Dec. 8, 1959 W. FALSTROM 2,916,739

SCANNER FOR ANTENNA SYSTEM

Filed July 28, 1955 2 Sheets-Sheet 1

FIG. 1

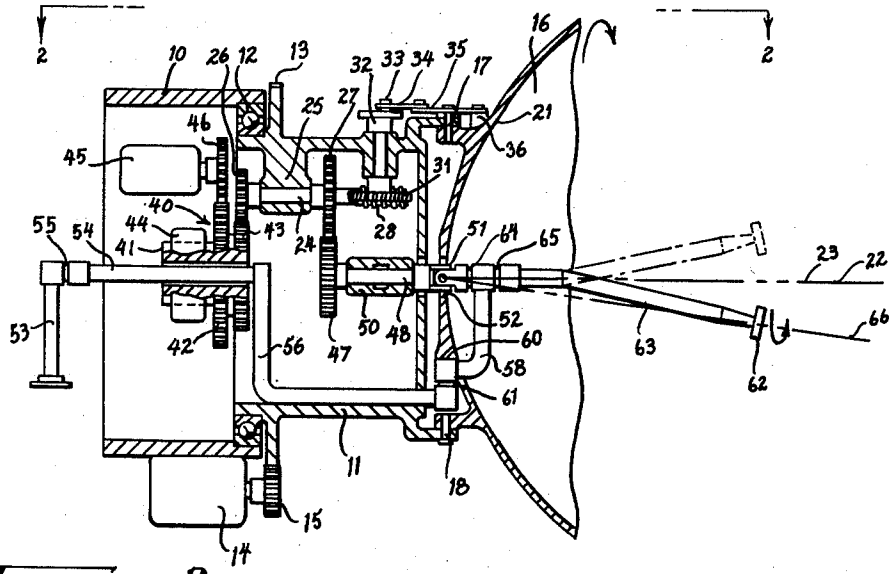
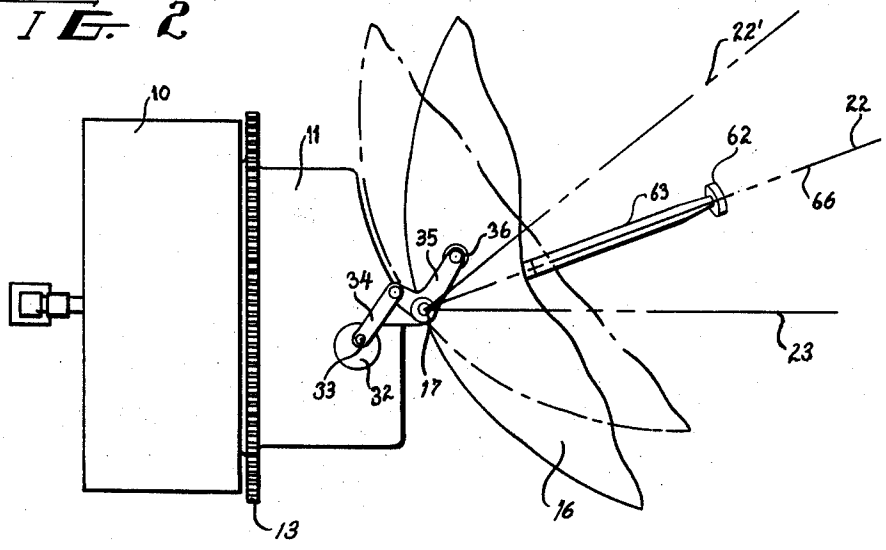


FIG. 2



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Filed July 28, 1955 2 Sheets-Sheet 2

