

Feb. 12, 1952

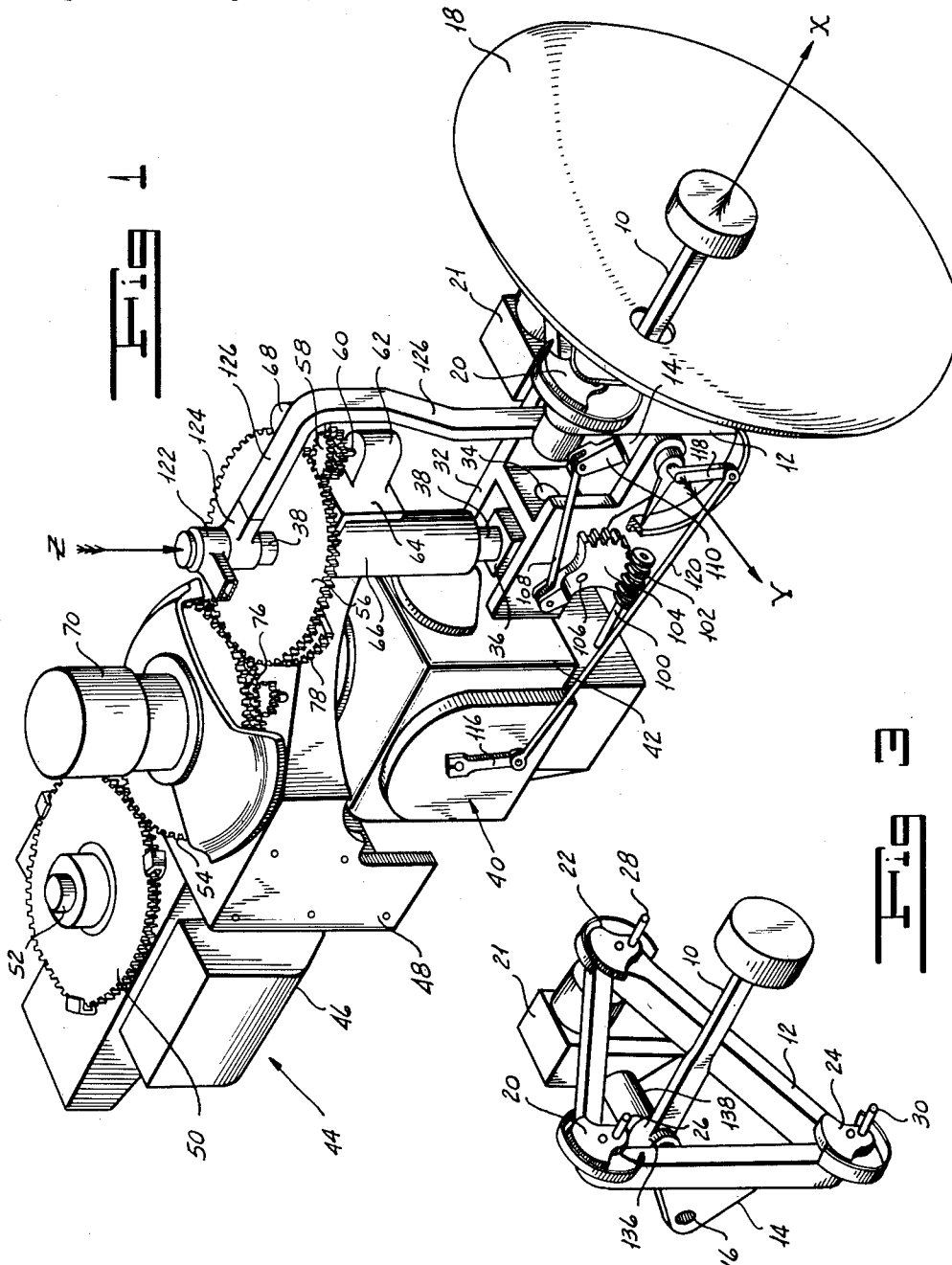
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2,585,579

