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Rosa et al.

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[45] **Jan. 29, 1974**

[54] **METHOD AND APPARATUS FOR CONTROLLING BEAM SKEW**

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[52] **U.S. Cl.** .... **343/100 PE**, 343/16 M

[51] **Int. Cl.** **G01s 7/36**

[58] **Field of Search** .... 343/16 M, 100 PE

[56] **References Cited**

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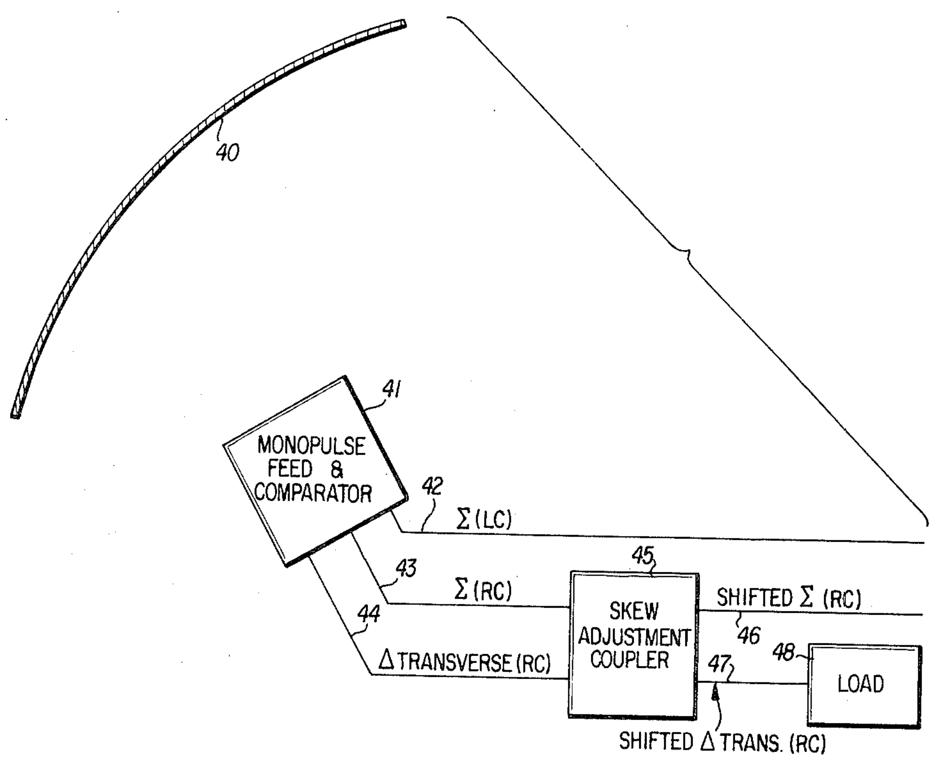
Assistant Examiner—Denis H. McCabe

[57] **ABSTRACT**

A method and apparatus for correcting radiated beam skew in a circularly polarized offset fed parabolic reflector antenna by the introduction of a difference pattern of one direction of circular polarization in the transverse plane, and adding it to the sum pattern of a corresponding direction of circular polarization to move the sum pattern to the position of the skewed sum pattern of the other direction of circular polarization. Mechanical means are used to boresight the two superimposed patterns.

10 Claims, 8 Drawing Figures



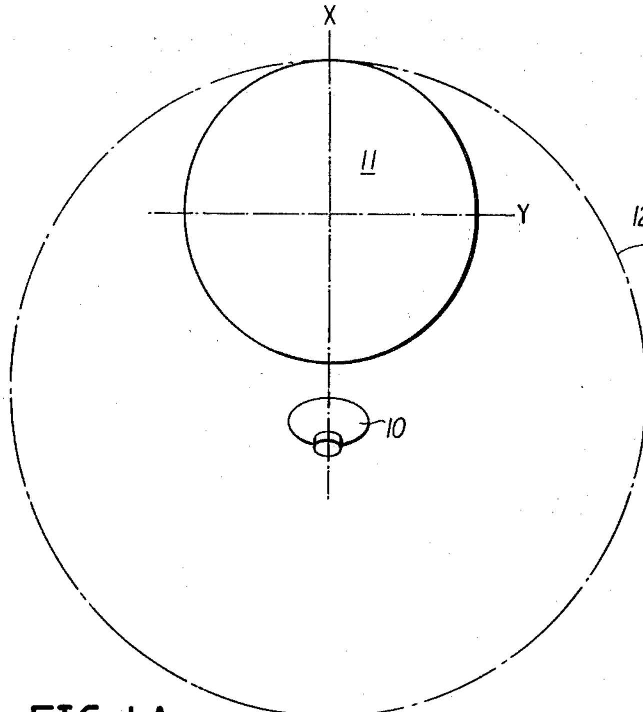


FIG. 1A

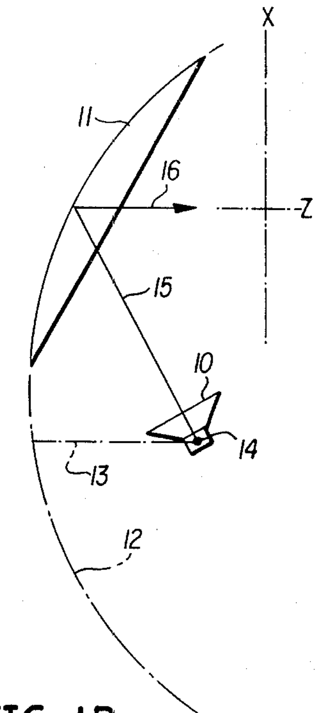


FIG. 1B

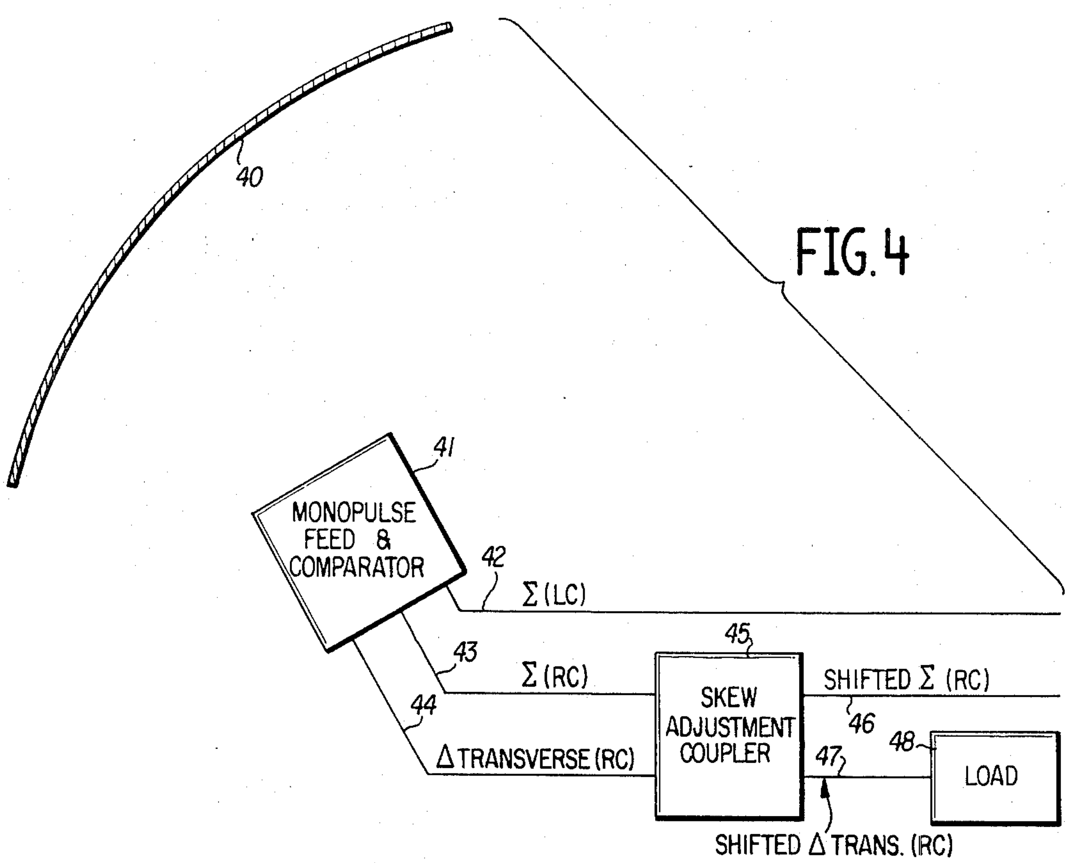


FIG. 4

FIG. 2A

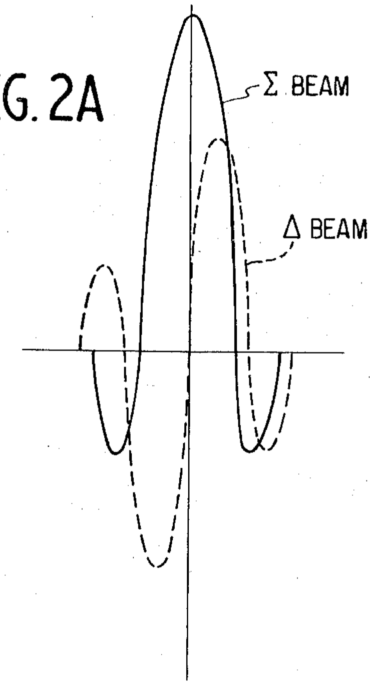
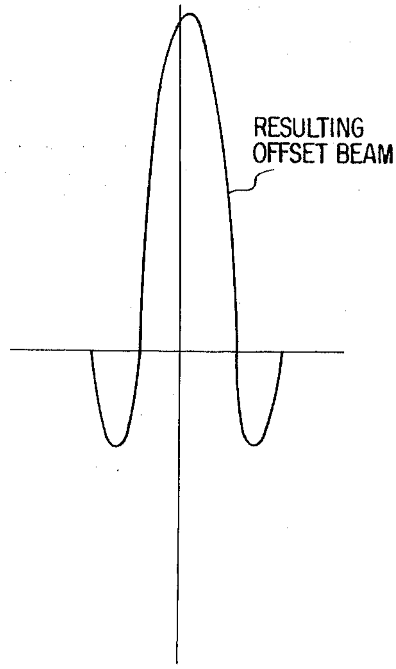


FIG. 2B



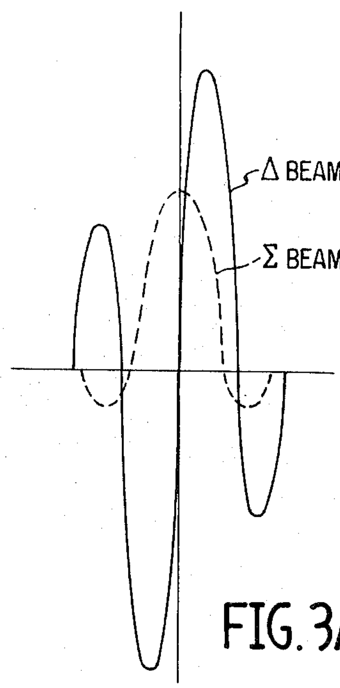


FIG. 3A

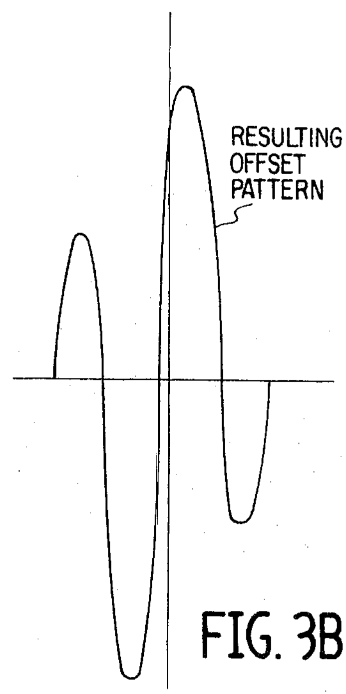
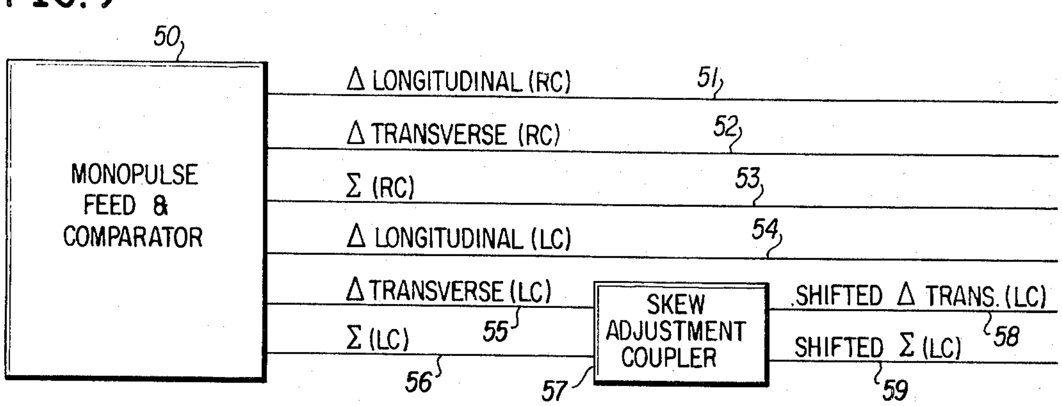


FIG. 3B

FIG. 5



METHOD AND APPARATUS FOR CONTROLLING BEAM SKEW

BACKGROUND OF THE INVENTION

The present invention relates generally to offset-fed parabolic antennas, and more particularly, to the correction of skew of the circularly polarized beam.

DESCRIPTION OF THE PRIOR ART

Offset-fed parabolic reflector antennas have been found to be effective and efficient antennas. The antenna is characterized by its parabolic reflecting surface. The radiating elements are located at the foci of the parabolic surface, but the axis of propagation is offset from the major axis of the parabolic reflector. This offset arrangement minimizes impedance mismatch, which results from radiation reflected back from the parabolic surface into the feed elements. Basic design and operating characteristics are described in articles by Crawford et al., *A Horn-Reflector Antenna for Space Communication;* Bell System Technical Journal, Vol. 40, pp. 1,095–1,116, July, 1961, and by Hines et al., *The Electrical Characteristics of the Conical Horn Reflector Antenna;* Bell System Technical Journal, Vol. 42, pp. 1,187–1,211, July, 1963.

As described in these articles, a linearly polarized beam in an offset-fed parabolic antenna has two cross polarized lobes in the transverse pattern plane. These lobes have been measured at about 18 db below the peak of the co-polarized pattern, and have a phase of +90° and −90° with respect to the co-polarized pattern. The shape of the cross polarized pattern is essentially the same as that of the difference pattern obtained with a monopulse feed. It should be noted that there is no cross polarization in the longitudinal pattern plane, because of the symmetry of the cross polarized patterns in that plane.

Beam skew results in the transverse plane when orthogonal linearly polarized beams are added in quadrature to effect circular polarization. The phase of the cross polarized lobes for longitudinal polarization are 0° and 180° with respect to the transverse co-polarized lobe, thus causing a shift of the transverse polarized beam. Similarly, the cross polarized lobes for transversal polarization cause a shift in the longitudinal polarized beam in the same direction. The beam skew for the opposite sense of circular polarization is in the opposite direction. The typical beam skew is about 0.1 of a beam width or 0.2 of a beam width between right and left circularly polarized beams.

When a monopulse type feed is used to effect circular polarization with the offset-fed parabolic antenna, the difference pattern is skewed, in a manner similar to the above, in the same direction as a correspondingly polarized sum pattern. The cross polarized pattern for a linearly polarized difference pattern is a sum pattern. When circular polarization is used, the cross polarized sum pattern in the transverse plane causes a skewed difference pattern, and, similarly, the cross polarized difference pattern causes a skewed sum pattern.

The primary difficulty in offset-fed parabolic reflector antennas of the prior art is that there is no effective way of boresighting oppositely skewed right and left circularly polarized patterns.

SUMMARY OF THE INVENTION

The present invention superimposes the oppositely skewed circularly polarized patterns by the introduction of a shifting pattern in the transverse plane. Once the two circularly polarized patterns are superimposed, they are easily boresighted by known mechanical means.

Accordingly, it is a primary object of the present invention to provide a new and improved method and apparatus to correct beam skew in a monopulse fed offset parabolic antenna.

It is another object of the invention to provide superimposed patterns which are easily boresighted by mechanical means.

A further object of this invention is to provide superimposed patterns by the addition of a correcting pattern in the transverse plane.

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of certain exemplary embodiments thereof, especially when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**(*a*) and (*b*) are diagrams of the front and side views of an offset-fed parabolic reflector antenna, respectively;

FIGS. **2**(*a*) and (*b*) are illustrative of the sum pattern shifting technique;

FIGS. **3**(*a*) and (*b*) illustrate the difference pattern shifting technique;

FIG. **4** is a block diagram of the preferred embodiment of the present invention with monopulse feed where tracking is not required; and

FIG. **5** is a block diagram of the preferred embodiment of the present invention with monopulse feed where tracking is required for both senses of circular polarization.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1**(*a*) illustrates the front view of an offset fed parabolic reflector antenna. For transmission, radiation is fed from horn source **10** into a parabolic reflector **11** and reflected therefrom. The parabolic reflector is only a portion of a parabola defined by line **12.** As shown in FIG. **1**(*b*), the horn **10** is located at foci **14** along the axis **13** of the parabola **12.** But the horn is pointed offset from the axis **13.** Radiation **15** emanating from horn **10** is reflected by surface **11** in the direction indicated by line **16.** For reception, the radiation travels the same path in the opposite circection. To facilitate the description of the present system, the longitudinal and transverse planes are described in FIGS. **1**(*a*) and (*b*). The longitudinal plane is defined by the X and Z axis of FIG. **1**(*b*). The transverse plane is defined by the Y and Z axis of FIG. **1**(*a*), where the Z axis is perpendicular to the plane of the paper in FIG. **1**(*a*). Basically FIG. **1**(*a*) depicts the edges of the longitudinal and transverse planes by vertical line X and horizontal line Y, respectively.

In a monopulse system, the cross-polarized pattern for a linearly polarized difference pattern is a sum pattern, and, conversely, the cross-polarized pattern for a linearly polarized sum pattern is a difference pattern.

These cross-polarized patterns appear in the transverse plane. To achieve circular polarization, two linearly polarized patterns are added in quadrature. The cross-polarized pattern of each linearly polarized pattern is in the plane of its orthogonal linearly polarized pattern and causes each linearly polarized pattern to shift or skew in the same direction. For circular polarization of the opposite sense, the pattern shifts or skews in the opposite direction.

Referring now to FIG. **2**(*a*) and (*b*), a technique for shifting a sum pattern is illustrated. If linearly polarized sum patterns are used for circular polarization, then the cross-polarized difference pattern skews the main sum pattern. In a given plane, the sum pattern, shown as a solid line in FIG. **2**(*a*), is present with the cross-polarized difference pattern, shown as a dashed line, of its orthogonal sum pattern. The addition of these two patterns cause the sum pattern to shift or skew as shown in FIG. **2**(*b*). The orthogonal sum pattern also skews in the same direction.

Similarly, FIGS. **3**(*a*) and (*b*) depict the technique for shifting a difference pattern. The cross-polarized pattern is a sum pattern (FIG. **3**(*a*) dashed line) and it shifts or skews the difference pattern in the same plane, as shown in FIG. **3**(*b*).

If only one sense of circular polarization is used, the effect is not detrimental, since the skew can be corrected by mechanical means. However, if operation in both senses of circular polarization is required, a very large boresight shift between the opposite circularly polarized beams results, since they shift in the opposite direction. To correct the beam skew between right and left circularly polarized beams, a difference pattern is introduced into the transverse plane for one sense of circular polarization and added to the main sum beam for that sense of circular polarization to skew it to the angular position of the beam of the opposite sense of circular polarization. This technique is illustrated in FIGS. **2**(*a*) and (*b*). Once the right and left circularly polarized beams are aligned, they can be boresighted or aligned to any other reference point by well known mechanical means.

Referring now to FIG. **4**, an embodiment of the present invention, where tracking is not required, is shown. Radiating patterns are reflected by parabolic reflector **40** into a typical monopulse feed and comparator **41.** Left circular and right circular sum patterns are produced on lines **42** and **43**, respectively, by monopulse feed and comparator **41.** These two patterns are skewed to opposite sides of boresight. If these two signals are superimposed, or placed at the same angular position, well known mechanical means can be used to boresight the superimposed patterns. Shifting of the right circular sum pattern is achieved by the addition of a right circular difference pattern in the transverse plane. This technique is shown in FIG. **2.** Thus a right circular transverse difference signal is provided by monopulse feed and comparator **41** on line **44.** Skew adjustment coupler **45,** usually a 15 db to 20 db coupler, couples a portion of the difference pattern into the sum pattern and produces a shifted right circular sum pattern on line **46,** which is at the same angular position as the left circular sum pattern. Of course, the left circular sum beam could as easily be shifted to the angular position of the right circular sum beam. Skew adjustment coupler **45** also provides a shifted circular transverse difference pattern on loaded line **47.** If skew adjustment coupler **45** is a conventional 90° type, the right circular transverse difference pattern is also shifted to the angular position of the left circular sum pattern. This technique is depicted in FIG. **3.**

FIG. **5** shows the preferred embodiment of the present invention which is capable of reception and tracking on either sense of circular polarization. Radiation received by monopulse feed and comparator **50** is used to produce right circular longitudinal difference signals, transverse difference signals, and sum signals on lines **51, 52,** and **53,** respectively, and left circular longitudinal difference signals, transverse difference signals, and sum signals on lines **54, 55,** and **56** respectively. In this embodiment, where tracking is required for both senses of circular polarization, left circular transverse signals and sum signals are both adjusted or shifted, so that all patterns are at the same angular position, thereby superimposed. Skew adjustment coupler **57** couples a fraction of the difference signal into the sum channel to produce a shifted sum beam on line **59** and, simultaneously, couples the same fraction of the sum signal into the difference channel to produce a shifted transverse difference beam on line **58.** Now mechanical adjustments can be made to boresight the superimposed beams.

Though the application of the present invention has been shown for adjustment of the received pattern, the same principles would apply to transmitted patterns. Dual mode transducers and duplexers can be used to achieve transmission and reception at the same station.

From the above description of the preferred embodiments, it will become apparent that the present invention eliminates the beam skew of a circularly polarized offset-fed parabolic reflector antenna by producing superimposed right and left circularly polarized beams which are readily boresighted by mechanical means.

While we have disclosed preferred embodiments of our invention, it will be clear to those skilled in the art that variations in the specific details of construction, which may have been illustrated and described, may be resorted to without departing from the spirit and scope of the invention, as defined in the appended claims.

We claim:

1. Apparatus for controlling beam skew in a circularly polarized offset-fed parabolic reflector antenna comprising:

monopulse feed and comparator means for receiving radiation from said parabolic reflector and for providing a right circular sum signal, a left circular sum signal and a transverse difference signal of one sense of circular polarization, each of said signals having a respective directional pattern; and

skew adjustment means connected to said monopulse feed and comparator means for receiving said transverse difference signal and the one of the sum signals which corresponds in sense of circular polarization to that of the transverse difference signal, and for shifting the directional pattern of said corresponding sum signal to the position of the directional pattern of said signal of the other sense of circular polarization;

whereby said shifted sum signal pattern and said sum signal pattern of the other sense of circular polarization are readily boresignted by mechanical means.

2. Apparatus for controlling beam skew in a circularly polarized offset-fed parabolic reflector antenna comprising:

monopulse feed and comparator means for receiving radiation from said parabolic reflector and for providing a right circular sum signal, a left circular sumg signal and a transverse difference signal of one direction of circular polarization; and

skew adjustment means connected to said monopulse feed and comparator means for receiving said transverse difference signal and the one of the sum signals which corresponds in direction of circular polarization to that of the transverse difference signal, and for shifting said corresponding sum signal to the angular position of said signal of the other direction of circular polarization;

whereby said shifted sum signal and said sum signal of the other direction of circular polarization are readily boresighted by mechanical means;

wherein said skew adjustment means comprises a 15 db coupler means having a first output port coupled to a load and a second output port for providing said shifted sum signal.

3. Apparatus for controlling beam skew according to claim 2 wherein said transverse difference signal and its corresponding sum signal are of right circular polarization.

4. Apparatus for controlling beam skew according to claim 2 wherein said transverse difference signal and its corresponding sum signal are of left circular polarization.

5. Apparatus for controlling beam skew according to claim 1 wherein said monopulse fed and comparator means further produces a transverse difference signal of the other sense of circular polarization, a right circular longitudinal difference signal and a left circular longitudinal difference signal, and wherein said skew adjustment means comprises means for shifting the directional pattern of said transverse difference signal of one sense of circular polarization.

6. Apparatus for controlling beam skew according to claim 5 wherein said skew adjustment means comprises a coupler means for coupling a fraction of said transverse difference signal of one sense of circular polarization into said corresponding sum signal and for coupling the same fraction of said corresponding sum signal into said transverse difference signal of one sense of circular polarization.

7. Apparatus for controlling beam skew according to claim 6 wherein said transverse difference signal of one sense of circular polarization and its corresponding sum signal are of right circular polarization.

8. Apparatus for controlling beam skew according to claim 6 wherein said transverse difference signal of one sense of circular polarization and its corresponding sum signal are of left circular polarization.

9. A method for controlling beam skew in a monopulse antenna system comprising:

receiving radiated signal of right and left circular polarization;

producing a right circular sum signal, a left circular sum signal, and a transverse difference signal of one sense of circular polarization, each of said signals having a respective directional pattern;

coupling a portion of said transverse difference signal into the one of the sum signals which corresponds in sense of circular polarization to that of the transverse difference signal, whereby the directional pattern of said corresponding sum signal is shifted to the position of the directional pattern of said sum signal of the other sense of circular polarization; and

mechanically boresighting said sum signal whose pattern was shifted and said sum signal of the other sense of circular polarization.

10. A method for controlling beam skew according to claim 9 wherein said coupling step further couples the same portion of said corresponding sum signal into said transverse difference signal, whereby the directional pattern of said transverse difference signal is shifted to the position of the directional pattern of said sum signal of the other sense of circular polarization.

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