FIG. 3

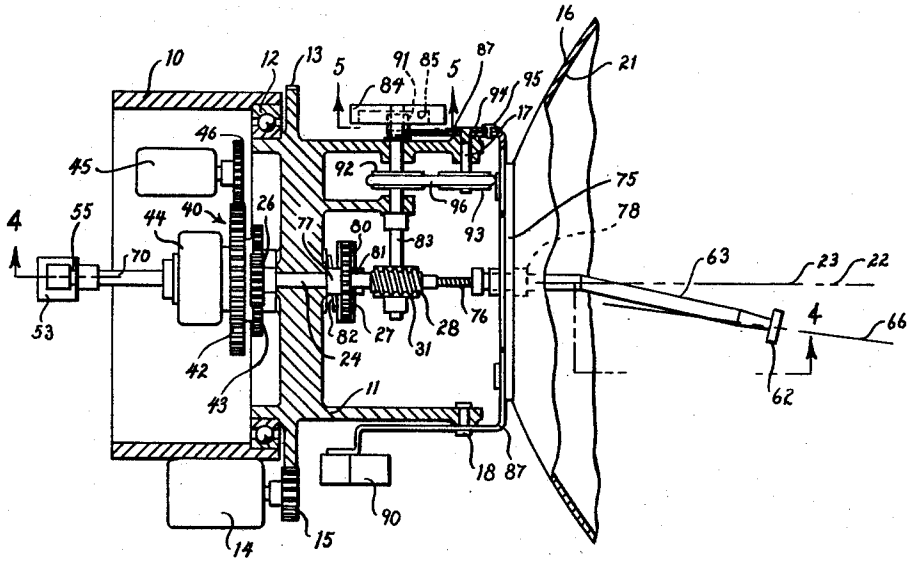


FIG. 4

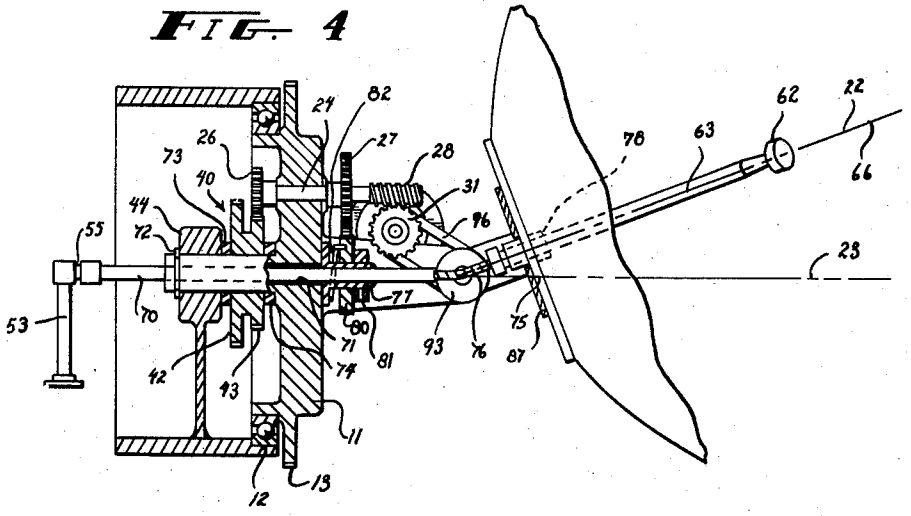
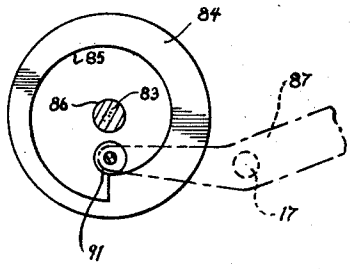


FIG. 5



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SCANNER FOR ANTENNA SYSTEM

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13 Claims. (Cl. 343—761)

This invention relates to scanners suitable for use with radio detection and ranging systems or the like, and, particularly, to scanners capable of producing an elliptical-spiral scanning pattern.

The purpose of a scanner is to direct a beam of energy, such as electromagnetic energy, into space and to make the beam trace a particular pattern in space. The repeated tracing of the pattern is referred to as scanning and the shape of the pattern characterizes the type of scanning, such as circular, spiral, or linear.

