perpendicular to the first axis, a third gimbal mounted on the second gimbal to provide a pivotal movement of the missile relative to the antenna about a third axis substantially perpendicular to the first and second axes, a shaft supported by the third gimbal, a reflector mounted on the shaft for rotary movement relative to the shaft, means coupled to the reflector for rotary movement with the reflector and weighted to provide a balance on the reflector for gyroscopic action of the reflector, a motor for rotating the reflector, and means responsive to signals received by the reflector to pivot the missile on the gimbals relative to the antenna so as to maintain the missile on a proper course towards the target.

34. In an antenna for directing the flight of a missile towards a target, a plurality of gimbals supported on one another to provide for pivotal movements of the missile relative to the antenna about a plurality of substantially perpendicular axes, a shaft supported on the gimbals, a reflector mounted on the shaft for rotary movement relative to the shaft and the gimbals, a retainer coupled to the refletcor for rotary movement with the reflector, the retainer being weighted to provide the reflector with a gyroscope action, a motor supported by the shaft and retainer for driving the reflector, and means associated with the reflector and the gimbals for pivoting the missile on the gimbals relative to the antenna in accordance with signals received by the reflector so as to maintain the missile on a proper course towards the target.

35. In an antenna for directing the flight of a missile towards a target, a plurality of gimbals supported on one another to provide for pivotal movements of the missile relative to the antenna about a plurality of substantially perpendicular axes, a shaft supported on the gimbals, a reflector mounted on the shaft for rotary movement relative to the shaft and in slightly skewed relationship to the shaft, the shaft being shaped to direct electrical enregy to the reflector for transmission by the reflector towards the target and to pass the electrical energy received by the reflector, balancing means supported on the shaft for rotary movement with the reflector, the balancing means being weighted to balance the reflector for gyroscopic action relative to the missile, a motor for driving the reflector, and means associated with the gimbals and the reflector for pivoting the missile on the gimbals relative to the antenna in accordance with the signals received by the reflector so as to maintain the missile on a proper course towards the target.

36. In an antenna for directing the flight of a missile towards the target, a plurality of gimbals supported on one another to provide for pivotal movements of the missile relative to the antenna about a plurality of substantially perpendicular axes, a shaft supported on the gimbals, a feed on the end of the shaft for providing energy for transmission to a target, a reflector supported on the shaft and surrounding the feed to direct the energy from the feed towards the target in a predetermined pattern and to direct to the feed energy received by it from the target, there being an axial opening in the shaft to provide a communication with the feed for the direction of energy through the shaft to the feed for transmission by the feed and for directing through the shaft the energy received by the reflector, means for weighting the reflector to provide the reflector with a balance relative to the gimbals for a gyroscopic action of the reflector, and means associated with the gimbals and the reflector for pivoting the missile on the gimbals relative to the antenna in accordance with the signals received by the reflector so as to maintain the missile on a proper course towards the target.

37. In an antenna for directing the flight of a missile towards a target, a plurality of gimbals supported on one another to provide for pivotal movements of the missile relative to the antenna about a plurality of substantially perpendicular axes, a shaft supported on the gimbals, a feed on the end of the shaft for providing energy for transmission to a target, a reflector supported on the shaft and surrounding the feed to direct the energy from the feed towards the target in a predetermined pattern and to a direct to the feed enregy received by it from the target, there being an axial opening in the shaft to provide a communication with the feed for the direction of energy through the shaft to the feed for transmission by the feed and for directing through the shaft the energy received by the reflector, means associated with the gimbals for providing a wave guide for communication with the shaft upon pivotal movements of the missile on the gimbals relative to the antenna, means for weighting the reflector to provide the reflector with a balance relative to the gimbals for a gyroscopic action of the reflector, and means associated with the gimbals and the reflector for pivoting the missile on the gimbals relative to the reflector in accordance with the signals received by the reflectors so as to maintain the missile on a proper course towards the target.

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