July 11, 1950 W. J. ALBERSHEIM 2,514,617

DIRECTIVE SCANNING ANTENNA SYSTEM

Filed April 13, 1946 2 Sheets-Sheet 1

FIG. 1

FIG. 2

FIG. 3

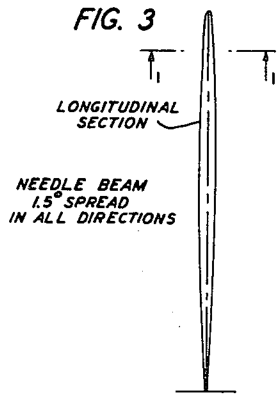


FIG. 4

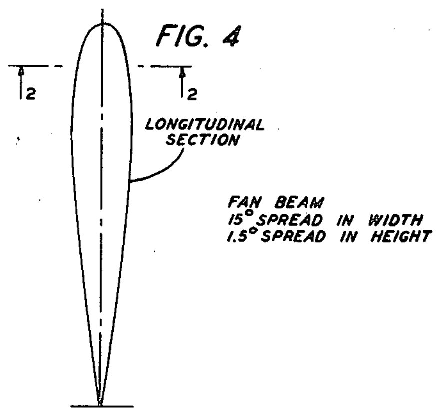


FIG. 5

C. R. SCREEN #1

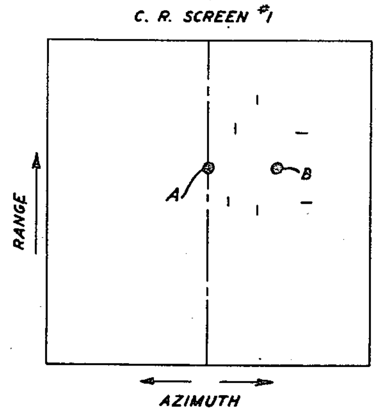
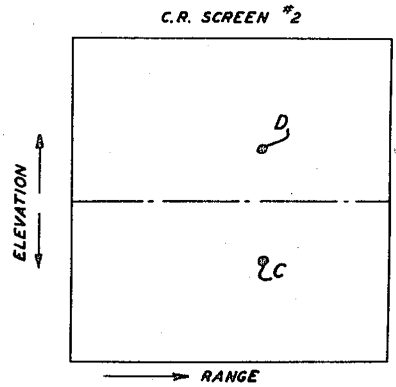


FIG. 6

C.R. SCREEN #2



INVENTOR
W. J. ALBERSHEIM
BY
N. D. Ewing
ATTORNEY

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FIG. 8

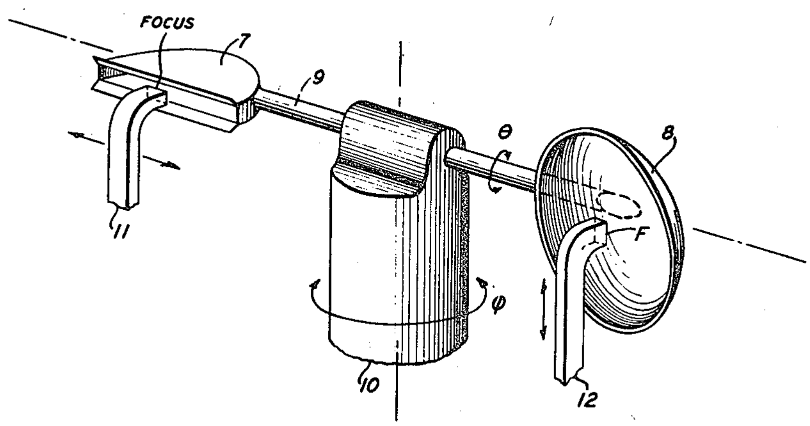
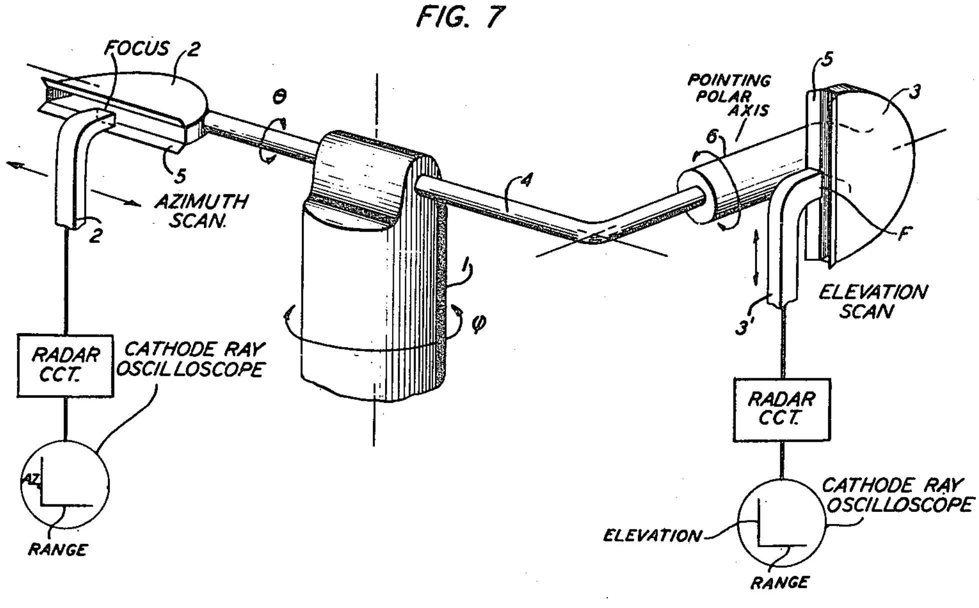