A scanner for radio detection and ranging system, commonly referred to as a radar system, will include a feed or antenna for directing energy delivered to the feed by a transmission line toward a reflector. The reflector, which is usually parabolic in shape, forms the energy received from the feed into a beam and projects it into space. The beam is moved in space by moving the reflector or the feed or both. The mechanism which produces these movements is referred to as a scanner. A circular scanning pattern, which is also referred to as a conical pattern, may be produced by locating the feed away from the directive axis of the reflector and rotating the feed about the directive axis. The circular pattern may also be produced by locating the feed away from the directive axis of the reflector and rotating the reflector about a line passing through the feed and the point where the directive axis intersects the reflecting surface of the reflector, which may be called the feed axis. In both cases, the beam will trace a circular pattern in space having the directive axis of the reflector as a center.

When the angle between the feed axis and the directive axis is changed, the size of the circular pattern will change correspondingly, and if this angle is changed while the reflector is rotating, a spiral pattern will be produced. The changing of this angle by a pivotal motion of the reflector is referred to as nodding the reflector.

In some radar applications, the target or search area is confined to the horizon and the ideal scanning pattern would be a long thin rectangle. It is an object of this invention to provide a scanner in which the reflector is nodded and both the feed and the reflector are rotated, producing an elliptical-spiral pattern. It is a further object of the invention to provide such a scanner which utilizes relatively low rotational velocities, thereby permitting use of a small, light weight and rigid structure that is easily dynamically balanced.

Another object of the invention is to provide a scanner having multiple scanning patterns, such as circular, spiral, elliptical-spiral and linear, and in which the scanning pattern may be changed rapidly and simply.

A further object of the invention is to provide a multiple pattern scanner in which the pattern changing means does not disturb the dynamic balance of the scanner.

An important object of the invention is to provide a scanner in which the horizontal axis of the pattern is maintained horizontal while the structure in which the

scanner is housed is rolling. Another object of the invention is to provide roll stabilization of the pattern by means within the scanner, thereby eliminating the need of a stabilized platform for the scanner.

Still another object of the invention is to provide a scanner in which the feed may be an electromagnetic antenna, a light source or detector, a sound source or detector, a heat source or detector, or the like.

The invention also comprises novel details of construction and novel combinations and arrangements of parts, which will more fully appear in the course of the following description. However, the drawings merely show and the description merely describes preferred embodiments of the present invention as applied to a radar scanner, which are given by way of illustration or example only.

In the drawings:

Fig. 1 is a sectional view of an embodiment of the invention;

Fig. 2 is a side view taken along the line 2—2 of Fig. 1;

Fig. 3 is a sectional view of another embodiment of the invention;

Fig. 4 is a sectional view taken along the line 4—4 of Fig. 3; and

Fig. 5 is a sectional view taken along the line 5—5 of Fig. 3 showing the cam follower in phantom.

In the embodiment of Fig. 1, the moving elements of the scanner are supported from a base 10. A frame 11 is rotatably mounted in the base 10 by a bearing 12, the frame 11 being provided with a peripheral gear 13. A drive motor 14 is mounted on the base 10, the rotating shaft of the drive motor carrying a pinion 15 which engages the peripheral gear 13.

A reflector 16, shown with the outer portion thereof broken away, is pivotally mounted on the frame 11 by pins 17, 18. The reflector 16 has a concave inner surface 21 which is usually parabolic in shape and which has an axis of symmetry or directive axis 22. The frame 11 has an axis of rotation 23 and the reflector 16 is mounted on the frame so that the pivot axis of the reflector through the pins 17, 18 is normal to the plane occupied by the directive axis 22 and the axis of rotation 23.

A countershaft 24 is rotatably mounted in a boss 25 which extends from the frame 11. Spur gears 26 and 27 and a worm 28 are affixed to the countershaft 24, the worm 28 engaging a worm gear 31 that is mounted on a crankshaft 32. The crankshaft 32 is mounted in the frame 11 and is provided with a crankpin 33, the crankpin 33 engaging one end of a drive link 34. A crankarm 35 is pivotally mounted on the pin 17, one arm of the crankarm engaging the other end of the drive link 34 and the other arm of the crankarm being affixed to a boss 36 on the reflector 16.

