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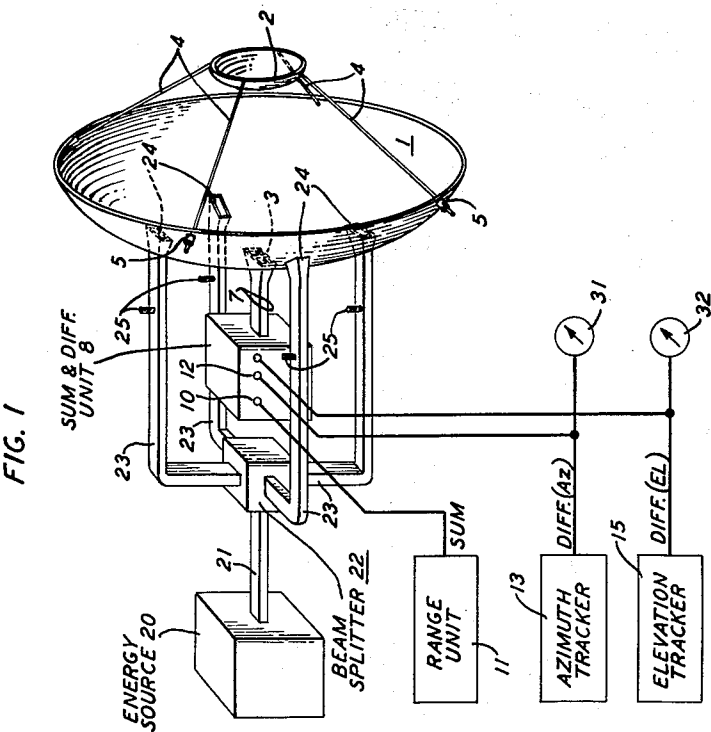
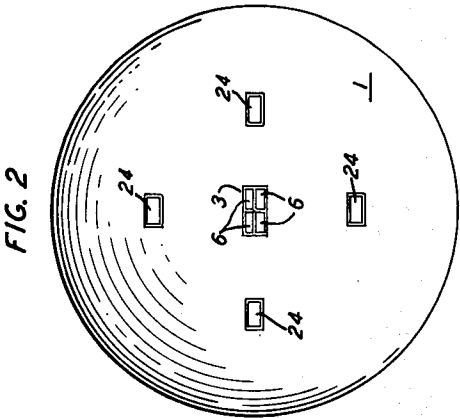
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3,164,835

ALIGNMENT OF MICROWAVE ANTENNA

Filed June 7, 1962

2 Sheets-Sheet 1



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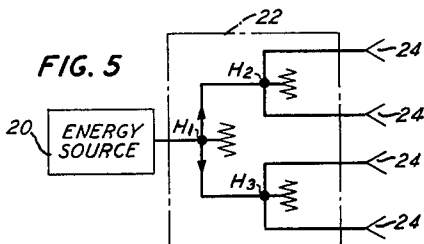
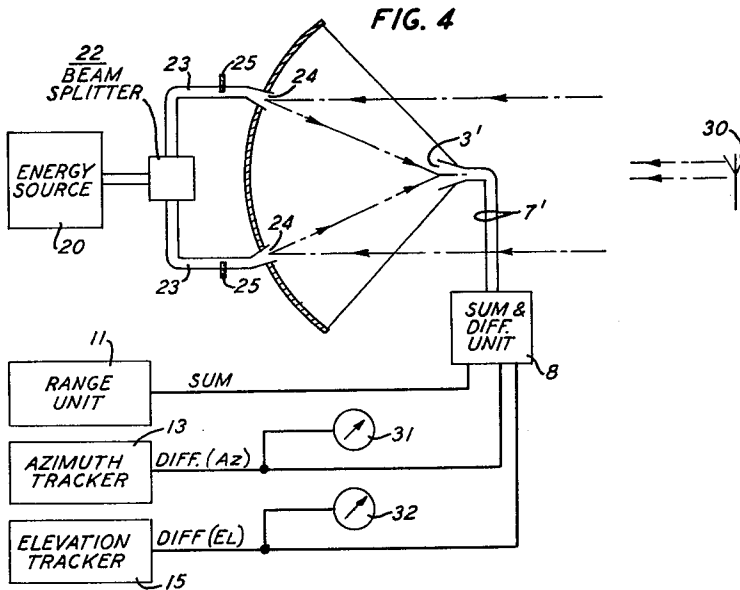
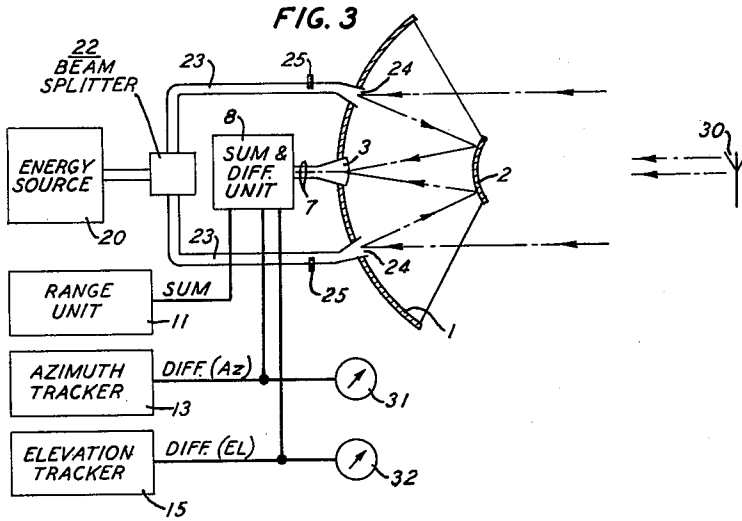
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ALIGNMENT OF MICROWAVE ANTENNA