FIG. 7



INVENTOR
W. J. ALBERSHEIM
BY
N. D. Ewing
ATTORNEY

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UNITED STATES PATENT OFFICE

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DIRECTIVE SCANNING ANTENNA SYSTEM

Walter J. Albersheim, Interlaken, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 13, 1946, Serial No. 662,035

3 Claims. (Cl. 343—10)

This invention relates to radio object location and detection, and more particularly to rapid and precise scanning by means of radio beams.

A principal object of the invention is to rapidly cross-scan an extended solid angle with perpendicular fan beams and to resolve without ambiguity multiple targets located at equal ranges.

Another object of the invention is to rapidly and precisely determine the location of targets by coupling together a rapid fan beam scanner with a precise needle beam scanner.

Referring to the figures of the drawing:

Figs. 1 and 2 represent cross-sections of the beams shown in Figs. 3 and 4 respectively;

Fig. 3 illustrates a needle beam;

Fig. 4 illustrates a fan beam;

Fig. 5 shows a cathode-ray screen for depicting range vs. azimuth coordinates of targets derived by a radar;

Fig. 6 shows a similar cathode-ray screen depicting elevation vs. range of the said targets;

Fig. 7 shows a double fan beam antenna system; and

Fig. 8 shows a combined fan beam and needle beam antenna system.

A needle beam may be defined ideally as a beam confined to a straight line. In practice however, a certain spread laterally is experienced, which may be of the order of 1.5 degrees or thereabouts, as illustrated in Figs. 1 and 3.

A fan beam may be defined as being sharp in one plane and broad in the other, and having in general the configuration of a fan i. e., a lateral spread of 15 degrees or more in one direction and 1.5 degrees in the other, as illustrated in Figs. 2 and 4.

In certain radar systems, such as ground operated anti-aircraft fire control, a rapid and precise scan of an extended solid angle is required to search for and follow rapidly moving targets.

Since point-by-point scanning by means of a needle beam as in television would be too slow, it has been suggested that radio fan beams be used for scanning the search area by single sweeps. To effectively determine the location of a target, two crossed fan beams mutually perpendicular to each other are utilized. The sweep of one fan beam determines the azimuth of the target, while the sweep of the perpendicular fan beam determines its elevation. Since the distance or range of the target is determined by the return radio echo delay time, the location of a single target in space is completely and uniquely determined. For example, the presence of a single, lone target within the field of view is completely and unambiguously determined by two correlated echo images, for example, spots A and D on two separate cathode-ray tubes (Figs. 5 and 6), one representing range vs. azimuth, the other representing elevation vs. range.

However, when a flight of multiple airplanes appears in view, specific target identification becomes difficult and ambiguous. The cathode-ray screens are then flooded with so many target presentations that correlation between individual azimuths and corresponding elevations is rendered practically impossible.

The resulting uncertainty in identification can be greatly reduced by selecting one of the possible targets on one of the screens showing range and "gating the range." By "gating" is meant the biasing of the receiving amplifiers to extinction at all times, in a known manner, except for a short time interval corresponding to the two-way travel time of an electromagnetic wave to and from a target within the chosen range.

Referring to Figs. 5 and 6, representing the coordinates appearing on the separate cathode-ray screens namely, azimuth vs. range, and range vs. elevation respectively, the faint dots shown therein represent the multiple targets whose appearance on the screens is suppressed by the aforementioned range "gating." The two heavy dots shown on each screen, namely (A, B) and (C, D) represent two targets located at equal ranges from the radar equipment. It is obvious that a true correlation between azimuth and elevation for these two target echoes is indeterminate—four combinations AC, AD, BC, BD being possible—two representing the true target coordinates and the other two representing false or pseudo targets. Should the gunner select echo image A in Fig. 5 as a target, he would be at a loss to determine whether to point his sights toward C or D on the elevation scale (Fig. 6).