A cluster gear 40 comprising a shaft 41 and gears 42 and 43, is rotatably mounted in a boss 44 extending from the base 10, the gear 43 engaging the gear 26. A stabilization drive motor 45 is mounted on the base 10, a pinion 46 being mounted to the rotating shaft of the drive motor 45 and engaging the gear 42. A spur gear 47 is mounted on a shaft 48 and engages the spur gear 27, the shaft being rotatably mounted in a boss 50 which extends from the frame 11. A universal joint 51 is mounted on the shaft 48 with its pivot axis coinciding with the pivot axis of the pins 17, 18, the universal joint 51 extending through an opening 52 in the reflector 16.

A length of waveguide 53 is coupled to another length of waveguide 54 which is coaxial with the axis of rotation 23, by a rotating waveguide joint 55. The waveguide 54 is rigidly joined to a length of waveguide 56 which is supported by the frame 11. A length of waveguide 58 is

supported by the reflector **16** at a shoulder **60** and is coupled to the waveguide **56** by a rotating waveguide joint **61**. A feed **62** comprising a waveguide doughnut antenna is positioned in front of the reflecting surface **21** of the reflector **16** by a length of waveguide **63** which is mounted on an end **64** of the universal joint **51** and is coupled to the waveguide **58** by a rotating waveguide joint **65**. When the reflector **16** is pivoted on the frame **11**, the feed **62** will also be pivoted about the axis through the pins **17**, **18** due to the fact that the waveguide **58** is mounted on the reflector at the shoulder **60**. When it is desired that the feed **62** remain fixed relative to the axis of rotation **23** while the reflector is pivoted, the rotating joint **61** may be eliminated and the waveguide **58** may be directly coupled to and supported by the waveguide **56**.

The drive motor **14** rotates the frame **11** and the reflector **16** about the axis of rotation **23**, driving through the pinion **15** and the peripheral gear **13**. Assuming for the moment that the cluster gear **40** is fixed relative to the frame **11**, the countershaft **24** is driven from the gear **43** by the rotation of the frame **11**. The countershaft **24** in turn drives the shaft **48** through the gears **27**, **47** and rotates the feed **62** about the directive axis **22** in a direction opposite to that of the frame and reflector. The countershaft **24** also drives the shaft **32** through the worm and gear combination **28**, **31**, the rotation of the crankshaft **32** producing an oscillating movement of the crankarm **35** and the reflector **16** about the pivot pins **17**, **18**. A second position of the oscillating reflector **16** is shown in phantom in Fig. 2 and a second position of the rotating feed **62** is shown in phantom in Fig. 1.

A line **66** through the center of the feed **62** and the center of the universal joint **51** may be defined as a feed axis. When the feed axis **66** is displaced from the directive axis **22** of the reflector **16**, as shown in the embodiment of Fig. 1, and the feed is maintained fixed with respect to the reflector, rotation of the frame **11** with the reflector maintained fixed relative to the frame will produce a circular scanning pattern. If the reflector is pivoted with respect to the frame while the frame is being rotated, the radius of the previously mentioned circular scanning pattern will be continually changing, and hence a spiral scanning pattern will be produced. When the pivoting motion of the reflector is such that its directive axis oscillates between the lines indicated by numerals **22** and **22'** of Fig. 2, a doughnut-shaped area will be covered by the scanning pattern. In the above discussion it has been presumed that the feed **62** has been maintained fixed relative to the reflector **16**. When the feed is rotated about the directive axis **22** by the gearing previously described in a direction opposite to that in which the reflector rotates, the previously described doughnut spiral pattern will be changed to an elliptical-spiral pattern and the area scanned will be a solid ellipse when the angles formed by the axes **22**, **22'** with the axis **23** are suitably chosen. The ratio of the major axis of the ellipse to the minor axis of the ellipse is a function of the ratio of the angle between the feed axis **66** and the directive axis **22** and the angle between the directive axis **22** and the axis of rotation **23**. When these angles are equal, the ellipse will be reduced to a straight line, producing a linear scanning pattern.