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2 Sheets-Sheet 2



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3,164,835

ALIGNMENT OF MICROWAVE ANTENNA

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This invention deals with microwave antennas and has for its object to simplify and expedite procedures for maintaining and insuring correct alignment between the component parts of such antennas and for detecting and evaluating any misalignment that may exist.

An important class of microwave antenna structures comprises those of which the radiation-gathering element is a reflector. Any such antenna bears a close resemblance to a reflecting telescope of which the principal light-gathering element is a concave mirror and in which the eye-piece is disposed close to the focal point of the mirror. In microwave antennas of this class the radiation-gathering element is a concave reflector or "dish." In the simplest form the energy-receiving apparatus, e.g., a microwave horn, is located on the geometrical axis of the dish and at or close to its focal point toward which the reflected radiation converges. In a modified form termed, by analogy with the telescope art, the "Cassegrainian" form, an auxiliary mirror is disposed on the axis of the dish and reflects the converging radiation back to the apex of the dish where the energy-receiving horn is located. At the cost of slightly greater complexity, the Cassegrainian design makes for substantially greater compactness.

A feature that is common to both forms is that the component which receives the converging beam from the dish reflector is mounted in front of the dish and hence in the path of the incident radiation. This component, and the supporting elements which hold it in place, inevitably cast shadows on the reflecting dish. To minimize such shadows these elements are usually of small dimensions and of light construction, and therefore susceptible to damage and subject to temperature changes. Hence the component which they support is liable to misalignment.

For optimum performance of a microwave antenna, it is imperative that the electrical axis coincide with the geometrical axis and this means that the axis of the front-mounted component, whether it be an energy-receiving horn or an intermediate reflector, must be accurately collinear with the axis of the reflector dish. To insure that the component parts are thus aligned it is customary, before putting the antenna to actual use, to carry out a "boresighting" operation in which, with the aid of a telescope, previously aligned with the geometric axis of the dish, the latter is pointed directly at a distant radiator while the front-mounted antenna component is manually adjusted, both angularly and in its position, the received energy being meantime monitored, until the optic or radiation axis coincides exactly with the geometric axis.

For some purposes, what is required of the radar apparatus is that, for any specified target, it shall deliver a strong signal when the target is on the optic axis and a signal of reduced strength when the target is off the axis; i.e., the "on target" signal is a maximum. But any such maximum is somewhat insensitive to angular departures. For precision control of tracking, therefore, it is preferable to develop an auxiliary "error" signal that is of zero magnitude for a target on the axis, of positive polarity when the target is off the axis in one direction and of negative polarity when it is off the axis in the opposite direction. Apparatus by which this auxiliary signal is developed can take a variety of forms, some of which are described in "Amplitude and Phase-Sensing Monopulse System Param-

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eters" by William Cohen and C. Martin Steinmetz, published in The Microwave Journal for October 1959, vol. 2, No. 10, page 27. The improvement of the angular deviation sensitivity that results from these refinements offers the same advantage in boresighting as it does in tracking. Accordingly, in boresighting, correctness of the location and disposition of the antenna components is recognized as a null magnitude of the auxiliary signal.