With n targets at equal range, the ambiguity increases as n^2 and the probability of scoring a hit is reduced by a factor n.

In accordance with one embodiment of the invention, the ambiguity which arises with respect to multiple targets located at equal ranges, may be fully resolved by slowly rotating one or both of the fan beam antennas around an axis directed at a target. The true target may be distinguished by the invariance of its position on the cathode-ray screens with respect to the rotation, whilst the positions of the pseudo targets move or are displaced in accordance with the rotation.

Another embodiment of the invention contemplates determinate and rapid scanning, by combining the characteristics of fan beam scanning with needle beam scanning, through a linking or coupling together of the corresponding antennas.

Referring to Fig. 7, a pair of perpendicular fan beam antennas 2, 3 are shown, each comprising a rectangular wave guide feed horn and a pill-box shaped reflector with divergent flares 5 at the mouth thereof for matching the pill-box antenna to free space. The rectangular feed may be a bent pipe with a flared mouth (not shown) located at the focus of the paraboloidal-shaped pill-box, whereby a fan-shaped beam may be radiated into space. The pill-box reflector has the shape of a D, and its details are more fully disclosed in the copending application of W. D. Lewis, Serial No. 574,334, filed January 24, 1945, which corresponds to the British Patent 606,927 accepted August 23, 1948, or in an article entitled "Microwave Radar Antennas" by E. M. Purcell published in Radio-Electric Engineering, vol. 6—7, May 1946, pages 3–6.

The antennae 2, 3 shown in Fig. 7 are respectively connected to conventional transceiver equipment well known to the radar art and represented in said figure schematically by the rectangular block designated Radar Circuit. This equipment may take various forms as exemplified for instance by U. S. Patent 2,475,707 issued July 12, 1949 to P. A. Jeanne, by U. S. Patent 2,422,697 issued June 24, 1947 to L. A. Meacham, by U. S. Patent 2,419,205 issued April 22, 1947 to C. B. H. Feldman, and by U. S. Patent 2,426,182 issued August 26, 1947 to O. E. De Lange.

These patents illustrate and describe the association and operation of the various essential components of a radar circuit, such as, the magnetron, the pulser, the wave guide "plumbing," the TR box, the ranging circuit, the radio receivers and the cathode ray oscilloscopes.

The two radars may operate on the same frequency or on different frequencies, or if desired, one may employ a common transmitter with the antennae 2, 3 sharing its output on a time division or energy division basis.

The azimuth versus range indications are displayed on a cathode ray oscilloscope connected to antenna 2, while the elevation versus range indications are correspondingly displayed on the cathode ray oscilloscope connected to antenna 3 as shown in Fig. 7.

The pill-box antennas are rigidly connected by a rod 4, bent and disposed so that the planar portions of said pill-boxes are mutually perpendicular. By means of this arrangement, a pair of crossed perpendicular fan beams are thereby radiated from the open mouths of the pill-boxes.

A solid angle in space, for example, at least 15 degrees square, may be scanned by the crossed fan beams, by rocking or oscillating the feed horn 2′ horizontally and feed horn 3′ vertically along a straight line. When each of these scanning fan beams strikes a target, an echo is reflected therefrom which produces a visible signal on a cathode-ray oscilloscope screen, as illustrated in Figs. 5 and 6.

The pair of antennas 2, 3 as a unit may be rotated or swung around through an azimuthal angle φ, by rotating pedestal support 1. When the azimuth of a target is found, it may be locked in by an automatic follower (not shown). The elevation angle θ is adjusted by rotating rod 4 in its bearing at the top of the pedestal.

When multiple targets at equal range appear on the screen as illustrated in Figs. 5 and 6, an ambiguity in correlating their true elevations and azimuths arise. To resolve this ambiguity, the operator performs the final step of rotating the polar axis 6. If both antennas are centered on the same target, the polar axis will be pointing directly at this target, and will continue to do so regardless of polar rotation. In this case, one of the points C, D remains stationary during the rotation of the polar axis, whereupon the polar rotation is stopped, the elevation of the antenna is locked in by an automatic follower (not shown) and the gun is in proper firing position.

If, on the other hand, the antennas point at pseudo or false targets, rotation of the polar axis 6 has the effect of causing the images C, D to be displaced along a circular arc. This displacement apprises the operator of a false target correlation between an azimuth and elevation image, whereupon he will readjust his elevation until a target image remains steadily centered and unaffected by polar rotation, indicating correct coordinate association. Thereupon, he will lock in the automatic elevation follower.

In accordance with another embodiment of the invention, it has been determined that rapid, precise and unambiguous coordinate determination in object location with radio beams may be obtained by rigidly coupling together a fan beam scanner and a needle beam scanner. Thus, in the embodiment illustrated in Fig. 8, the centering of the fan beam on the target for determination of one coordinate (azimuth) concomitantly swings the rigidly coupled needle beam to the proper azimuth. The needle beam is then swept vertically to determine the other coordinate, i. e., the elevation.

Referring to Fig. 8, two antennas 7 and 8 are shown, namely, a fan beam radiator 7 of the "pill-box" type aforementioned, and a needle beam radiator 8 of the paraboloidal type such as is disclosed in the United States Patent of A. C. Beck, No. 2,409,183 issued October 15, 1946. The two antennas are rigidly coupled together by a rod 9, which constitutes an axis for the elevational adjustment of the antennas 7, 8. The pair of antennas may be rotated as a unit about the azimuthal pedestal axis 10. The feeds 11, 12 for the antennas comprise rectangular pipes or horns.

The system shown in Fig. 8 operates in the following manner:

The rotational axes 9, 10 are set in the approximate direction of the target.

Feed horn 11 is rapidly oscillated sideways to produce a lateral sweep of the vertical fan beam radiated from the pill-box antenna 7. When this beam strikes a target, it is centered and locked-in by an automatic follower (not shown). The azimuth position of the antenna assembly and gun are thereby fixed.

Then, feed horn 12 is rapidly rocked or oscillated up and down to produce a vertical sweep of the needle beam radiated by antenna 12, for determining the elevational coordinate of the target. Since the azimuth of the needle beam is already fixed on the target due to its rigid coupling relation to the fan beam, it is bound to strike the same target somewhere in its vertical swing to produce the revealing echo.

By means of a second automatic follower circuit, the elevational position of the antenna assembly and of the gun are centered and locked-in. The gun is now ready to fire.

Various forms of fan beam radiators may be utilized, such as elongated cylindrical paraboloids, cylindrical lenses or elongated sections of paraboloids of revolution.

Various other forms of needle beam radiators may be used, such as paraboloids of revolution, circular lenses or any crossed combinations of the radiator systems which singly produce fan beams.

What is claimed is:

1. In a radar system, a pair of scanning, radio antennas providing crossed fan beams for target interception by received echoes from the target, a rigid connecting member having two sections at right angles to each other, one section being connected to one antenna as a polar pointing axis therefor, means for supporting and rotating said member and antennas in an azimuthal plane, means for rotating both antennas in an elevational plane, and means for independently rotating one of said antennas about said polar axis whereby unambiguous resolution of multiple targets at equal ranges may be provided.

2. In a radar system, a pair of directive radio antennas each having a plane of principal action, scanning means to sweep the plane of action of each of said antennas about a respective scanning axis, support means for said pair of antennas adapted for rotation of said pair jointly about a first rotational axis and independent rotation of said pair jointly about a second rotational axis perpendicular to the first, further support means for one of said antennas adapted for independent rotational adjustment of said one antenna about a third rotational axis perpendicular to the second, said one antenna being supported with its scanning axis perpendicular to said third rotational axis, and the other of said antennas being supported with its scanning axis perpendicular to said second rotational axis.

3. In a radar system, a pair of directive radio antennas each having a plane of principal action, scanning means to sweep the plane of action of each of said antennas about a respective scanning axis, support means for said pair of antennas adapted for rotation of said pair jointly about a first rotational axis and independent rotation of said pair jointly about a second rotational axis perpendicular to the first, further support means for one of said antennas adapted for independent rotational adjustment of said one antenna about a third rotational axis perpendicular to the second, said one antenna being supported with its scanning axis perpendicular to said third rotational axis, and the other of said antennas being supported with its scanning axis perpendicular to said second rotational axis, transceiver means coupled to both of said antennas for supplying radio frequency waves thereto and receiving therefrom echoes returned by distant reflecting objects, individual oscilloscopes for said antennas, circuit means responsive to the echoes received from one of said antennas for indicating on one of said oscilloscopes the range and relative azimuth of the objects from which said last-mentioned echoes are received, and circuit means responsive to the echoes received from the other of said antennas for indicating on the other of said oscilloscopes the range and elevation of the objects from which said last-mentioned echoes are received, whereby with said third rotational axis aligned with one of said objects the ambiguity of the indications in the presence of another object at the same range can be resolved by observing the effect of said rotational adjustment on the said indications.

WALTER J. ALBERSHEIM.

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