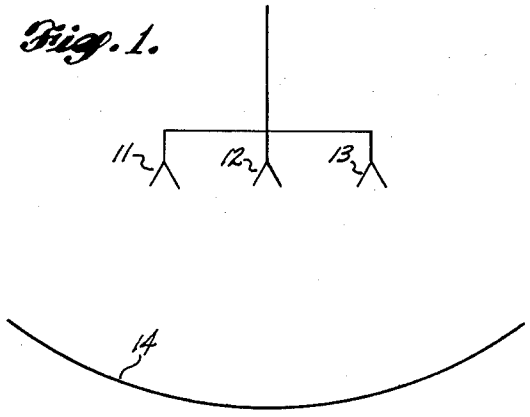
Fig. 1.



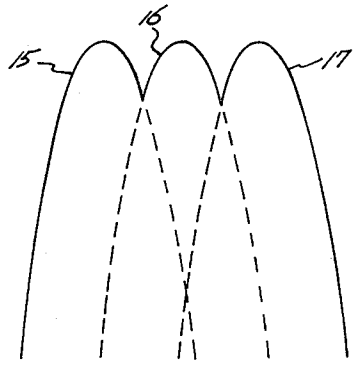


Fig. 2.

Fig. 3.

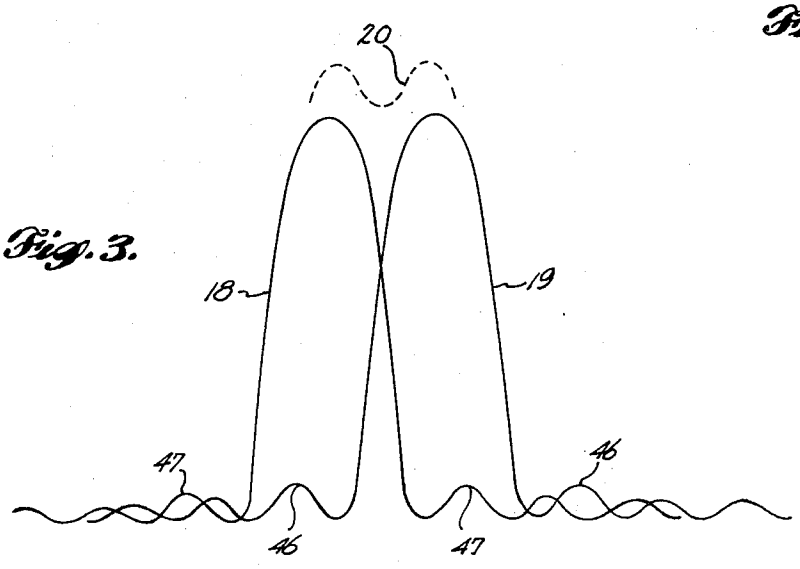


Fig. 4.

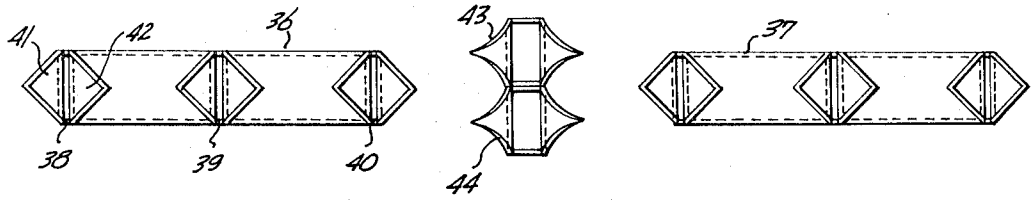
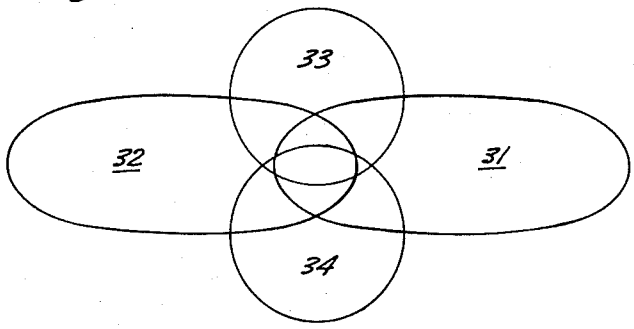


Fig. 5.