When a scanner with a spiral scanning pattern is used to cover an area lying along the horizon, it is essential that the major axis of the ellipse lie along the horizon. When the scanner is mounted in a fixed position, this may be accomplished by simply changing the relative rotation angle between the moving parts. However, when the scanner is mounted in a moving vehicle, such as an airplane or a ship, the base **10** does not remain fixed relative to the horizon and some form of continuous stabilization is essential. In the embodiment of Fig. 1, means are provided for stabilizing the major axis of the elliptical-spiral scanning pattern even though the vehicle on which the base **10** is mounted is oscillating or rolling with respect to the horizon. A roll correction signal is produced by a conventional type of roll-sensing device, such as a gyroscope and servomechanism, not shown, and the correction signal is coupled to the stabilization drive motor **45**. When the major axis of the elliptical-spiral scan coincides with the horizon, that is, when the feed and the reflector have the desired rotation angle relationship, there is no output from the stabilization drive motor **45** and the cluster gear **40** remains fixed. However, when there is an error due to the rolling of the base **10** with respect to the horizon, there is an output from the stabilization drive motor **45** which rotates the cluster gear **40** to change the rotational angular relation between the feed and the reflector, thereby bringing the major axis of the elliptical-spiral pattern into alignment with the horizon as desired. This type of stabilization system is extremely simple, the only additional parts required in the scanner being the drive motor **45** and the gears **42**, **46**. This is an improvement over previous types of stabilization systems which required that the base **10** and the entire scanner be mounted on a plaform which was in turn mounted on the vehicle, the platform with the complete scanner thereon being stabilized by tilting the platform with respect to the vehicle.

In Fig. 3, another embodiment of the invention similar to that of Fig. 1 is illustrated, like parts in the two embodiments being identified by the same numerals. This embodiment differs from that of Fig. 1 in that energy is fed to the feed **62** through a different path, a different method of coupling the drive motor to the pivoting reflector is provided and means are provided for shifting the elliptical-spiral scanning pattern to a circular scanning pattern.

The waveguide **53** is coupled to a length of waveguide **70** by the rotating waveguide joint **55**, the waveguide **70** being rotatably mounted in an axial opening **71** in the frame **11**. The frame **11** is provided with an extension **72** that is rotatably mounted in the boss **44**, the cluster gear **40** rotating freely on the extension **72** and being spaced from the boss **44** and the frame **11** by washers **73**, **74**. The reflector **16** is mounted on a base plate **75**, a friction bearing **78** being mounted in the base plate **75** along the directive axis **22**. One end of the waveguide **63** is positioned within the friction bearing **78** and is coupled to the waveguide **70** by a length of flexible waveguides **76**. A flanged collar **77** is mounted on the waveguide **70** by suitable means, such as welding, and a gear **80**, corresponding to the gear **47** of Fig. 1, is retained in place on the flanged collar **77** by a bushing **81** and a set screw therein, not shown. A slip clutch comprising a coil spring **82** mounted on the flanged collar **77** and engaging a groove in the gear **80**, couples the gear **80** to the collar **77**.

The groove in the gear **80** is shaped so that when the gear is driven in one direction by the countershaft **24**, the gear will engage the end of the spring **82** and the gear **80**, the flanged collar **77** and the waveguide **70** will rotate in unison, thereby driving the feed **62** through the friction bearing **78** in a direction opposite to that in which the frame **11** is rotating. When the direction of rotation of the frame **11** and hence the countershaft **24** is reversed, the end of the spring **82** is disengaged from the groove in the gear **80** and the gear **80** turns freely on the flanged collar **77** without imparting any rotational motion to the feed. Hence, when the direction of rotation of the frame **11** is reversed, the reflector and the feed are rotated in unison by the friction bearing **78**.

The worm gear **31** is mounted on a shaft **83** which is rotatably mounted in the frame **11**. A cam **84** having cam surfaces **85**, **86** is mounted on the shaft **83** (Fig. 5), the cam surface **86** corresponding to the periphery of the shaft **83** in the embodiment of Fig. 3. The reflector **16** and the base plate **75** are mounted on a yoke **87** which is pivotally mounted on the frame **11** by the pivot pins **17**, **18**. A balance weight **90** is mounted on one arm of the

yoke 87 and the cam follower 91 is mounted on the end of the other arm of the yoke 87. A pulley 92 is mounted on the shaft 83 and a similar pulley 93 is mounted on the pivot pin 17, the pivot pin 17 being rigidly attached to the yoke 87 by a flange 94 and a rivet 95. A flexible belt 96 couples the pulleys 92, 93 together.