MICROWAVE ANTENNA AND MOUNTING AND STABILIZING MEANS THEREFOR

Original Filed Sept. 25, 1945

4 Sheets-Sheet 1



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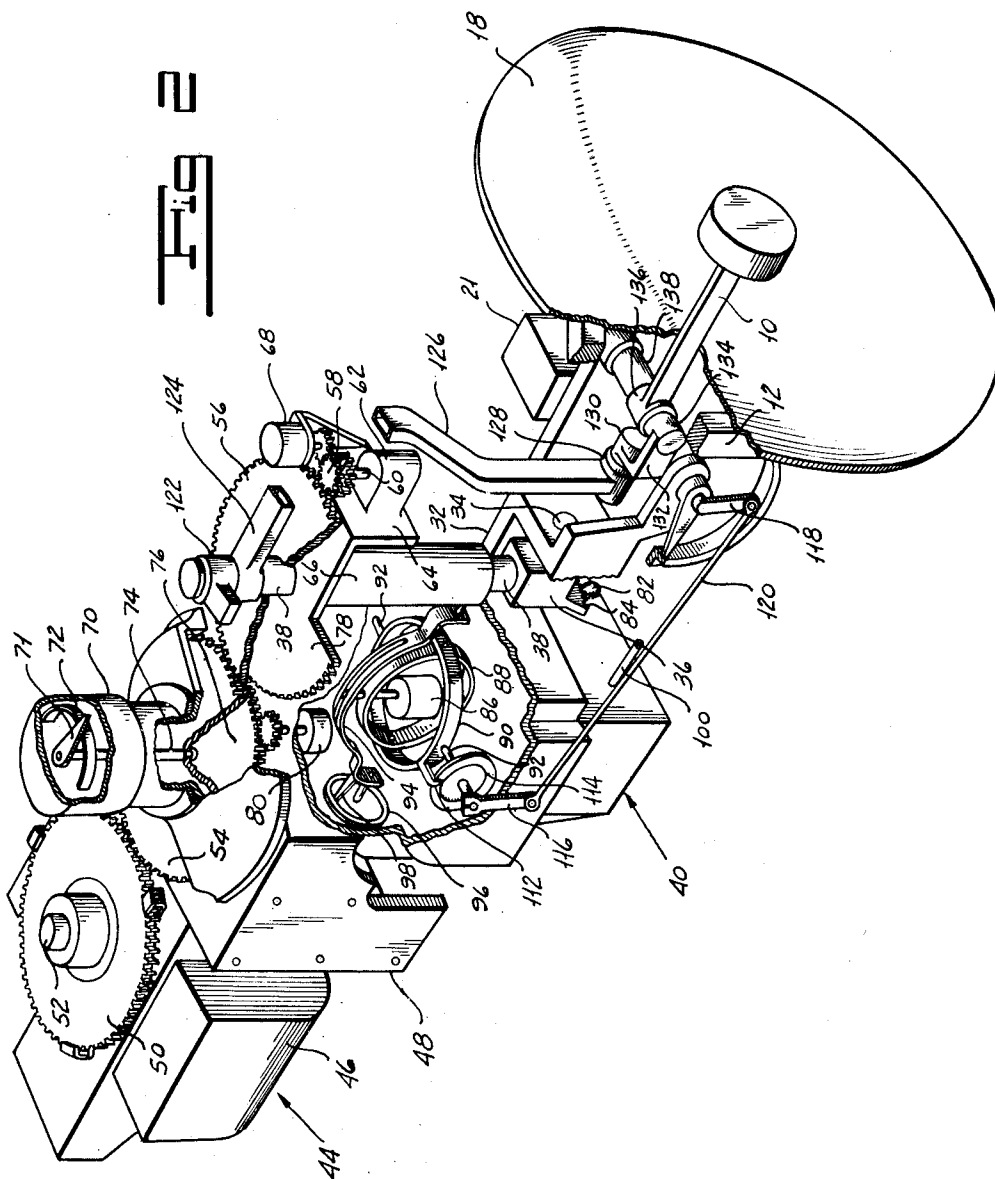
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MICROWAVE ANTENNA AND MOUNTING AND STABILIZING MEANS THEREFOR

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4 Sheets-Sheet 3

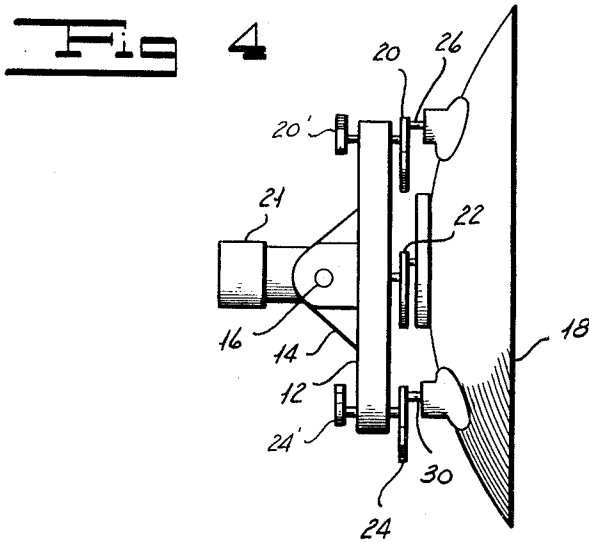
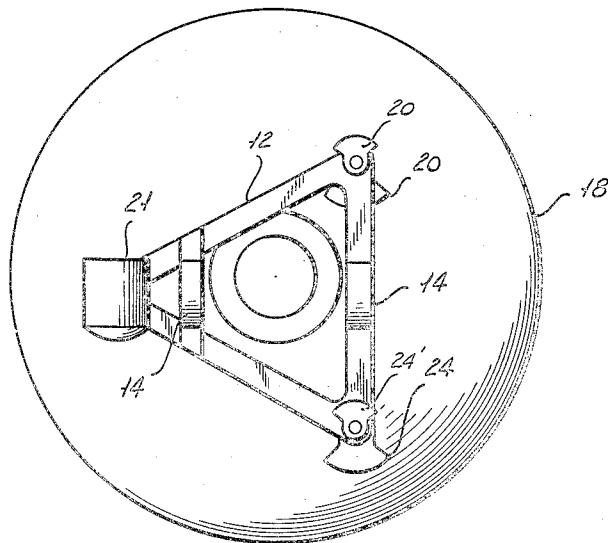