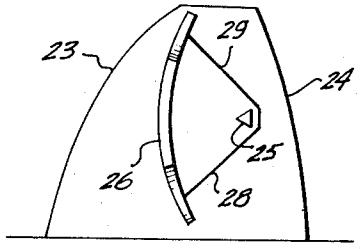


Fig. 6.

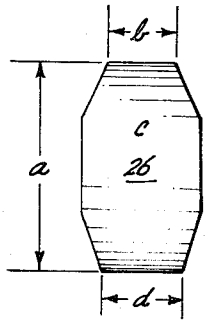


Fig. 7.

United States Patent [19]

Buehler et al.

[11] **3,815,140**

[45] **June 4, 1974**

[54] **MULTIPLE FEED FOR MICROWAVE PARABOLIC ANTENNAS**

[75] Inventors: **Walter E. Buehler**, Issaquah; **Clarence D. Lunden**, Federal Way, both of Wash.

[73] Assignee: **The Boeing Company**, Seattle, Wash.

[22] Filed: **Nov. 6, 1972**

[21] Appl. No.: **304,226**

[52] **U.S. Cl.** **343/779**, 343/109, 343/840, 343/872

[51] **Int. Cl.** **H01q 19/14**

[58] **Field of Search** 343/109, 776, 777, 778, 343/779, 840, 872

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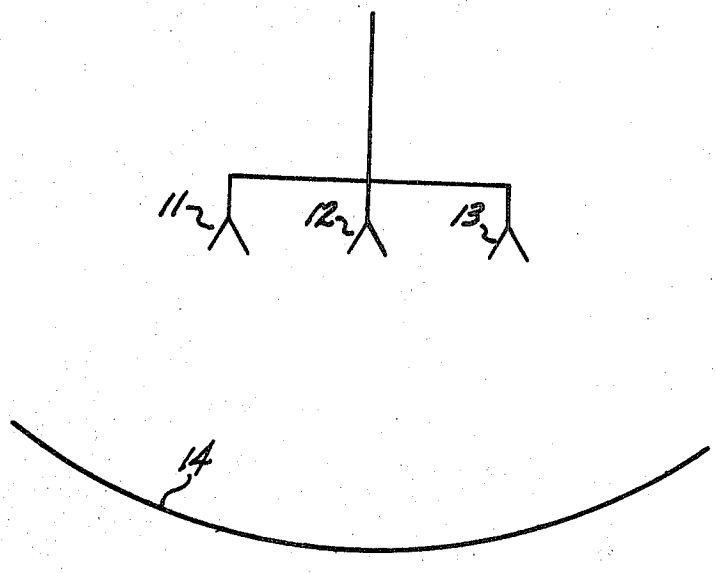
Primary Examiner—Eli Lieberman

Attorney, Agent, or Firm—Christensen, O'Connor, Garrison & Havelka

[57] **ABSTRACT**

A multiple feed microwave antenna. Individually fed illuminators are placed in a predetermined configuration with respect to each other and to a single parabolic reflector and are fed with predetermined current values so as to produce a highly directional microwave radiation pattern. The radiation pattern is relatively broad and contains a plurality of discrete areas of information, distinguished by different carrier and modulating frequencies. By varying the number of illuminators and their separation, fine control over the beamwidth and the shape of the directional radiation pattern may be obtained.

8 Claims, 7 Drawing Figures



MULTIPLE FEED FOR MICROWAVE PARABOLIC ANTENNAS

BACKGROUND OF THE INVENTION

The present invention relates broadly to the art of directional antennas, and more specifically to that art concerned with multiple feed parabolic reflector antenna systems.

With respect to the present use of antennas, the applications of directional beam antennas are becoming increasingly varied and important. An important example of the need for highly directional antennas concerns instrument landing systems (ILS) for aircraft. As the airplane plays an increasing role in the movement of people and freight not only in the United States, but throughout the world, the necessity of having an accurate and dependable landing system by which aircraft may be safely landed during periods of inclement weather is becoming more and more immediate.

Prior art ILS have been restricted, with a few military exceptions, to the VHF/UHF frequency bands. There have been many problems with present landing systems using these frequency bands, two of the most important of which are the lack of control over the configuration of the beam, resulting in reflections along the beam path due to buildings, mountains or other obstacles adjacent to the glide path to the airport, and the physical size of the antennas necessary to obtain even a minimal directional beam. According to standard antenna theory, the dimensions of a radiating antenna in the plane normal to the desired direction of transmission must be at least several wavelengths, and preferably more, before significant directivity is achieved. At transmission frequencies in the UHF/VHF range, this requirement of directivity results in bulky antenna configurations, which are expensive to manufacture, require significant amounts of space at the landing facility, and are difficult and expensive to maintain.

Many of these directivity problems with present instrument landing systems can be solved by utilizing current microwave technology. By using microwave technology, the physical size of the antenna may be significantly reduced. For instance, a parabolic dish can easily be made up to 10 wavelengths in length, thus achieving good directivity of the beam while maintaining a relatively physically compact antenna.

However, with respect to even a microwave system, many significant problems still exist, including the real problem of beam control wherein reflections from nearby objects may cause false information to be present in the aircraft monitor. In addition, it is frequently necessary to transmit a composite beam with multiple information, which heretofore has required multiple antenna systems, normally referred to as antenna arrays.

To overcome some of these specialized problems, the prior art shows the use of multiple feeds in a single antenna system, rather than antenna arrays. For instance, U.S. Pat. No. 3,274,602 to Randall et al. shows a multiple horn antenna system which has the capability of producing either a narrow beamwidth or a broad beamwidth secondary illumination pattern. U.S. Pat. No. 3,534,375 to Paine shows an antenna system having a plurality of feeds in which only one specific feed is used for transmission at any one time, depending upon the location of the subreflector. Other patents showing multiple feeds with a single reflector are U.S. Pat. No. 3,234,559 to Bartholoma and U.S. Pat. No. 2,530,079 to Riblet.

None of the above-mentioned patents, however, shows a basic appreciation of the problems of beam shaping and beam control by the use of multiple illuminators. These problems concern the control of the physical configuration of the beam, including its directivity, its width, its apex shape, its roll-over rate, and its sidelobes. Furthermore, many of the patents dealing with multiple feeds show systems wherein only one feed at a time is active, or if more than one feed is active, they are all fed with an identical signal, creating one single broad beam to the receiver. In accordance with the above, it is an object of the present invention to provide a highly directional radiation pattern, having more than one discrete area of different information, respectively, contained in it.

Another object of the present invention is to provide a practical microwave instrument landing system.

Another object of the present invention is to provide a multiple feed antenna having highly directional characteristics.

A further object of the present invention is to provide a multiple feed antenna in which the shape of the directed pattern may be accurately controlled.

A still further object of the present invention is to provide a multiple feed, highly directional pattern, having minimum sidelobes.

DESCRIPTION OF THE DRAWINGS

A more thorough understanding of the present invention may be obtained by a study of the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a simplified diagram of a multiple feed antenna configuration utilizing a single parabolic reflector.

FIG. **2** is a simplified diagram of a typical radiation pattern developed from a multiple feed antenna configuration as shown in FIG. **1.**

FIG. **3** is a diagram of the individual and combined radiation patterns for a two-feed antenna.

FIG. **4** is a front view of the microwave feed configuration of the present invention.

FIG. **6** is an elevational view of the antenna system of the present invention.

FIG. **7** is a front view of the parabolic reflector utilized in the present invention.

SUMMARY OF THE INVENTION

Briefly, in accordance with a preferred embodiment, the present invention includes a parabolic reflector, and a plurality of individually fed illuminators. Each illuminator alone produces a beam of certain dimensions, and by combining the beams through the use of a predetermined configuration of illuminators, including their number and spacing, the physical configuration of the beam, including sidelobes, may be accurately controlled. Furthermore, certain illuminators may be fed by different information sources, thus resulting in a multiple information beam pattern.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, a simplified diagram of a multiple feed antenna system is shown utilizing three subfeeds, **11, 12, 13** and a reflector **14.** In FIG. **1,** the sub-

feeds are all located in the same plane. The use of three such feeds would ordinarily result in individual transmitted beam patterns similar to that shown in simplified fashion in FIG. 2. By adjusting the configuration, spacing and excitation of the individual illuminators 11–13, a complex resulting beam may be achieved which will be the composite of the individual beams, due to the addition of the individual beam patterns. This complex resulting beam is the antenna pattern which will be seen by the receiver, and which will appear as essentially one beam.

The analysis of the shape of the resulting beam is accomplished by examining the patterns of the individual illuminators 15, 16, and 17 as if each had occurred separately, and then combining them, as shown in FIG. 3. For a two feed radiation pattern shown in FIG. 3, beams 18 and 19 might be individual radiation patterns for the separate illuminators, assuming that the antenna was highly directional and that the excitation was equal between the two beams. A complex resulting beam which is the composite of the two individual beams is shown by the dotted lines 20 in FIG. 3. The precise complex resulting pattern of two or more individual beams ordinarily requires a complex theoretical analysis, and an accurate representation of the composite beam requires a time-consuming tracing analysis by the designer of the antenna system. Even in the example shown in FIG. 3 for instance, the true resulting pattern can only be accomplished by analysis of the addition and cancellation of the two interfering beams at every point in the plane shown.

Additionally, the individual feeds or illuminators may be configured, with respect to the reflector, such that highly directive, yet distinct, individual beams are generated having distinct information in each beam. The system of the present invention allows the receiver to discern the distinct information present in the individual beams, without broadening the overall beam coverage, even though the main beams may overlap each other to some extent.

It is thus clear, from the above description, that a complex beam may be achieved as a result of addition of individual beams generated by multiple feeds with respect to a single parabolic reflector. Thus, multiple feeds, in conjunction with a single parabolic reflector, may be utilized to establish a single broad beamed, highly controlled single beam, or multiple feeds may be used to establish a single radiation pattern containing several closely controlled distinct, individual beams, having discrete information which may be discerned by the receiver. These configurations of individual beams may be controlled by mainpulating the individual beams and the beam parameters so as to make up a complex transmitted radiation pattern.

Referring to FIG. 4, a complex multiple illuminator configuration for use in an instrument landing system is shown which results in a composite pattern having discrete lobes of discernable information. The actual shape of the resulting beam pattern is dependent on several factors: (1) the number of individual illuminators in the system; (2) the relative position of the individual illuminators with respect to one another; (3) the relative magnitudes of the excitation applied to each of the illuminators; (4) the relative phase of the excitation present in the illuminators; and (5) the specific characteristic pattern developed by each illuminator without regard to the other factors.

Each of the above-mentioned factors will in some respect affect the ultimate configuration and directivity of the complex resulting pattern transmitted by the antenna system. Referring to FIG. 5, the radiation pattern for the antenna system shown in FIGS. 4, 6 and 7 is illustrated. FIG. 6 shows the complete randome installation of an ILS, utilizing principles of the present invention. A plastic randome shell 23 with a front window 24 of 1/4 inch low-loss plastic protects the illuminator configuration 25 and the parabolic reflector 16. The multiple illuminator configuration is held in place by four struts which extend to the edge of the reflector blank, two of the struts 28 and 29 being shown in FIG. 6. FIG. 7 shows the actual configuration of the parabolic reflector, its dimensions being: distance $a = 92$ inches, $b = 25$ inches, $c = 28$ inches, and $d = 27$ inches. The radiation pattern shown in FIG. 5 is taken in a plane which is normal to the direction of transmission of the antenna pattern. Thus, although the composite radiation pattern is still highly directive, the several individual discrete areas of the radiation pattern may be discerned from each other so that discrete information can be transmitted within various portions of the complex resulting radiation pattern. For instance, lobes 31 and 32 are the result of the T sections of microwave waveguide 36 and 37 of FIG. 4, and lobes 33 and 34 the result of the single sections 43 and 44. By adjusting the above-mentioned factors affecting the resulting beam, and tracing the composite beam for a variety of specific values, nearly any configuration of radiation pattern may be achieved.

The configuration of illuminators shown in FIG. 4 consist of two microwave T sections 36 and 37, each T section having three slots, or illuminators. The two T sections are made from RG 49, 1 inch by 2 inch waveguide and are placed end-to-end as shown, the center of the end slots being separated from each other by three and one-quarter inches. Each of the T sections generates a single composite broad beam, shown as the horizontal lobes 31 and 32 in the radiation pattern of FIG. 5. Each of the illuminator slots, 38, 39 and 40 of a single T section are identical in size and shape and have a common source of signal energy, identical in phase and energy level. Each slot is provided with a pair of triangular extensions, or "ears," 41 and 42, which extend outward from the slots, adjacent to their transverse edges, and which assist in the shaping of the individual beams. The spacing of the slots is predetermined such that a broad beamed single complex resulting beam is generated by each of the T sections. Thus, the radiation pattern for each of the T sections 36 and 37 would appear to an observer as a single broad beam.

The configuration shown in FIG. 4 also utilizes two single sections, 43 and 44, each having one illuminator slot. Each of the illuminators in the single sections 43 and 44 generate a beam having a near circular lobe pattern, as shown by lobes 33 and 34 in FIG. 5. As more fully explained later, each of the lobes in the pattern is different, in terms of carrier and/or modulating signal frequency. The total resulting radiation pattern, consisting of lobes 31, 32, 33 and 34, is highly directive and controllable, and composed of discrete lobes of different information. Furthermore, utilizing the principles of the present invention, there is virtually no limit to the number of discrete lobes of information which may

be transmitted by the use of a multiple feed configuration in conjunction with a parabolic reflector.

Referring again to FIG. 5, the carrier frequencies utilized in the present invention are 5.01 GHz for the horizontal lobes 31 and 32, and 5.23 GHz for vertical lobes 33 and 34. A 150 Hz audio signal is used to modulate the carrier signal of lobes 32 and 34, while a 90 Hz audio signal modulates the carrier of lobes 31 and 33. The signal strength of each beam, or lobe, in the radiation pattern of FIG. 5 is nearly equal, according to the preferred embodiment, but they may be varied, depending upon the specific application. As explained above, each of the horizontal lobes 31 and 32 are formed by using three individual feeds. These horizontal lobes intersect each other, as shown in FIG. 5 at approximately −6 db. The vertical lobes 33 and 34 intersect each other at approximately −3 db. Again, the precise power point intersection may be varied and is determined by the specific application.

Thus, extremely complex radiation patterns may be generated by the use of a single parabolic reflector and multiple illuminators. The individual beams and the resulting complex pattern may be tailored for specific applications by varying the orientation, location, or size of the illuminator slots cut into the waveguide. In the preferred embodiment, the shaping factors are selected such that a near rectangular shape at the end of the pattern is achieved. Each of those factors discussed above which effect the ultimate shape of the individual beam and the total radiation pattern has its associated variable in microwave technology. The number of illuminators, for instance, is determined by the number of individual slots cut into the waveguide. The relative position of the illuminators with respect to each other is determined by the physical spacing between the individual slots. The excitation of the individual illuminators is controlled by varying the length of the slots, or by placing an attenuator in the slot feed.

The phase of the excitation, furthermore, may be controlled by varying the waveguide length between the individual slots. Thus, the waveguide apparatus may be easily and adequately utilized by a person ordinarily skilled in the art to take account of and to take advantage of all of the factors which may alter the shape of a particular beam in a microwave antenna system.

The control of these factors in a multiple feed antenna system permits the designer to tailor a resulting radiation pattern for a particular application. Thus, in an ILS system for instance, a resulting radiation pattern may be developed which will give sufficient discrete landing information via multiple information beams to an aircraft and yet be sufficiently controllable and directional so as to avoid either natural or man-made reflectors close to the glide path.

Furthermore, combinations of antenna systems may be utilized so as to result in a series of composite resulting beams for an exceptionally irregular approach, such as a dog leg, to the landing field. In such an instance, antennas would be placed at strategic locations along the approach so that the aircraft successively picks up the transmitted beams. By configuring several illuminators so as to result in a single complex beam, and then further configuring various individual beams containing discrete information into a highly complex radiation pattern, nearly any desired radiation pattern for a particular application may be attained.

In addition to the accurate control over the shape of the composite multiple information radiation pattern, the present invention is also capable of significantly reducing the minor lobes of the transmitted beam. The minor lobes are those small lobes which extend in directions other than that of the main beam, such as 46 or 47 in FIG. 3. The minor lobes immediately adjacent to the main beam are usually called sidelobes. Minor lobes are present in the radiation patterns of directional antennas and are usually undesirable as they could possibly cause erroneous information to be received, due to reflection and ultimate interference with the main beam.

By arranging the location of the various beams in relation to one another, cancellation of the minor lobes to an appreciable extent may be achieved. The illuminators are arranged so that their respective individual generated beams will add with each other, as shown in FIG. 3, to the extent that a composite beam is produced having reduced minor lobes.

The present invention thus makes possible a compact antenna system for use in many applications, such as instrument landing systems or survellance radar systems, in which a highly directive, closely controlled, multi-information radiation pattern antenna system is required. Complex antenna radiation patterns may be developed, utilizing specific configurations of illuminators. Furthermore, the use of multiple beams will inherently result in some minor lobe cancellation, depending on the specific illuminator configuration.

Although a preferred embodiment of the invention has been disclosed herein for purposes of illustration, it will be understood that various changes, modifications, and substitutions may be incorporated in such embodiment without departing from the spirit of the invention as defined by the claims which follow:

What is claimed is:

1. A multiple feed microwave antenna system comprising:

a parabolic reflector; and

a plurality of illuminators arranged symmetrically about the focal point of said parabolic reflector and operative to provide at least four modulated orthogonal beams of microwave energy overlapping at specified power points along an axis of transmission defining a desired landing path for an airplane, said orthogonal beams comprising first and second pairs of mutually perpendicular beams, each of said pairs of beams including two beams having different modulating frequencies, wherein the illuminators producing said first pair of said orthogonal beams includes first and second spaced illuminator sections, each of said first and second illuminator sections including at least one means for feeding source energy to said parabolic reflector for producing said first pair of orthogonal beams, and wherein the illuminators producing said second pair of said orthogonal beams includes third and fourth illuminator sections, each of said third and fourth sections including a multiplicity of means for feeding source energy to said parabolic reflector for producing said second pair of orthogonal beams.

2. An apparatus according to claim 1, wherein the aperture of said parabolic reflector is in the shape of an elongated octagon.

3. An apparatus according to claim 2, wherein said first, second, third, and fourth illuminator sections are first, second, third, and fourth wave guide sections, and each of said means for feeding source energy is a slot cut into said wave guide sections.

4. An apparatus according to claim 3, wherein said slots in said third and fourth wave guide sections are separated by a distance which is substantially equal to one wave guide wavelength.

5. An apparatus according to claim 4, wherein said parabolic reflector has a focal ratio of substantially 0.5, and said plurality of illuminators are grouped orthogonally about the focal point of said parabolic reflector, said first and second wave guide sections being fixedly positioned an equal distance from said focal point in a vertical direction, coincident with the major axis of the aperture of said reflector, and said third and fourth wave guide sections being fixedly positioned an equal distance from said focal point in a horizontal direction and coincident with the minor axis of said substantially elliptically shaped aperture of said reflector.

6. An apparatus according to claim 5, wherein said first and second wave guide sections are at such an equal distance from said focal point that said first pair of orthogonal beams transmitted by said antenna system overlap at −3 db power points, and wherein said third and fourth wave guide sections are at such an equal distance from said focal point that said second pair of orthogonal beams transmitted by said antenna system overlap each other at −6 db power points.

7. An apparatus according to claim 6, wherein said first and second wave guide sections includes a single slot, and wherein said third and fourth wave guide sections includes three slots.

8. An apparatus according to claim 7, including means to enclose said parabolic reflector and said plurality of illuminators, said enclosing means including a plate member of low signal loss plastic forming a window for the transmission of said radiation pattern from said reflector.

* * * * *