If, while the antenna is in use, a misalignment should take place or if the operator should suspect that one may have taken place, the only way in which the true facts and the magnitude of the misalignment, if any, may be determined, is to repeat the boresighting operation. This procedure is, at best, time-consuming and inconvenient. Under some circumstances it is impossible.

The invention provides auxiliary apparatus by which such boresighting operations are simulated. To this end the principal reflector is provided with an array of radiators symmetrically disposed about its geometric axis, and these are supplied with auxiliary, phase-coherent radiation from an auxiliary source located behind the reflector. Because the auxiliary apparatus is behind, rather than in front of the reflector, it casts no shadow on the reflector. Hence it may be constructed of heavy, rigid material with a view to ruggedness alone. Advantageously, it comprises a network of waveguides including beam splitters or hybrid junctions and supplied with energy from a common auxiliary source. The individual waveguides that supply the individual radiators may be provided with phase-adjusting trimmer screws, after adjustment of which the individual auxiliary waves that are launched from the common auxiliary source and from the individual radiators are in phase coincidence with all necessary precision.

With this apparatus the alignment checking procedure is much simplified and facilitated. At the time of the initial boresighting operation, when it is known that the alignment of the various components of the antenna is substantially perfect, the character of the received signal having been noted, the distant radiator employed for boresighting is switched off and the auxiliary source is switched on. The trimmer screws in the auxiliary waveguides are now adjusted until the signal received from the auxiliary radiators is of the same character as that received from the distant radiator in the course of the boresighting operation: a maximum magnitude of the total signal or a null magnitude of the angle-error signal. It is then known that the individual rays from the several auxiliary radiators, all in phase coincidence in the plane of the dish reflector, are likewise in phase coincidence at the energy-receiving apparatus; that is to say, that the antenna components are in perfect alignment.

Thereafter, whenever it may be suspected that a misalignment has occurred or indeed, in the course of a routine maintenance check, it is only necessary to switch the auxiliary source into action and to observe, as on a meter, the magnitude and character of the received signal and to compare it with the magnitude and character of the auxiliary signal earlier observed. If there is any noticeable alteration, it can only have been due to a misalignment. Such misalignment may now be corrected manually, as by readjusting the members by which the front-mounted component is supported until the received signal is again of the required character.

Evidently this procedure can be carried out at the convenience of operating personnel and in complete disregard of the availability of a boresighting radiator. The invention therefore greatly expedites and facilitates determination of misalignment and correction of any misalignment that may be discovered.

The invention will be fully apprehended from the following detailed description of an illustrative embodiment

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thereof taken in connection with the appended drawings in which:

FIG. 1 is a schematic diagram showing a radar antenna embodying the invention;

FIG. 2, is a front view of the reflector dish of FIG. 1;

FIG. 3 is a cross-sectional view of a radar antenna of FIG. 1;

FIG. 4 is a cross-sectional view of a radar antenna of alternative configuration; and

FIG. 5 is a schematic circuit diagram showing a four-way phase splitter for use in the apparatus of FIGS. 1, 3 and 4.

Referring now to the drawings, FIG. 1 shows a radar antenna of the Cassegrainian configuration. It comprises a principal concave reflector or dish 1 for gathering incoming radiation and for directing it onto an auxiliary convex reflector 2 by which, in turn, it is reflected toward a receptor 3 which may be mounted at the apex of the dish 1. The auxiliary reflector 2 is supported by rigid rods 4 fixed to the rim of the dish 1. To allow of adjustments of the disposition of the auxiliary reflector 2, the supporting rods 4 are provided with adjusting screws 5. Because the supporting rods 4 cast shadows on the dish 1, they are normally of small diameters, and consequently of limited rigidity.

The receptor 3 of the illustration is a group of four electrically separate horns 6 arranged in a close-packed group, as shown in FIG. 2. Each is coupled to its own waveguide and the four waveguides extend in a bundle 7 to a sum-and-difference unit 8 located behind the dish 1. This unit comprises a combination of waveguide hybrid junctions that are intercoupled in such a way as to deliver, at one output point 10 a signal that is proportional to the sum of the energies picked up by the four component horns for delivery to a range unit 11, at a second output point 12 an azimuth difference signal to an azimuth tracking unit 13 and, at a third output point 14, an elevation difference signal for delivery to an elevation tracking unit 15. To insure that these units shall indicate deviations of direction, they may also be supplied, in conventional fashion by connections not shown, with a phase-coherent signal, e.g., the sum signal at an appropriate amplitude level. The system is thus of the so-called "monopulse" variety as described, for example, by Cohen and Steinmetz in the article referred to above. The sum-and-difference unit 8 is likewise of well-known construction. The individual hybrid junctions of which it is composed may be interconnected to deliver the sum signal and the two difference signals in various ways, for example, as shown by R. M. Page in his Patent 2,929,056. It is now well established that the monopulse principle embodied in the apparatus makes for a high degree of angular sensitivity, both in azimuth and in elevation, in that a small angle of deviation between the geometrical axis of the antenna and the line of sight to a distant source of radiation or of echoes is manifested as an azimuth difference signal or an elevation difference signal, as the case may be.

In accordance with the invention an auxiliary energy source 20 is provided which supplies its energy by way of a waveguide 21 to a four-way beam splitter 22 having four symmetrically disposed output ports to which branch waveguides 23 are severally coupled; and these four auxiliary waveguides 23 extend through the wall of the reflector dish 1 to terminate in four apertures 24 that are symmetrically disposed on a circle concentric with the dish and displaced from each other around the circle by equal angles. Each of these apertures 24 thus constitutes an auxiliary radiator for the purposes of the invention. In principle, any number of auxiliaries greater than two, e.g., three, six, etc., would serve as well as four. The number four is selected for illustration as a convenience in the fabrication of the beam splitter 22, in the disposition of the auxiliary radiators in the reflecting surface of the dish 1, and to conform with the four individual component

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horns 6 of which the energy receptor 3 is constituted. The four waveguides 23 are fabricated with care to be of like dimensions, thus to deliver the energy of the auxiliary source 20 to all four apertures 24 in equal shares and in phase coincidence. Spurious departures from phase coincidence which may result from imperfections of manufacture may be corrected in well-known fashion by adjustment of trimmer screws 25.

Whatever the number of auxiliary radiators 24, they are preferably disposed in the surface of the dish 1 with their polarization axes parallel—for example, as shown in FIG. 2, their horizontal dimensions may be about twice their vertical dimensions, thus to deliver vertically polarized auxiliary radiation. In addition, and for best operation, the outer boundaries of these apertures lie in planes of which the normals are slightly tipped inward with respect to the normals of the inner reflecting surface of the dish 1, thus to direct their auxiliary radiation toward the auxiliary reflector 2.

Referring to FIG. 3 which shows a cross-sectional view of the antenna of FIG. 1, radiation originating at a distant source 30 reaches the reflector dish 1 as a collimated beam, is reflected by the concave dish 1 toward the convex auxiliary reflector 2 which again reflects it into a receptor 3, e.g., the quadruple horn of FIG. 1. Final adjustments of the component parts of an antenna such as that of FIG. 1 are normally made by "boresighting" on the distant radiator 30, thus bringing the geometric axis and the electrical axis of the antenna as a whole into optimum alignment. To this end meters 31, 32 are provided by which the azimuth difference signal and the elevation difference signal may be individually monitored. Like the tracking units 13 and 15, the meters 31, 32 should be so energized as to indicate errors of direction. Given that the geometric axis of the principal reflector dish 1 is precisely collinear with the line of sight from the receptor 3 at its apex to the distant radiator 30, final alignment is normally achieved by manual adjustment of the adjusting screws 5 until the auxiliary reflector 2 is so oriented that the radiation from the distant source 30 reaches the receptor 3 in a fashion such that the sum signal output of the sum-and-difference unit 8 is a maximum while the azimuth difference signal and the elevation difference signal are each of zero magnitude, as indicated by the readings of the meters 31, 32.

In accordance with the invention, once the boresighting operation has been completed and the alignment among the component parts of the antenna has been perfected, the radiation from the distant source 30 is switched off, or if preferred, the antenna is aimed toward a part of the open sky in which it is known that no radiators and no echo reflectors are to be found. The auxiliary energy source 20 is then turned on and the four auxiliary radiators 24 project their beams, alike in intensity and in phase, toward the auxiliary reflector 2 which reflects them into the receptor 3; i.e., into the horns 6. Equality of energy and coherence of phase among the four auxiliary beams is indicated by null readings on both meters 31, 32.

The apparatus may now be placed in operation in the field with confidence that, if for any reason the auxiliary reflector 2 shall have become misaligned, the misalignment can readily be determined and corrected without resorting to a new boresighting operation. For, when any such misalignment is suspected, the auxiliary source 20 may be turned on and the difference signal meters 31, 32 monitored. If their readings are zero there is no misalignment. If their readings are other than zero, some misalignment has occurred and, because of the rugged construction of the auxiliary apparatus 20-23, this misalignment is presumptively due to a shift in the position of the auxiliary reflector 2. Operators may now readjust the adjusting screws 5 while monitoring the difference meters 31, 32 until the meters again read zero, in which event they may have confidence that the misalignment has been cured.

FIG. 4 shows a Newtonian alternative to the Cassegrainian construction of FIG. 1. Here, the incoming radiation is reflected by the principal reflector dish 1 directly into the horn receptor 3' without the interposition of an auxiliary convex mirror. The four component waveguides extend in a bundle 7' from the receptor 3' to a sum-and-difference unit 8 like that of FIG. 1 which, however, is located in a position such as not to cast a shadow on the principal dish 1.

The beam splitter unit 22 of each of the figures may conveniently be a combination of three waveguide hybrid junctions intercoupled as shown in FIG. 5. Thus, energy from the auxiliary source 20 is divided by the first hybrid junction H_1 into two equal parts and delivered to the second hybrid junction H_2 and to the third hybrid junction H_3 . Each of these, in turn, divides the energy it receives into two equal parts so that, as a result, the energy of the source 20 has been divided into four equal parts for delivery to the four auxiliary radiators 24. As is well known, each such hybrid junction has four ports. For operation in this fashion the first port serves as an input port, the second and third as output ports, while the fourth is terminated, as symbolically indicated by the resistors in FIG. 5, for no reflection.

The individual waveguide hybrid junctions of which the beam splitter 22 and the sum-and-difference unit 8 are constituted may be of the so-called "Magic Tee" variety, as described by W. A. Tyrrell in an article entitled "Hybrid Circuits for Microwaves" published in the Proceedings of the Institute of Radio Engineers for November 1947, Vol. 35, page 1294. Various alternative constructions, equally suitable for the purposes of the invention, are available in the prior art.

The advantage, for the purpose of the invention, of radar circuits of the monopulse variety is identical with the advantage they offer for tracking purposes generally: sensitivity to angular misalignment. Whatever the type of receptor and associated deviation-indicating circuits employed, the invention provides for discovering and correcting misalignments with whatever precision the system may provide for the tracking of targets.

What is claimed is:

1. In combination with a microwave antenna comprising

a first member for gathering incoming radiation and a second member onto which gathered radiation is directed,

a plurality of sources of auxiliary radiation fixedly attached to said first member and disposed to direct their auxiliary beams toward said second member and means for deriving electrical signals indicative of the interaction between said auxiliary beams and said second member.

2. In combination with a microwave antenna comprising

a first member for gathering incoming radiation and a second member onto which gathered radiation is directed,

a symmetrical array of like sources of phase-coherent auxiliary radiation fixedly attached to said first member and disposed to direct their auxiliary beams toward said second member

and means for deriving electrical signals indicative of the phase relationships between said auxiliary beams at said second member.

3. In combination with a microwave antenna comprising

a first member for gathering incoming radiation and a second member onto which gathered radiation is directed,

said second member being attached to said first member by supports of limited rigidity, and being hence subject to misalignment,

means for testing the alignment of said second member which comprises

a symmetrical array of like sources of phase-coherent auxiliary radiation fixedly attached to said first member and disposed to direct their auxiliary beams toward said second member,

means for recovering the radiation of said auxiliary beams incident on said second member,

means for deriving electrical signals indicative of the interaction between said auxiliary beams and said second member,

and means for monitoring said electrical signals.

4. In combination with a microwave antenna comprising a first member for gathering incoming radiation and a second member onto which gathered radiation is directed,

said second member being attached to said first member by supports of limited rigidity, and being hence subject to misalignment,

means for testing the alignment of said second member which comprises

a symmetrical array of auxiliary radiators fixedly attached to said first member, the radiation axes of said radiators being directed toward said second member, a source of auxiliary radiation,

coupling means extending from said source to said radiators and proportioned to supply said radiators with phase-coherent energy in essentially equal quantities,

means for recovering the radiation launched by said auxiliary radiators and incident as auxiliary beams on said second member,

means for deriving electrical signals indicative of the interaction between said auxiliary beams and said second member,

and means for monitoring said electrical signals.

5. In combination with a microwave antenna comprising a concave reflector for gathering radiation incoming from a distant point and for directing it as a convergent beam upon energy-receiving apparatus, said concave reflector having a geometrical axis,

at least one component of said apparatus being supported in front of said reflector and being subject to shift in position with respect to said axis,

an array of like auxiliary sources of coherent radiation symmetrically disposed in the reflecting surface of said reflector, said sources having the property of directing said coherent radiation to simulate radiation incoming from a distant point in a direction parallel to said axis,

whereby said auxiliary energy recovered by said receiving apparatus is sensitive to said shift in position of said front-supported component.

6. In combination with a microwave antenna comprising a reflector for gathering radiation incoming from a distant point and for directing it as a beam upon energy-receiving apparatus,

at least one component of said apparatus being supported in front of said reflector and being subject to misalignment,

an array of like apertures symmetrically disposed in the surface of said reflector with their axes directed toward said front-supported component,

and auxiliary means supported behind said reflector for supplying said apertures with phase-coherent microwave energy in like quantities,

whereby energy originating in said auxiliary means is launched through said apertures toward said receiving apparatus and auxiliary energy recovered by said receiving apparatus is sensitive to misalignment of said front-supported component.

7. In combination with a microwave antenna comprising a reflector for gathering radiation incoming from a distant point and for directing it as a beam upon energy-receiving apparatus,

at least one component of said apparatus being sup-

ported in front of said reflector and being subject to misalignment,
 an array of like apertures symmetrically disposed in the surface of said reflector with their axes directed toward said front-supported component,
 and auxiliary means supported behind said reflector for supplying said apertures with phase-coherent microwave energy in like quantities,
 whereby energy originating in said auxiliary means is launched through said apertures toward said receiving apparatus and auxiliary energy is recovered by said receiving apparatus,
 means for testing the alignment of said front-supported component which comprises
 means for recovering the radiation of said auxiliary beams incident on said front-supported component,
 means for deriving electrical signals indicative of the interaction between said auxiliary beams and said front-supported component,
 and means for monitoring said electrical signals.

8. In the operation of radar apparatus having a first member for gathering incoming radiation and a second member onto which gathered radiation is directed, said second member being attached to said first member by supports of limited rigidity and being hence subject to misalignment, said apparatus having means for recovering radiation incoming from a distant source, means for deriving electrical signals which, when said members are

correctly aligned, is indicative of the angular deviation between the geometrical axis of said first member and the direction of said distant source, and means for monitoring said electrical signals, said first member being further provided with a symmetrical array of like sources of phase-coherent auxiliary radiation fixedly attached to said first member and disposed to direct their auxiliary beams toward said second member,
 the method of insuring and restoring correctness of alignment among the component parts of said antenna which comprises the following steps:
 (a) aiming said antenna toward a region devoid of radiation sources and radiation reflectors,
 (b) energizing said auxiliary radiators, thereby to direct their auxiliary beams onto said second member,
 (c) monitoring the electrical signals derived from said auxiliary beams, and
 (d) orienting said second member until the magnitudes of said auxiliary signals are indicative of true alignment between said first and said second members.

References Cited in the file of this patent

UNITED STATES PATENTS

2,653,238	Bainbridge	Sept. 22, 1953
2,897,493	Thomas	July 28, 1959