Fig 5



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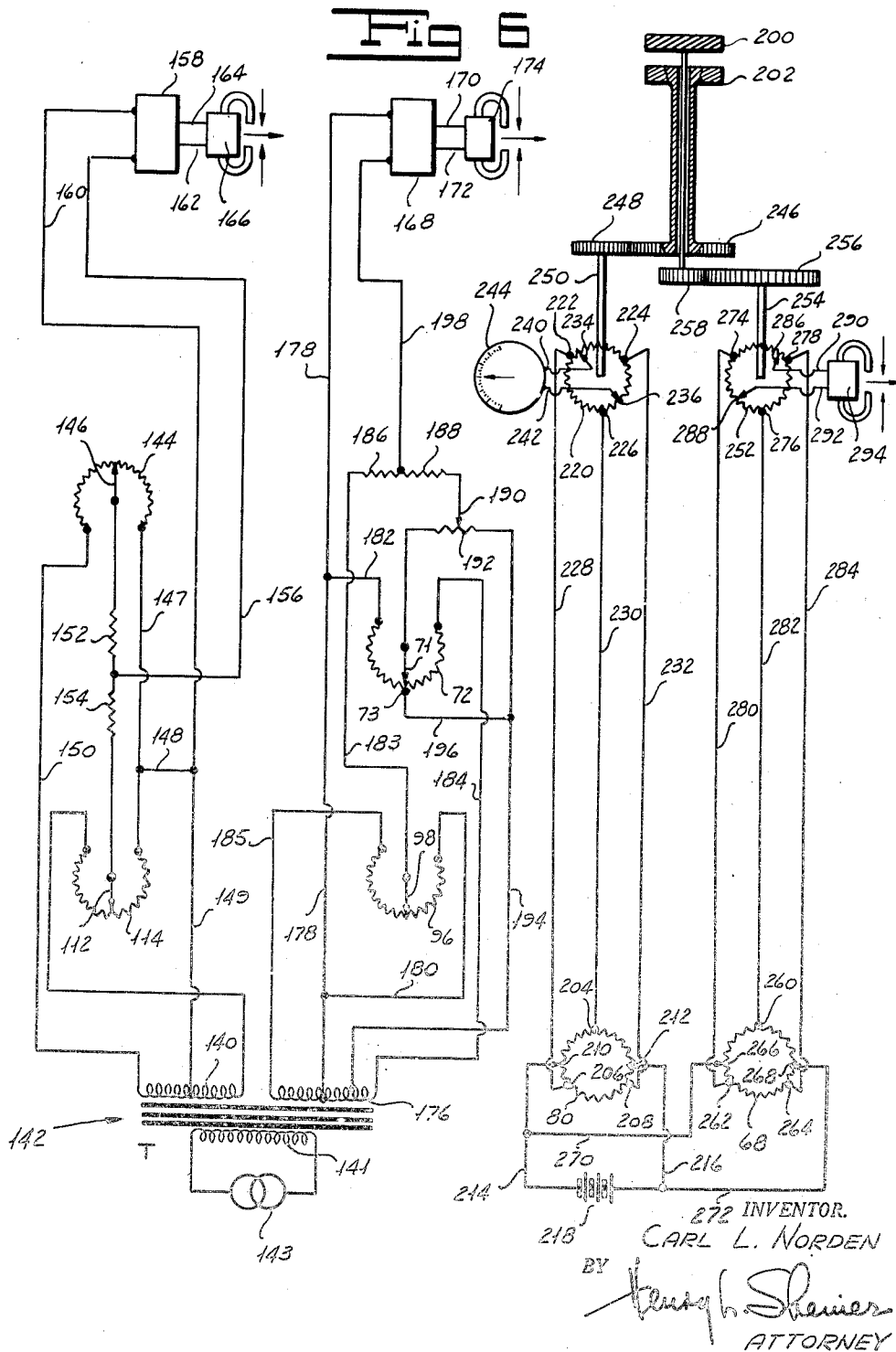
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4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,585,579

MICROWAVE ANTENNA AND MOUNTING AND STABILIZING MEANS THEREFOR

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Original application September 25, 1945, Serial No. 618,448, now Patent No. 2,499,228, dated February 28, 1950. Divided and this application June 21, 1949, Serial No. 100,388

13 Claims. (Cl. 250—33.65)

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My invention relates to a microwave antenna and mounting and stabilizing means therefor.

This application is a division of my copending application Serial No. 618,448 filed September 25, 1945, for Stabilization of Directional Devices, now Patent No. 2,499,228.

In the use of microwaves, such as in radar in aircraft in connection with navigation, bombing, and the like, it becomes necessary to control and stabilize the antenna in three axes. The first of these axes is the azimuth axis, that is the axis around which the airplane yaws. The second is the cross-level axis which is the axis along the line of the microwave beam corresponding to what would be the line of sight if the device were an optical instrument. The third axis about which stabilization must take place is the level axis which is one perpendicular to the cross-level axis and extending in a horizontal direction. The cross-level axis is one around which roll along the line of sight takes place and the level axis is one about which pitch along the line of sight takes place. It is desirable too to produce a conical scanning of the radar beam and this requires that the antenna reflector be rotated with respect to the microwave feed horn.

One object of my invention is to provide a microwave antenna, a mounting therefor, and means for stabilizing the antenna about three axes disposed at right angles to each other.

Another object of my invention is to provide a stabilized microwave antenna in which conical scanning of a radar beam may be achieved while avoiding objectionable vibrations.

Another object of my invention is to provide a stabilized microwave antenna provided with conical scanning means for the radar beam which reduces gyroscopic forces to a minimum.

Another object of my invention is to provide a microwave antenna, a mounting therefor and stabilization and control means.

Other and further objects of my invention will appear from the following description.

In the accompanying drawings which form part of the instant specification, and which are to be read in conjunction therewith:

Figure 1 is a perspective view of a stabilization and control apparatus of a radar antenna of the horn and reflector type, showing one embodiment of my invention.

Figure 2 is a view similar to Figure 1 with parts broken away to show details of construction.

Figure 3 is a detail view of the antenna horn and the mounting frame for the reflector drawn in the same orientation as shown in Figure 1 but

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removed from associated parts in order to show its construction.

Figure 4 is a side elevation of the parts shown in Figure 3 with the antenna in position.

Figure 5 is a rear elevation of the assembly shown in Figure 4.

Figure 6 is a schematic view showing the circuits used in controlling the apparatus of Figure 1.

Referring now to Figure 1, the vertical axis around which control in azimuth is achieved is indicated by the arrow Z. The cross-level axis along the radar beam is indicated by the arrow X. The level axis at right angles to the cross-level axis is indicated by the arrow Y. The antenna comprises a feed horn 10 rigidly attached to a frame 12 as can readily be seen by reference to Figures 1 and 3. The frame 12 is provided with lugs 14, shown in Figures 3, 4 and 5. The lugs 14 are provided with openings 16 so that the frame 12 may be mounted for pivotal movement around the level or Y axis. The antenna reflector 18 is carried by the frame 12 through a plurality of cranks 20, 22, and 24, and their associated crank pins 26, 28, and 30, so that the antenna may be given a rotary motion providing the desired conical scanning of the radar beam, as will be described more fully hereinafter. An H-frame 32 carries the axis around which the frame 12 is pivoted. The frame 32 is mounted about an axle 34 so that the frame may pivot about the cross-level or X axis. The axle 34 is carried by a block 36 which is in turn supported by a post 38 which is rotatably mounted about the azimuth axis or Z axis. The movement of the antenna assembly about the level axis Y and the movement of the H-frame 32 about the cross-level axis X are controlled by a vertical gyroscope unit, indicated generally by the reference numeral 40, carried in a housing 42 secured to the H-frame 32. The control is implemented by servomotors controlled by the gyroscope. The rotation of the post 38 about the azimuth axis Z is controlled by an azimuth gyroscope unit, indicated generally by the reference numeral 44, positioned in a housing 46 which is carried by the main frame structure 48, which also supports the servomotor controlled by the azimuth gyroscope and the associated means for controlling the direction of the antenna in azimuth. The entire assembly may be mounted in an aircraft in any convenient position through means of the main frame 48. The azimuth gyroscope may be of any suitable type and is well known to the art. It is adapted

to stabilize a part such as gear 50 in azimuth. The gear 50 may be disconnected, if desired, by means of a clutch knob 52 through which the gear 50 is normally clutched to the part stabilized in azimuth by the gyroscope. The gear 50 meshes with an idle gear 54 which meshes with a gear 56 which is rotatably carried by the post 38. The gear 56 meshes with a gear 58 which is fixed to a shaft 60 which controls a servomotor 62 secured to a bracket 64 which is secured to the post 38. The post 38 is rotatably mounted in housing 66 carried by the main frame 48. Accordingly, rotation of the servomotor 62 will rotate the bracket 64 and the post 38 and the associated structure supported thereby around the azimuth axis Z. It will be observed further that this rotation is controlled by the azimuth gyroscope. In other words, if the servomotor 62 is stationary the post 38 will remain fixed in azimuth with relation to gear 50.

There are three potentiometers associated with the azimuth gearing. A turn follow-up potentiometer 68 is geared to the output of the servomotor 62 as can readily be seen by reference to Figure 2. This potentiometer will register angular movement of the post 38 around the Z axis with relation to the azimuth gyroscope. A drift angle potentiometer 72 is carried within the housing 70 which is mounted on the frame 48. This potentiometer is adapted to control cross-trail. The potentiometer shaft 74 is driven by gear 76 which is in mesh with gear sector 78 which is formed integrally with bracket 64, so that it moves with the bracket and hence with post 38. In this way the angle between shaft 74 and the potentiometer housing 70 will represent the drift angle, that is, the angle between the post 38 and the main frame 48. A third potentiometer 80 is carried by the main frame 48 and is driven from gear 76, and is so connected in the control circuit, as shown in Figure 6, as to register the differential angular movement of the post 38 with respect to the aircraft. By means of the circuit, shown in Figure 6, which will be described more fully hereinafter, the gearing and potentiometers are employed to control the antenna about the azimuth or Z axis and about the cross-level axis or X axis. If desired, refinements may be included, such as means for imparting a scanning movement about the azimuth axis to the antenna and the inclusion of follow-up motions therefor, which may be housed within the potentiometer housing 70. These refinements are not essential to the present invention and are accordingly not described.

Movement of the post 38 will rotate the entire axial system comprising the X axis and the Y axis about the Z axis. In other words, level and cross-level movements are referred to the line of the radar beam as distinguished from the direction of flight of the aircraft. Still referring to Figure 2, the post 38 terminates in a lower block 36 upon which the H-frame 32 is pivotally mounted by means of the shaft 34 as was pointed out hereinabove. The housing 40 for the vertical gyroscope unit is rigid with and forms part of the H-frame 32. A servomotor lodged within the housing 40 has an output gear 82 which meshes with the gear sector 84 which is formed integrally with the block 36 which in turn pivots about the axis shaft 34. Rotation of the gear 82 will rock the H-frame 32 about the cross-level or X axis.

The gyroscope which is shown diagrammatically in Figure 2 comprises a vertical rotor 86

carried by an inner gimbal ring 88 which is in turn carried by an outer gimbal ring or Cardan 90. The Cardan is pivotally supported along a level axis by trunnions 92. The spin axis of the gyroscope is normally maintained in a vertical direction by an erecting bail 94. A potentiometer sector 96 is carried by the housing 40 and cooperates with a brush 98 carried by the erecting bail 94. The brush 98, therefore, is adapted to indicate motion of the H-frame 32 with respect to the gyroscope, that is, motion about the cross-level or X axis, and thus permits the control thereof through the servomotor which drives gear 82, as described above.

Referring now to Figure 1, it will be seen that the angular position of the antenna assembly about the level or Y axis is controlled by a second servomotor (not shown) which is positioned within the lower part of housing 40. This servomotor is adapted to rotate a shaft 100 having a worm 102 meshing with a worm gear segment 104 formed as a lever pivoted about pivot pin 106. A link 108 is connected to an arm 110 secured to the frame 12 to rock the frame about the level or Y axis. The servomotor which operates worm 102 is controlled by the potentiometer brush 112, shown in Figure 2, which is carried by the Cardan 90 and cooperates with the potentiometer sector 114 which is rotatably carried around one of the trunnions 92. The arm 116, the arm 118, and the connecting link 120 insure that there is a fixed angular relationship between the position of the antenna assembly and the potentiometer sector 114.

It will be observed that the level, cross-level and azimuth axes do not intercept at a common point as is the case usually in gimbal Cardan suspensions, but that the intersection of the level and cross-level axes is spaced from the intersection of the cross-level and azimuth axes. This feature is of importance in view of the necessity of accommodating microwave guide joints, since microwave guides must be used in utilizing microwaves in radar. The microwave guide from the radar equipment (not shown and forming no part of this invention) leads to a stationary joint member 122 located above the post 38. A rotatable joint member 124 cooperates with the stationary joint member 122. A microwave guide 126, shown in Figure 1, terminates in a microwave guide joint member 128, shown in Figure 2, which is stationary with respect to the block 36. The joint member 128 cooperates with a moveable joint member 130.

Angular wave guide bend section 132 leads the microwaves from the joint member 130 to the joint member 134 which is stationary with respect to the H-frame 32. The joint member 134 cooperates with joint member 136 to which the feed horn 10 communicates so that the feed horn is rotatable with the antenna unit and is supported by the member 138.

The three microwave guide joints comprising members 122 and 124, 128 and 130, and 134 and 136 are thus arranged upon the respective Z axis, X axis, and Y axis, and further are coincident therewith even though they are spaced from the intersections of pairs of axes. In this way I am enabled to make provision for the necessary mechanical movements.

While it is to be understood that the radar apparatus as such forms no part of the instant invention, it comprises suitable visual indicators, such as cathode ray oscilloscope screens or other suitable apparatus for indicating target

coordination or controlling antenna movements in accordance with such indications.

The antenna frame structure 12, shown in Figures 3, 4 and 5, comprises a triangular frame carrying rotatable cranks 20, 22, and 24. The antenna reflector 18 is carried by the crank pins 26, 28 and 30. One of the cranks 22 is driven by a motor 21. Since each pair of cranks when connected to the antenna reflector constitutes a parallel motion device the reflector will be caused to execute a parallel crank movement. Since the crank pin 28 rotates, the antenna reflector will rotate as a whole moving in a small circle having a radius equal to the distance between the axis of rotation of the crank and the crank pin 28. This type of scanning movement is advantageous since it minimizes gyroscopic resistance of the reflector. The gyroscopic effect due to reflector rotation may be considerable due not only to the mass of the reflector but due to the speed of scanning which may be, in the embodiment illustrated, in the vicinity of 2000 R. P. M. The gyroscopic effect due to the reflector rotation will tend to cause precession so that the resulting torque will place an additional load upon the azimuth gyroscope and other stabilizing and control members which would decrease the efficiency of the apparatus or require additional bulk by increased weight of the installation. For example, when the antenna is tilted downwardly about the Y axis, the gyroscopic effect will tend to make it precess about the Z axis thus generating a torque which must be overcome by the azimuth gyroscope. The conical scanning arrangement I have shown reduces this undesirable effect to a minimum. I accomplish this by using a small crank radius positioned at a distance from the center of gyration of the reflector about the X axis, since gyroscopic resistance will vary in the proportion which the square of the crank radius bears to the square of the radius of gyration of the reflector about the X axis. The use of a large radius of gyration together with a small crank radius will give a small gyroscopic resistance.

To reduce the tendency to vibration, the antenna is dynamically counter-balanced by means of weights formed integrally with each of the cranks 20, 22, and 24, and by counter-balancing weights 20' and 24', as will readily be observed by reference to Figures 4 and 5. The weights and the proportions of the weights are selected so that the forces on each of the crank shafts are balanced about the crank shaft axis and are also balanced longitudinally of the crank bearings. All bearing reactions are accordingly reduced to a minimum and the tendency to vibration due to rotation of the reflector upon the frame structure 12 is reduced to a minimum.

The apparatus shown in Figures 1 to 5, inclusive, may be utilized with any suitable control apparatus as, for example, one which is shown diagrammatically in Figure 6, to which reference is now made. The circuit diagram illustrates an A. C. follow-up circuit for the control of the antenna about the level or Y axis. The vertical gyroscope potentiometer sector 114 is connected across one-half of a split secondary winding 140 of a transformer indicated generally by the reference numeral 142, and a second potentiometer 144 having a brush 146 is connected across the other half of the same winding by means of conductors 147, 148, 149, and conductor 150. The brushes 112 and 146 of

these two potentiometers are connected through equal resistors 152 and 154 to an input connection 156 of a phase sensitive amplifier indicated diagrammatically by the reference numeral 158. The other connection to the amplifier 158, that is, conductor 160, is connected to conductor 149 and thence to the center tap of the secondary transformer winding 140. The output signal of the amplifier 158 is impressed by conductors 162 and 164 to a two-way relay 166 through which the servomotor which drives the shaft 100 of Figure 1 and its worm 102 is controlled. When the brushes 146 and 112 are in corresponding position upon their resistor sectors 144 and 114, the voltages impressed across resistors 152 and 154 will be equal and opposite thus giving a null input to the amplifier 158. In this condition the servomotor is stationary. If the brushes 146 and 112 are not in a position to produce equal and opposite signals across the resistors 152 and 154, the resultant voltage to the input of the amplifier 158 will be of a value corresponding to the unbalance of position between the brushes and will agree in phase with the brush which is farther from the center tap end of its potentiometer. The relay 166 will be operated in a direction agreeable to the signal created by the difference in position between the brushes 112 and 146, so as to cause the servomotor to rotate the antenna assembly about the level or Y axis and thus through arm 118, link 120 and arm 116 and rebalance the potentiometer 114 with the potentiometer 144. The potentiometer 144 may be controlled in any convenient manner as, for example, by coupling it to a bomb sight computer part designed for rotating the telescope mirror or prism of an optical sight in elevation. In this manner it will be readily apparent that the control in elevation, that is, the control of the sight angle of the antenna may be readily achieved.

In Figure 6 I have also shown a circuit for controlling the antenna position about the cross-level or X axis. The output of a phase sensitive amplifier 168 is impressed by conductors 170 and 172 upon a relay 174 to control the servomotor which actuates the gear 82 shown in Figure 2 to rock the H-frame 32 and its associated parts. The transformer 142 is provided with a primary coil 141 across which an alternating current input is impressed by means of an alternator 143. The transformer 142 is provided with two secondary windings, one secondary winding 140 being split and furnishing an alternating current potential for the control of the input to the amplifier 158, the second secondary winding 176 of the transformer 142 is likewise provided with a center tap which is connected by conductor 178 to the phase sensitive amplifier 168 as the reference signal. A branch conductor 180 connects the center tap to one end of the potentiometer 96 which is associated with the vertical gyroscope, as can be seen by reference to Figure 2. The potentiometer 72 which is carried in the housing 70 shown in Figure 2 has one end of its resistor connected to the center tap through branch conductor 182 and the conductor 178. The other end of the resistor of the potentiometer 72 is connected by conductor 184 to one end of the secondary winding 176. The other end of the resistor of potentiometer 96 is connected by conductor 185 to the other end of the secondary winding 176. The brushes 71 and 98 of the potentiometers are interconnected by a conductor

183, and a pair of equal resistors 186 and 188. The resistor 188, however, is not connected directly to the brush 71 but through a brush 190 and a potentiometer 192 which is connected across the brush 71 and a quarter tap of the secondary winding 176 by a conductor 194. A branch conductor 196 connects the quarter tap conductor 194 to the center of the potentiometer resistor 72. The potentiometer resistor 12 is wound to have a resistance proportional to the sine of the arc measured from the center tap of the potentiometer resistor 72, and hence the voltage of the brush 71 is a function of the sine of the drift angle. Since the ends and center of the potentiometer sector 72 are maintained at the voltages at the taps of the secondary winding of the transformer, a variation in voltage distribution along the resistor 72 due to current drain by the potentiometer sector 192 is reduced to a minimum. The resistors 186 and 188 may be sufficiently high to make the effects of the current drain negligible. Since one end of the sector 192 is always at the voltage of the brush 71 and the other end of the resistor 192 is at the voltage of its quarter tap connection 194 as a reference voltage, the voltage of the brush 190 will be proportional to its setting multiplied by the movement of the brush 71 from the center tap 73 of the resistor 72. Accordingly, if the trail be set in by hand by means of the potentiometer 192 and its brush 190, the voltage of the brush 190 will be proportional to the trail multiplied by the sine of the drift angle. The rocking of the frame 32 around the cross-level or X axis will bring the potentiometer resistor 96 which is carried for movement therewith to a balancing position by moving the sector 96 relative to the brush 98 which is being stabilized by the gyroscope 86 shown in Figure 2.

This is accomplished in a manner similar to that described above with respect to the generation of the signal by the unbalance of brushes 146 and 112. The signal produced by the unbalance of brushes 71 and 98 will appear across resistors 186 and 188 agreeable in amount and in direction to the amount and direction of the unbalance of the brushes. This signal is impressed by conductor 198 as a control signal to the phase sensitive amplifier 168.

The regulation of the antenna about the azimuth or Z axis is accomplished by the circuits shown in Figure 6 through turn control knob 200 and drift control knob 202. The turn control knob is used for the purpose of turning both the aircraft and the antenna. The drift control knob is used for turning only the aircraft. While maintaining the antenna at a predetermined orientation where there is a crosswind or a transverse component of target motion the maintenance of a collision course involves the establishment of a correct drift angle. This is described in the parent application Serial No. 618,448, referred to above. The turn knob 200 and the drift knob 202 are used for this purpose. The potentiometer 80 which is shown in Figure 2, is provided with three taps 204, 206 and 208 positioned 120° apart, and a pair of brushes 210 and 212 positioned 180° apart. The brushes are connected by conductors 214 and 216 across a source of potential such as battery 218. The rotation of the gear 76, shown in Figure 2, relative to the main frame 48 corresponds to a change in azimuth of the antenna relative to the aircraft. This rotation will rotate the brushes 210 and 212 around the resistor ring of the

potentiometer 80, thus varying the voltage distribution to the taps 204, 206 and 208. A similar potentiometer 220 is provided with taps 222, 224 and 226 spaced 120° apart. Tap 222 is connected to tap 206 by a conductor 228, tap 226 is connected to tap 204 by a conductor 230, and tap 224 is connected to tap 208 by a conductor 232. A pair of brushes 234 and 236 are connected by conductors 240 and 242 to a voltmeter 244 which serves as a pilot director indicator. The brushes 234 and 236 will furnish a zero indication when approximately 90° out of phase with the brushes 210 and 212 of potentiometer 80. Where the position of these brushes is varied in either direction, a corresponding indication will be set up upon the meter 244 so that if the airplane is controlled by the pilot to maintain a zero reading upon the meter 244 the aircraft will be turned relative to the antenna which is being stabilized in azimuth through an angle controlled by the potentiometer 220. In order to reduce the errors inherent in potentiometer systems of this construction to negligible values, the potentiometer 80 is geared to the gear 76 so as to make a complete revolution in response to a turn of this gear through a fairly small angle. The knob 202 is connected to the potentiometer 220 through a gear 246 and a gear 248 which operates a shaft 250 adapted to rotate the potentiometer resistor. A complete rotation of the shaft 250 may correspond to an aircraft turn through an angle of 10° or any other suitable angle determined by the gear ratio. The effect of turning the knob 200 is, as pointed out above, to turn the aircraft and the antenna as a unit so that when the turn is completed the antenna will occupy the same position in azimuth with respect to the aircraft as it did when the turn was commenced. I accomplish this by means of the potentiometer 68 which is shown in Figure 2, and a second potentiometer 252, the resistor of which is carried by a shaft 254 and rotatable therewith. The shaft 254 is turned by a gear 256 which meshes with a gear 258 which is controlled by the knob 200. The resistor of potentiometer 68 is circular and provided with three taps 260, 262, and 264 spaced 120° from each other and a pair of brushes 266 and 268 spaced 180° apart. The brushes 266 and 268 are connected by conductors 270 and 272 across the source of potential 218. The potentiometer resistor 252 is provided with three taps 274, 276, and 278 positioned 120° apart. The tap 274 is connected to the tap 262 by conductor 280, tap 276 is connected to the tap 260 by a conductor 282, and tap 278 is connected to the tap 264 by a conductor 284. The brushes 286 and 288 of the potentiometer 252 are positioned 180° apart and are connected by conductors 290 and 292 to a relay 294. The relay 294 controls the servomotor 62 shown in Figure 2. The operation of potentiometers 252 and 68 is the same as the operation of potentiometers 220 and 80 just described, with the exception that the output of the brushes in one case is connected across a voltmeter and in the second case connected to control the relay 294. Whenever the knob 200 is turned it will unbalance the potentiometer 252, thus energizing the relay 294 and causing the servomotor 62 to rotate the antenna around the azimuth axis until the potentiometer 68 is in balance with the potentiometer 252. This movement is communicated through the gear sector 78 and the gear 76 to the potentiometer 80, thus unbalancing it

with respect to potentiometer 220. This unbalance will signal a turn upon the meter 244 as pointed out above. The pilot will then operate the aircraft to bring the meter 244 back to its zero indication, and in doing so will execute a turn of the aircraft causing it to follow the antenna, so that the net result of turning knob 200 will be to turn both the aircraft and the antenna through the same angle. In this manner it is possible through knob 200 to keep the aircraft and antenna directed at the target, as will be the case in a homing or collision course. When knob 200 and knob 202 are grasped together as a unit and turned as such through a given angle, one effect will be that just described to turn both the aircraft and the antenna through a certain angle. The turning of knob 202, however, will unbalance potentiometer 220 with respect to potentiometer 80 so that the aircraft will be turned by the pilot in response to the signal on the meter 244 through an angle determined by the amount of unbalance of the potentiometer 220. This angle which will be clear is determined by the gear ratios between gears 246 and 248. The net effect of turning both knobs simultaneously then is to establish a proportion between aircraft turn and antenna turn in response to a deviation from the desired course. In this manner I may establish a navigation course or a collision course at will. If a smaller ratio of aircraft turn to antenna turn than that provided by turning both knobs 200 and 202 as a unit is desired, knob 200 may be turned at a greater rate of speed than knob 202.

It will be seen that I have accomplished the objects of my invention. I have provided a microwave antenna, a mounting therefor, and means for stabilizing the antenna about three axes disposed at right angles to each other. I have provided a stabilized microwave antenna in which conical scanning of a radar beam may be achieved while avoiding objectionable vibrations, and in which gyroscopic forces are reduced to a minimum. I have provided a novel control means for stabilizing a microwave antenna.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. In a microwave antenna system, means for mounting said antenna system for angular movement relative to an azimuth axis, a level axis, and a cross-level axis, said azimuth axis and cross-level axis intersecting each other, and said level axis and said cross-level axis intersecting each other, said points of intersection being separated from each other, a microwave guide having a joint coaxial with the azimuth axis and spaced from the intersection of said azimuth axis with the cross-level axis, a joint coaxial with the cross-level axis and spaced from the intersection of the said cross-level axis with the level axis.

2. A microwave antenna, including in combination a radar antenna, an antenna gyroscope,

means for supporting said antenna gyroscope, means for stabilizing said support from said gyroscope, means for mounting the antenna upon said support, means for rotating said mounting means through a circular locus of small dimension with respect to the radius of gyration of said antenna whereby the rotational scanning movement of said antenna will have a reduced gyroscopic resistance due to the scanning movement.

3. A microwave antenna as in claim 2, including counter-weights moving with said antenna in a circular locus forming a system dynamically balanced about an axis parallel to and an axis transverse to the axis of rotation of said locus of scanning movement.

4. A microwave antenna, including in combination a radar antenna, means for mounting said antenna comprising a frame, a plurality of bearings carried by said frame, a plurality of cranks mounted in said bearings for rotation therein, said cranks supporting an antenna reflector, the radius of said cranks being equal and small with respect to the radius of gyration of said antenna reflector whereby gyroscopic resistance of the scanning movement of the antenna reflector is minimized.

5. A stabilized microwave antenna system, including in combination a frame, a vertical gyroscope carried by said frame, an antenna, means for mounting said antenna on said frame for pivotal movement about a level axis, a follow-up means interconnecting said vertical gyroscope and said antenna, a servomotor controlled by said follow-up means and carried by said frame for pivoting said antenna with relation thereto about the level axis, mounting means for carrying said frame in balanced position for pivotal movement about a cross-level axis, a cross-level follow-up means between the frame and said vertical gyroscope, a servomotor controlled by said cross-level follow-up means for pivoting said frame with relation to said frame mounting means about a cross-level axis, an azimuth gyroscope, means for supporting said frame mounting means for pivotal movement about an azimuth axis, and means controlled by said azimuth gyroscope for stabilizing said supporting means in azimuth.

6. A stabilized microwave antenna system as in claim 5, in which said cross-level follow-up means includes a drift potentiometer having a resistor, a voltage source, a center tap connection between said voltage source and the resistor of said potentiometer, a trail potentiometer having a resistor connected across the center tap connection and the brush of the drift potentiometer, a servomotor, and means for controlling said servomotor to position said frame about a cross-level axis as a function of the voltage of the brush of said trail potentiometer.

7. A control system for stabilizing a microwave antenna, including in combination means for mounting an antenna for pivotal movement about a level, a cross-level, and an azimuth axis, a servomotor for turning the antenna about an azimuth axis, an azimuth gyroscope, means responsive to movement of said antenna relative to said gyroscope for actuating said servomotor, a second servomotor for rotating the antenna about the cross-level axis, a vertical gyroscope, means responsive to relative movement between the vertical gyroscope and said antenna about the cross-level axis for actuating said second servomotor, a third servomotor for rotating said

antenna about the level axis, means responsive to relative movement between said antenna and said vertical gyroscope for actuating said third servomotor to rotate said antenna about the level axis.

8. A control system as in claim 7, in which said means responsive to relative movement between said antenna and said vertical gyroscope about the cross-level axis includes a potentiometer having a brush, a second potentiometer having a brush, means for connecting said potentiometers in parallel across a source of potential, means for connecting said brushes in series with a resistor, a phase sensitive means, and a conductor connected to an intermediate point in said resistor for impressing a signal upon the phase sensitive means to control said second servomotor.

9. A control system as in claim 7, in which said means responsive to relative movement between said antenna and said vertical gyroscope about the cross-level axis includes a potentiometer having a brush, a second potentiometer having a brush, means for connecting said potentiometers in parallel across a source of potential, means for connecting said brushes in series with a resistor, a phase sensitive means, and a conductor connected to an intermediate point in said resistor for impressing a signal upon the phase sensitive means to control said second servomotor, a third potentiometer having a brush, means for supplying a potential to said third potentiometer, means for connecting said third potentiometer and its brush in series with said first resistor, the construction being such that the third potentiometer brush may be set to introduce a correction which is a function of the sine of the drift angle.

10. A control system as in claim 7, in which said means responsive to movement of said mounting relative to the azimuth gyroscope includes a circular potentiometer provided with three taps positioned 120° apart and a pair of brushes positioned 180° apart, a second potentiometer of similar construction having its taps connected in parallel with the taps of said first circular potentiometer, the brushes of said second potentiometer being connected to a phase sensitive means adapted to control the servomotor for turning the antenna about the azimuth axis.

11. A control system as in claim 7, in which said means responsive to movement of said mounting relative to the azimuth gyroscope includes a circular potentiometer provided with three taps positioned 120° apart and a pair of brushes positioned 180° apart, a second potentiometer of similar construction having its taps connected in parallel with the taps of said first circular potentiometer, the brushes of said second potentiometer being connected to a phase sensitive means adapted to control the servomotor for turning the antenna about the azimuth axis, a third circular potentiometer having three taps positioned 120° apart and a pair of brushes positioned 180° apart, means responsive to the movement of said antenna in azimuth for rotating

the brushes of said third potentiometer, a fourth circular potentiometer having three taps positioned 120° apart connected in parallel with taps of said third potentiometer, said fourth potentiometer having a pair of brushes positioned 180° apart and conductors connecting said brushes across a voltmeter.

12. A control system as in claim 7, in which said means responsive to movement of said mounting relative to the azimuth gyroscope includes a circular potentiometer provided with three taps positioned 120° apart and a pair of brushes positioned 180° apart, a second potentiometer of similar construction having its taps connected in parallel with the taps of said first circular potentiometer, the brushes of said second potentiometer being connected to a phase sensitive means adapted to control the servomotor for turning the antenna about the azimuth axis, and manual means for moving the resistor of said second circular potentiometer relative to its brushes.

13. A control system as in claim 7, in which said means responsive to movement of said mounting relative to the azimuth gyroscope includes a circular potentiometer provided with three taps positioned 120° apart and a pair of brushes positioned 180° apart, a second potentiometer of similar construction having its taps connected in parallel with the taps of said first circular potentiometer, the brushes of said second potentiometer being connected to a phase-sensitive means adapted to control the servomotor for turning the antenna about the azimuth axis, a third circular potentiometer having three taps positioned 120° apart and a pair of brushes positioned 180° apart, means responsive to the movement of said antenna in azimuth for rotating the brushes of said third potentiometer, a fourth circular potentiometer having three taps positioned 120° apart connected in parallel with taps of said third potentiometer, said fourth potentiometer having a pair of brushes positioned 180° apart and conductors connecting said brushes across a voltmeter, and manual means for moving the resistor of said fourth circular potentiometer relative to its brushes.

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