When the shaft 83 rotates, the belt 96 is driven by the pulley 92 and tends to rotate the pivot pin 17. This torque applied by the belt rotates the counterbalanced yoke 87 until the cam follower 91 engages one of the cam surfaces 85, 86. The rotation of the shaft 83 also rotates the cam 84, thereby causing the yoke 87 and the reflector 16 to pivot about the frame as a function of the shape of the cam surfaces on the cam 84. The gearing of the embodiment of Fig. 3 is arranged so that when the reflector is rotated in one direction along with the frame, the feed is rotated in the opposite direction by action of the slip clutch and the cam follower 91 is urged against the cam surface 85, thereby pivoting the reflector with respect to the frame and producing the desired elliptical-spiral scanning pattern. When the direction of rotation of the frame is reversed, the feed and the reflector will rotate in unison and the cam follower 91 will be urged against the cam surface 86 thereby retaining the reflector fixed with respect to the frame and producing a circular scanning pattern. It should be noted that this shift from one type of scanning pattern to another is accomplished by reversing the direction of the drive motor 14 and that it does not require any mechanical shifting of the moving components of the scanner and hence does not affect the dynamic balance of the scanner structure.

In the embodiment of Fig. 1, the crankshaft 32 and its associated components produce a sinusoidal oscillation of the reflector 16 with respect to the frame 11. The cam surface 85 of the embodiment of Fig. 3 will produce saw-tooth oscillation of the reflector with respect to the frame 11. The particular pattern of oscillation desired will depend upon the application to which the scanner is to be made; however, it is seen that any type of oscillation may be achieved by providing a suitable cam surface on the cam 84.

If the cam surface 86 was similar in shape to that of the cam surface 85, the reversing of the drive motor 14 would shift the scanning pattern from elliptical-spiral to circular-spiral. In one instance the feed and reflector would be counterrotating and the reflector would be pivoted by the cam surface 85 providing the elliptical-spiral pattern, in the second instance the feed and the reflector would be rotating in unison and the reflector would be oscillated by the cam surface 86, providing the circular-spiral pattern.

Although the above embodiments of the invention have been described in conjunction with waveguide for transmitting electromagnetic energy to the antenna 62, it is clear that other means of transmission such as coaxial conductors may be utilized and that a source or a sensing device for sound, heat, light, or other forms of radiation may be substituted for the antenna at the feed 62, thereby providing a scanner suitable for transmitting and/or receiving any type of radiation.

Although several exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions without necessarily departing from the spirit of the invention.

I claim as my invention:

1. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame, said reflector having an axis of symmetry; drive means coupled to said frame for rotating said frame and reflector; a feed having an axis of rotation parallel with said axis of symmetry, said feed being positioned in front of said reflector so as to direct radiated energy toward said reflector; and power means coupled to said feed for rotating said feed in controlled relation to said rotating frame and reflector for producing a predetermined scanning pattern.

2. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame; drive means coupled to said frame for rotating said frame and reflector; a feed positioned in front of said reflector so as to direct radiated energy toward said reflector; and means coupling said feed to said drive means for rotating said feed in synchronism with said frame and reflector for producing a predetermined scanning pattern.

3. A scanner as defined in claim 2 in which said frame and said feed rotate in opposite directions at the same angular velocity relative to said drive means.

4. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame; drive means coupled to said frame for rotating said frame and reflector; a feed positioned in front of said reflector so as to direct radiated energy toward said reflector; and power means rotating said feed in controlled relation to said frame and reflector for producing a predetermined scanning pattern.

5. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame; drive means coupled to said frame for rotating said frame and reflector; means coupling said reflector to said drive means whereby said reflector may be oscillated with respect to said frame while said frame and reflector are rotating; a feed positioned in front of said reflector so as to direct radiated energy toward said reflector; and means coupling said feed to said drive means for rotating said feed in controlled relation to said frame and reflector for producing a predetermined scanning pattern.

6. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame, said reflector having a directive axis; drive means coupled to said frame for rotating said frame and reflector; a feed rotatably and pivotally mounted on said frame, said feed having an axis of rotation coaxial with said directive axis; means coupling said reflector to said drive means whereby said reflector may be oscillated with respect to said frame while said frame and reflector are rotating; and power means for rotating and oscillating said feed in controlled relation to said frame and reflector for producing a predetermined scanning pattern.

7. In a scanner, the combination of: a base; an antenna having a reflector element and a feed element mounted for rotation relative to one another; a first drive motor mounted on said base; a differential gear unit having first, second and third couplings, the rotation of said first coupling relative to the rotation of said second coupling being a function of the rotation of said third coupling; a first power gear unit connecting said first drive motor to one of said antenna elements and to said first coupling, said first drive motor rotating said one element relative to said base; a second power gear unit connecting the other of said antenna elements to said second coupling; and a second drive motor mounted on said base and connected to said third coupling for varying the rotation of said other antenna element relative to said one antenna element.

8. A scanner as defined in claim 5, in which said means coupling said feed to said drive means includes differential means, and power means for actuating said differential means in response to an external reference signal, said differential means varying the relative rotation of said feed and said frame.

9. A scanner as defined in claim 6, in which said frame and said feed rotate in opposite directions at the same angular velocity relative to said drive means and in which said reflector and said feed oscillate in phase.

10. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame; a cam mounted on said frame and having two fixed cam surfaces; reversible drive means for rotating said cam; a cam follower coupled to said reflector and engaging said cam for os-

cillating said reflector as said cam rotates; and means driven by said drive means for urging said cam follower against one of said cam surfaces when driven in one direction and against the other of said cam surfaces when driven in the opposite direction.

11. In a scanner, the combination of: a frame; a reflector pivotally mounted on said frame; a cam mounted on said frame and having concentrically positioned cam surfaces fixed relative to each other; reversible drive means for rotating said cam; a cam follower pivotally mounted on said frame and coupled to said reflector for engaging said cam and oscillating said reflector as said cam rotates; and a slippable drive system coupling said drive means to said cam follower for urging said cam follower against one of said cam surfaces when driven in one direction and against the other of said cam surfaces when driven in the opposite direction.

12. In a roll compensated scanner, the combination of: a housing for mounting on a vehicle which may be rolling; a reflector; first drive means mounted on said housing and coupled to said reflector for continuously rotating said reflector at a predetermined speed; a feed positioned in front of said reflector so as to direct radiated energy toward said reflector; coupling means connecting said feed to said first drive means for continuously rotating said feed relative to said reflector at a predetermined speed, said coupling means including a connection to a normally fixed reference carried on said housing; and second drive means for varying said reference in response to the rolling of the vehicle for changing the angular relation between said feed and reflector without changing said predetermined speeds.

13. In a roll compensated scanner, the combination of: a housing for mounting on a vehicle which may be rolling; a reflector; first drive means mounted on said housing and coupled to said reflector for continuously rotating said reflector at a predetermined speed about an axis; a feed positioned in front of said reflector so as to direct radiated energy toward said reflector; a countershaft carried on said reflector for rotation about said axis with said reflector, said countershaft being rotatably mounted for rotation relative to said reflector also; a roll reference gear carried on said housing, with said countershaft coupling said free to said reference gear for continuously rotating said feed relative to said reflector at a predetermined speed; and second drive means mounted on said housing for varying the angular position of said reference gear in response to the rolling of the vehicle for changing the angular relation between said feed and reflector without changing said predetermined speeds.

References Cited in the file of this patent

UNITED STATES PATENTS

2,437,275	Skene et al.	Mar. 9, 1948
2,512,139	Cady	June 20, 1950
2,526,314	Alexanderson et al.	Oct. 17, 1950
2,537,822	Fritts	Jan. 9, 1951
2,543,188	Moseley	Feb. 27, 1951
2,678,394	Curtis	May 11, 1954

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,916,739 December 8, 1959

William Falstrom

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 14, for "free" read -- feed --.

Signed and sealed this 17th day of May 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents