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Ehrenspeck

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[54] **OPTIMIZED REFLECTOR ANTENNA**

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[52] **U.S. Cl.** **343/817,** 343/837, 343/915

[51] **Int. Cl.** **H01q 19/10**

[58] **Field of Search** 343/834, 835, 836, 343/837, 915, 817

[56] **References Cited**

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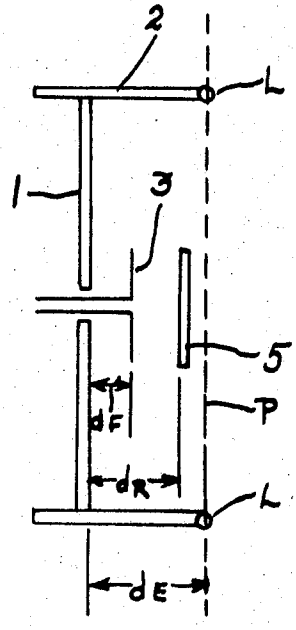
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[57] **ABSTRACT**

An optimized reflector antenna is provided which includes a reflector with a rim of adjustable width around its perimeter and a feed system having a predetermined spacing from the reflector. The rim is excited by radiation coupling and its edge acts like a secondary radiator that yields a substantial and unique effect on the radiation patterns of the antenna by preselecting the rim dimensions in amplitude and phase in reference to the feed system.

17 Claims, 16 Drawing Figures



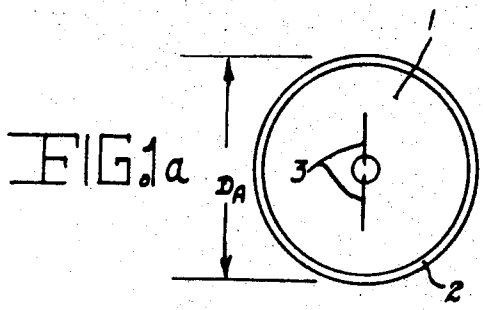


FIG. 1a

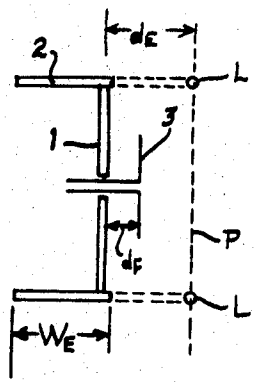


FIG. 1b

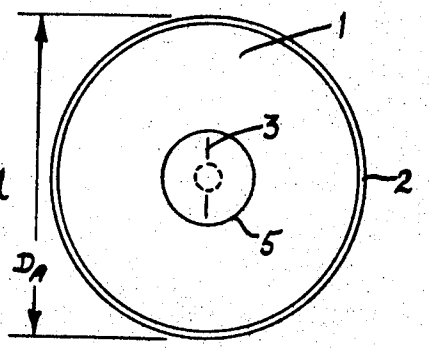


FIG. 3a

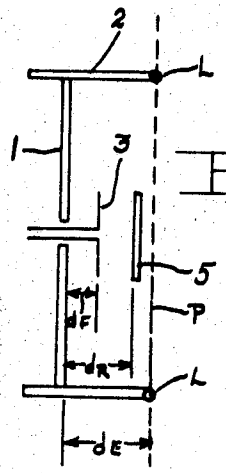


FIG. 3b

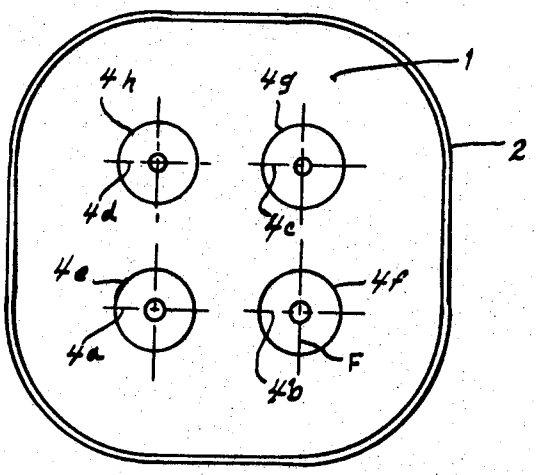


FIG. 4

OPTIMIZED REFLECTOR ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to directional antennas and more specifically to reflector antennas, i.e., those antenna types which consist of a metallic reflector and a feed that illuminates the reflector area. Such antennas are used for almost any receiving or transmitting applications. Their directivity is a function of the area of the reflector and the efficiency of its illumination. The reflector may have various sizes and shapes: large paraboloidal shapes with hundreds of wavelengths in diameter are applied as high-gain antennas for satellite and other space applications and radio astronomy; medium-size planar reflectors with diameters up to 10 wavelengths or reflectors of rectangular or oval contours of equivalent area are used for multi-element arrays for telemetry and satellite tracking; smaller planar reflectors or corner reflectors with areas equivalent to those of a circular-shaped reflector of approximately one to three wavelength diameter are widely used as communication and TV receiving antennas, and more recently as transmitting and receiving antennas in ground terminals for satellite communication networks.

The present invention refers primarily to medium and small size reflector antennas. The most significant requirements which have to be met for the described applications are high gain, lowest side- and backlobe level, smallest dimensions and simplest construction. Antennas which are presently in use do not sufficiently fulfill these conditions. The corner reflector, as one example, has favorable radiation patterns, but its gain is limited to values of approximately 14 dB. A paraboloidal reflector with small diameter, as another example, reaches relatively high gains, but its side- and backlobes are unfavorably high. Still another example, the grid-reflector antenna, is low in gain as long as it is energized by only one feed. Somewhat higher gains from the latter antenna can be only obtained with an enlarged reflector area and a more complicated feed system of 4 to 8 dipoles.

It is the object of this invention to avoid all of these disadvantages and to describe a reflector antenna which realizes much higher gains for the same reflector area, has lower side- and backlobes, is smaller in axial length, and offers a much simpler construction than other types of reflector antennas such as those described above.

DESCRIPTION OF THE PRIOR ART

It is noted the inventor of the present invention has in the past been issued U.S. patents in the same general area of reflector type antennas; for example, "The Short Backfire Antenna," U.S. Pat. No. 3,430,043 issued Apr. 8, 1969; "Endfire Antenna Construction," U.S. Pat. No. 3,218,646 issued Nov. 16, 1965, and "Short Backfire Antenna," U.S. Pat. No. 3,508,278 issued Apr. 21, 1970.

SUMMARY OF THE INVENTION

The antenna according to the invention consists in its simplest form of a planar reflector with a rim of adjustable width around its perimeter and a feed system that may, for example, consist of a single dipole or a combination of dipoles which are arranged in the center of the reflector area at a spacing of approximately one-quarter to one-half of a wavelength from the reflector. Thus the antenna according to the invention resembles a center-fed reflector with height-adjustable side walls.

It has been found that by energizing the feed system the perimeter rim is also excited by radiation coupling and its edge acts like a secondary radiator that yields a marked effect on the radiation patterns of the antenna if its dimensions are optimized in amplitude and phase in reference to the feed system. Thus this new antenna according to the invention is comprised of a combination of two radiators:

1. The feed system in the center area of the reflector called the "feed radiator."

2. The edge of the rim, called the "edge radiator." Because both of the radiators are arranged in front of a common reflector both sources have unidirectional patterns with the directivity maximum of their combination in the axis normal to the reflector. The radiation patterns of the combination antenna can be determined by superposition of the patterns of both sources. Highest directivity is obtained when the amplitude-optimized farfield contributions of both, the feed and edge radiator, are in-phase and lowest when they are in antiphase.

DESCRIPTION OF THE DRAWINGS

FIG. 1*a* shows a front view of one embodiment of the invention in its simplest form;

FIG. 1*b* shows a cross-sectional view of FIG. 1*a*;

FIG. 2*a* is a cross-sectional view of a second embodiment of this invention;

FIG. 2*b* illustrates an idealized aperture-field distribution curves of the feed and of the edge radiator as if both were separately energized;

FIG. 2*c* illustrates the amplitude distribution curve of the combination of both radiators after optimum phase adjustment;

FIG. 2*d* is a front view of FIG. 2*a* showing the aperture;

FIG. 3*a* shows a front view of the antenna of the present invention including a combination of a dipole with a reflector as a feed radiator;

FIG. 3*b* shows a cross-sectional view of FIG. 3*a*;

FIG. 4 shows another embodiment of the invention including a multiplicity of separately energized dipoles or disk-dipole configurations arrayed in front of a common reflector;

FIG. 5*a* shows E- and H-plane patterns of the antenna of the present invention before the essential optimizing procedure;

FIG. 5*b* shows E- and H-plane patterns of the antenna of the present invention after the essential optimizing procedures;

FIG. 5*c* shows the corresponding antenna configuration for FIG. 5*a*;

FIG. 5*d* shows the corresponding antenna configuration for FIG. 5*b*;

FIG. 6*a* shows an antenna configuration with an extended aperture;

FIG. 6*b* shows the field distribution across the extended aperture of FIG. 6*a*; and

FIG. 7 shows the experimental directivity curve as a function of frequency of an S-band antenna model with the configuration of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a better understanding of the invention, the following description with the accompanying drawings are supplied.

FIGS. 1*a* and 1*b* show an example of the antenna according to the invention in its simplest form; FIG. 1*a* is a front and FIG. 1*b* is a cross-sectional view. Circular planar reflector 1 has a diameter D_A. It is surrounded by the circumferential rim 2 of width W_E. Rim 2 can be moved to the right with its outer position indicated by the dashed lines in FIG. 1*b*. The rim may be pressure fitted and its width adjusted by exacting pressure in either direction. The rim edge L marked by the two small circles in FIG. 1*b* is the edge radiator. Its plane which also constitutes the aperture plane of the combination antenna is indicated by the dashed line P at a spacing d_E from reflector 1. Feed 3 is spaced at a distance d_F of approximately one-quarter to one-half of a wavelength from reflector 1. It is in its simplest form a dipole for linear polarization as shown in FIGS. 1*a* and 1*b*, or a crossed dipole for circular polarization. Reflector 1 and rim 2 form the reflector antenna of adjustable depth d_E which is energized by feed 3. Feed 3 may be energized by any of the conventional means such as a transmitter or by a received signal.

The directivity of the single-dipole feed radiator changes only little for reflector areas from approximately 0.7 λ^2 to 1.5 λ^2. It has been found, however, that the directivity of the combination of feed and edge radiator, although continuously increasing with the reflector area, passes through maxima and minima. Experiments on circular-shaped antenna models with varied reflector diameters and thus with circular edge radiators of different circumferential length revealed that directivity maxima are reached for diameter selections of approximately 1.35, 2.35 and 3.35 λ and minima occur for diameters of approximately 1.75 and 2.75 λ.

The antenna is, according to the invention, adjusted for its highest directivity at a given frequency if the following three conditions are satisfied:

1. The diameter D_A of the rim edge, i.e., the edge radiator L, is chosen to be one of its optimal values of approximately D_A, opt.$=(n+0.35)\lambda$, with $n=1, 2, 3 \ldots$

2. The spacing d_E of the edge of rim 2 from reflector 1 is adjusted such that the farfields of the edge radiator L and the dipole radiator 3 are in phase coincidence in the direction normal to the plane of reflector 1.

3. The radiation-coupling between the feed and the edge radiator is made strong enough so that the edge radiator L can markedly contribute to the farfield of the two-radiator combination.

The basic principle of the antenna according to the invention can best be understood and analyzed by studying the field distribution in the radiating aperture. FIG. 2*a* is a cross-sectional view of a typical antenna model with all parts designated by the same letters as in FIG. 1*b*. The dipole-feed radiator 3 is parallel to reflector 1 and oriented in a direction normal to the plane of drawing. The amplitude distribution curves in the aperture P of this antenna can be measured with a small dipole probe which is moved across the aperture in a plane parallel to and spaced at a small distance from the plane of reflector 1. The dashed-dotted line X indicates the plane of the probe movement and Y the normal axis of the antenna.

FIG. 2*b* presents in a coordinate system with X as its horizontal and Y as its vertical axis idealized aperture-field distribution curves of the feed and of the edge radiator as if both were separately energized. The X-axis abscissae are always drawn to the same scale as the dimensions of reflector 1. The long-dashed line is the distribution curve of the dipole radiator which, according to extensive aperture field distribution measurements can be approximated by a cosine curve for reflector diameters smaller than about 2.5 λ. Short-dashed lines are cosine-shaped distribution curves of the edge radiator L with the amplitudes of the two maxima (appearing at points K on the X-axis directly above the rim edge L) assumed as half the maximum aplitude of the feed radiator. Although the major portion of the aperture field originating in the feed radiator can be assumed to be contained in the reflector area it is evident from FIG. 2*b* that the field of the edge radiator extends outside the edge L of rim 2 as well as inside the reflector area.

FIG. 2*c* demonstrates in the X–Y plane the amplitude distribution curve of the combination of both radiators after their optimum phase adjustment has been performed. It is noted that the width of the radiating aperture of the antenna is now markedly extended beyond the rim 2. Experiments have shown that approximately the same distribution curve is measured in the Y–Z plane (not shown). From the resulting two-dimensional enlargement of the radiating aperture area a directivity increase follows which is approximately proportional to the ratio of the areas of the new larger "effective" aperture and the smaller physical aperture of the antenna. These conditions are described in FIG. 2*d* which is a front view of the antenna shown in FIG. 2*a*. The circular area in the center of the sketch is the physical aperture area A with its circumferential rim 2. The virtual area outside A which is marked by crossed lines indicates the aperture area added by the maximum directivity adjustment according to the invention. It is noted that the area of the new effective aperture has approximately twice the size of the physical aperture and, therefore, the directivity of the antenna has increased by approximately 3 dB. The increase could be even somewhat higher if more of the energy were coupled into the edge radiator. The most favorable ratio of the energy portions radiated by the feed and the edge radiator has to be determined experimentally. It will be shown later in FIG. 6 that the results obtained from this analysis are in good agreement with measurements performed with practical models of antennas according to the invention.

It should be mentioned that the effective aperture can also become smaller than the physical aperture if feed and edge radiator are in phase opposition. Then the reflector area is only partly illuminated and the directivity lower than expected from the size of the reflector area.

The described two-source analysis of the antenna according to the invention clearly demonstrates that the maximum-directivity adjustment which is the most typical and advantageous characteristic of the antenna can be successfully performed only by satisfying all three conditions 1, 2, and 3, previously described. If, however, condition 1 cannot be fulfilled (for structural reasons, for example) still an optimum directivity adjustment can be reached by satisfying at least conditions 2 and 3. Such a limited adjustment can be applied to

practically any reflector size in the described antenna configuration. It will, however, result in somewhat lower directivity increases.

The optimum rim diameter for condition **1** is simply determined by introducing into the equation $D_{A(opt.)} = (n + 0.35)$. λ the wavelength of the desired operating frequency for the antenna. It is, however, not so easy to determine that edge radiator spacing d_E which fulfills condition **2** because the phase relations between the two sources are very complicated. If the phase of the energized feed is used as reference, the total phase shift between the dipole and the edge radiator is a function of the distance between the dipole **3** and the rim edge L and of the spacings d_F and d_E. Also the spacial phase shift between feed and edge radiator have to be taken into account. It is much easier to perform an empirical phase adjustment between the farfields of the two sources by a variation of spacing d_E, until maximum radiation is measured in the direction normal to the plane of reflector **1**. Therefore, for the maximum directivity adjustment according to **2** a rim must be used that provides a sufficiently wide variation of the edge spacing d_E. The antenna of FIG. **1***b*, for example, can be directivity-optimized by sliding rim **2** on the circumferential edge of reflector **1**.

Finally, for the satisfaction of condition **3**, it has to be taken into account that the radiation coupling between feed and edge radiator is inversely proportional to their mutual spacing and thus decreases for larger reflectors. It has been found that for reflector areas smaller than approximately $2\lambda^2$ a single dipole as shown in FIG. **1***b* or other equivalent feed is applicable. Antennas with reflector areas between approximately $2.5\lambda^2$ and $5\lambda^2$, however, need a feed with an effective radiating aperture larger than that of a single dipole to provide efficient coupling of energy into the edge radiator and at the same time a more favorable illumination of their areas. Such a type of feed is, for example, the combination of a dipole with a small reflector, as applied in the short-backfire antenna. FIGS. **3***a* and **3***b* show an antenna according to the invention which utilizes such a feed system in its circular reflector. The letter designations have again the same meaning as those in FIG. **1***b*. Additional small reflector **5**, here a circular metal disk, has a spacing d_R from reflector **1**. The directivity-optimizing procedure is the same as that for antennas according to FIG. **1***b*.

For reflector areas larger than approximately $5\lambda^2$ the directivity does not continue to increase because the radiation coupling between feed and edge radiator is strongly reduced and the illumination of the extended reflector area is unfavorable. To overcome these conditions another feed system is needed; for example, one consisting of several separately energized dipoles or disk-dipole configurations which are arrayed in front of the common reflector **1** as shown in FIG. **4**. It has been found that for best results all dipoles should be arranged in the center area of the antenna in mutual spacings of approximately 1 to 1.25 λ. Also the edge radiator should be spaced approximately this distance from the neighboring dipole radiators. In FIG. **4** a front view of such an antenna with a feed radiator of four crossed dipoles **4***a*–**4***d* is shown, with the main parameters designated by the same letters as in FIG. **3***b*. It is noted that the reflector shape is that of a square with round corners. From these conditions it follows that the reflector shape must be different from a circle. It has been found that for the optimum directivity adjustment the perimeter of such reflector antennas, i.e., their edge radiator L must be chosen one of its optimal values of approximately C_A, opt. $= (1, 1 + n\pi)\lambda$ with $n = 1, 2, 3$ .... The maximum directivity adjustment is again performed in the same way as previously described. Additional small reflectors **4***e*–**4***h* are shown which are associated with crossed dipoles **4***a*–**4***d*, respectively.

The directivity increase obtained by the maximization adjustments of an antenna according to the invention cannot be accurately predicted because of the complicated interaction between all parameters. It can, however, be well demonstrated by comparing the E- and H-plane patterns of an antenna of the described type before and after the optimizing procedure as shown in FIGS. **5***a* and **5***b*, respectively. The corresponding antenna configurations for FIGS. **5***a* and **5***b* are FIGS. **5***c* and **5***d*, respectively, and are also added with the same letters as in the circular antenna of FIG. **1***b* designating the same parts. The reflector diameter is $D_A = 1.75$ λ, and the spacing d_F is kept constant at 0.25 λ.

The antenna of FIG. **5***c* consists only of reflector A and the dipole radiator F. In terms of FIG. **1***b* the rim has a width of $W_E = 0$ and consequently the spacing of the edge radiator is also $d_E = 0$; this means that the reflector edge itself constitutes the edge radiator L as indicated by the small circles.

The measured E- and H-plane radiation patterns of this antenna configuration are presented in FIG. **5***a* by the solid and dashed lines, respectively. The E-plane pattern indicates a half-power beamwidth of 48° and the H-plane pattern of 100°.

The antenna of FIG. **5***d* has the same dimensions as the antenna of FIG. **5***c* but now also includes the circumferential rim **2** with the edge radiator L at its outer edge. Rim **2** had, for the optimum directivity adjustment, to be extended out from reflector **1** until its optimum spacing $d_E = 0.66$ λ was reached. For larger spacings the directivity decreases again.

The E- and H-plane patterns of this optimized antenna are shown in FIG. **5***b* illustrated by the solid and dashed lines, respectively. It is noted that the half-power beamwidths of the optimized patterns have now narrowed from their previous value of 48° to 32.5° in the E-plane and from 100° to 39° in the H-plane. These results prove that mostly the drastic changes of the beamwidth in the H-plane pattern are causing the directivity of the optimized antenna of FIG. **5***d* to increase by nearly **6** dB over that of the antenna of FIG. **5***c*. It is also noted that the sidelobe level remains at least 16 dB below the maximum of the main beam and thus has not assumed unfavorable values due to the optimum-directivity adjustment of the antenna.

The marked performance improvement offered by the antenna according to the invention becomes evident if it is compared with other types of reflector antennas. Their directivity is usually calculated from the well-known area-directivity equation $D = (4\pi A/\lambda 2) \cdot e$, with A as the reflector area expressed in λ^2 of the operating frequency and e as the aperture illumination efficiency. The area of the radiating aperture is in general assumed as identical with the physical area of reflector **1**. Although this equation is strictly valid only for reflector diameters of many wavelengths, it can also be used to obtain approximate directivity values of reflector antennas with smaller reflector areas. For most fa-

vorable side-and backlobe conditions in the radiation patterns, the areas of most reflector antennas can be illuminated only with efficiencies between approximately 60 to 70 percent. Because low side- and backlobe levels were also a most significant goal of the antenna according to the invention the following comparisons were in general based on an aperture illumination efficiency of 65 percent.

According to the area directivity equation, a directivity of 11.6 (10.6 dB) is calculated for the antenna of the configuration of FIG. 1*b* with a reflector diameter of 1.35 λ, i.e., with a reflector area of 1.43 λ². The E- and H-plane patterns of this antenna indicate half-power beamwidths of 38° and 45°, respectively. The measured maximum directivity of 22.5 (13.5 dB) for this antenna is almost 3 dB higher than the calculated value. This large directivity increase which would correspond to a reflector area of almost twice its size cannot be explained by a much higher aperture illumination efficiency which would then have markedly surpassed its 100 percent limit and would, in addition, not be compatible with the favorably low sidelobe level always measured with those antennas. It has been found that this directivity increase is rather the result of the extension of the radiating aperture of the optimized antenna to a larger effective aperture, as previously discussed in connection with FIG. 2*a*. The measured directivity increase of almost 3 dB indicates that the described antenna model acts as if it would be nearly twice as large in reflector area, or in terms of aperture size, that the maximum-directivity adjustment of the antenna according to the invention enlarges its physical aperture to an "effective" aperture of twice the area.

The directivity of another optimized antenna model according to the invention with 2.35 λ diameter ($A = 4.33\ \lambda^2$) is calculated to be 35.4 (15.5 dB). For best performance it had to be constructed according to the configuration of FIG. 3*b*, with the rim adjusted to a width of 0.57 λ. The measured directivity of 65 (18.1 dB) which is 2.6 dB above the calculated value, indicates an effective aperture area approximately 1.8 times the physical aperture. The half power beamwidths are 24.5° and 23.5° in the E- and H-plane patterns, respectively. A comparison of this antenna model with one of the same reflector diameter but without the rim and disk showed that the optimization of the antenna in the three steps of selecting the optimum reflector diameter to $D_A = 2.35\ \lambda$, adding to the feed radiator the reflector disk **5**, and finally arranging the rim and adjusting d_E to its optimum value resulted in a directivity increase of more than 10 dB. Antenna models according to FIG. **4** with an area equivalent to that of a circular reflector of approximately 3.35 λ diameter gave directivity values of over 20 dB with a feed radiator of 4 dipoles. Still another antenna model according to the invention with 16 dipoles in front of a reflector area corresponding to a reflector of 6.35 λ diameter reached a directivity maximum of 25 dB.

The aperture extension of the described antenna model with 2.35 λ diameter was measured with a small dipole probe which was moved in a plane parallel to, and spaced at a distance of approximately 0.75 λ from reflector **1**. FIG. 6*a* shows the antenna configuration and FIG. 6*b* shows the field distribution across the aperture in the same X, Y coordinate system as used in FIG. **2**. The curves have the same amplitude level in the antenna axis Y and are measured toward both sides and outside of the rim until the field amplitudes have decreased to the −20 dB energy level. The solid-line curve with its measured points indicated by small circles is the field-distribution curve in the E plane and the curve with the small crosses is the distribution in the H plane of the feed radiator. Although the two curves should be presented in a three-dimensional coordinate system because they are measured in two orthogonal planes both are for simplicity of the drawing shown together in the X—Y system.

With the effective aperture of the antenna defined as that area which contains all radiated power in and around the normal axis, including all energy levels not more than 20 dB below that in the normal axis, it is noted that the maximum directivity adjustment extended the radiating aperture to the points *h* and *v* in the E and H plane of the feed radiator, respectively. Since points *h* and *v* appear at nearly the same distance of approximately 2λ from the Y-axis, the effective aperture of the optimized antenna can according to FIG. **6** be described as a circle of approximately twice the diameter of the edge radiator. This information is, however, not sufficient for the calculation of the directivity increase. Rather the amplitude as well as the phase distribution over the entire aperture would need to be known and taken into account. The directivity of this antenna was, as previously mentioned, measured as 2.6 dB above that calculated according to the area-directivity equation for a 65 percent aperture illumination efficiency.

The model of FIG. 1*b* presents the simplest and most versatile configuration for the antenna according to the invention. Its complete circular symmetry makes it applicable to circular as well as linear polarization provided the feed has the feasible polarization response. It is another advantage of this configuration that it offers the lowest sidelobe level, the highest aperture illumination efficiency and the widest pattern bandwidth of all models of this antenna type. The most significant features of the antenna are, however, those directivity maxima which occur with the periodicity $(n + 0.35) \cdot \lambda$, when the in-phase adjustement is performed. Comparable directivity values could with conventional reflector antennas only be reached with much larger reflector areas.

The high-gain performance of the antenna according to the invention is not limited to the use of planar reflectors; curved reflectors such as paraboloidal or spherical ones or stepped reflectors may also be applied, and their peripheral contours may be oval or rectangular instead of circular as shown in FIG. 1*b*. Instead of the linear dipole of FIG. 1*b* crossed or folded dipoles, spirals, loops, open-ended wave guides, or arrays of those may be applied as feed radiators.

In the antenna model of FIG. 1*b* the optimum phase adjustment is performed by sliding the rim over the outer edge of reflector A until maximum directivity is reached. Another adjustment method applies two telescoping cylinders. Still another method is provided by the arrangement of several parallel rings of wire or metal stripes with the maximum directivity adjustment performed by changing the number of rings and/or their mutual spacing up to values of approximately one-tenth of the wavelength of the highest frequency.

The configuration of antennas according to FIGS. 1*b*, 3*b*, and **4** is applicable to any polarization of which the feed radiator is capable. If, however, only linear polar-

ization response is needed, those sections of the rim which are not substantially oriented in the E plane of the feed radiator can be omitted because they give only negligible contributions to the directivity increase. Thus circular reflectors, for example, need only those approximately 90° wide sectors of the rim, which are mostly oriented in the direction of polarization. In analogy, square reflectors need only the two sides of the rim which are parallel to the dipole-feed radiator. Antennas with a feed radiator consisting of four and more feeds, however, need the rim around the entire perimeter.

So far only antenna dimensions for discrete frequencies have been discussed and it was shown that the antenna according to the invention can for any desired frequency be optimzed for its highest directivity. However, extensive experimental work has revealed that certain parameter combinations can be found that lead to optimized antennas that exhibit superior performance over wide frequency ranges. FIG. 7 shows the experimental directivity curve as function of frequency of an S-band antenna model with the configuration of FIG. 3*b*. The antenna is according to the invention optimized for frequency $f_M = 3.4$ GHz by selecting one of those optimum reflector diameters, here 2.35 λ_M, and applying the previously described optimum phase adjustment. The directivity values were measured with a three-dimensional pattern integrator over a 4:1 frequency range and are presented versus frequency values which are normalized with reference to frequency f_M over a range from 0.3 f_M to 1.2 f_M. FIG. 7 also contains, for the same frequency range and reflector area, the calculated directivity curve D_A for an assumed aperture illumination efficiency of 65 percent. Used as a reference curve, it allows a direct performance comparison of the antenna according to the invention with a conventional reflector antenna having the same area.

The directivity curve of FIG. 7 has maxima at the points m_1 and m_2; i.e., for those two discrete frequency values for which the reflector has diameters of 1.35 λ_M and 2.35 λ_M and consequently the edge radiator has its directivity maxima. A directivity minimum is noted for point *l*, i.e., for that frequency value for which the reflector diameter is 1.75 λ_M and the edge radiator has its lowest directivity; but even this lowest directivity value still corresponds to an aperture illumination efficiency of approximately 60 percent.

The E- and H-plane patterns were also measured for the entire frequency range 0.30 f_M to 1.20 f_M. From their study it is evident that the antenna has favorable patterns over a frequency range of approximately 3.6:1 with the sidelobes mostly below −20 dB and reaching levels up to −10 dB only at the highest frequencies. The lowest experimental frequency of 0.30 f_M was dictated by limitations in the frequency range of the power source. Since the patterns did not shown any signas of deterioration at the lower end of the frequency band it can be concluded that the described type of the antenna according to the invention has a pattern bandwidth even much wider than 4:1.

It should be mentioned that the phase adjustment performed for the 2.35 λ antenna is not optimal for that frequency which corresponds to a reflector diameter of 1.75 λ. Therefore, a new adjustment for the latter will result in a directiviy increase for this frequency which according to measurements amounted to 2 dB. However, with this adjustment the directivity for the frequency corresponding to a 2.35 diameter of the antenna has decreased and the directivity curve as function of frequency is completely different from that shown in FIG. 7. Thus the pattern bandwidth of such antennas can simply be changed by varying their diameter D_A and/or rim-edge spacing d_E.

What is claimed is:

1. A reflector antenna with optimized directivity being comprised of a common reflector having a predetermined area and perimeter, a feed radiator arranged in the center of said area at a spacing of approximately one-quarter to one-half of a wavelength from said common reflector, a rim surrounding said perimeter, said rim having a width and an edge, both said feed radiator and said edge being arranged in front of said common reflector, means to energize said feed radiator while also simultaneously exciting the perimeter rim to permit the edge thereof to act as a secondary radiator, both said feed radiator and said secondary radiator having unidirectional patterns with the directivity maximum of their combination being in the axis normal to the common reflector, and means to adjust said width of said rim to position said edge so that the amplitude-optimized farfield contributions of said combination are exactly in phase to provide substantially increased directivity, the parameters of said reflector and said edge being arranged to permit said edge to operate exclusively as a secondary radiator.

2. A reflector antenna as described in claim **1** wherein the diameter of said edge is equal to $(n+0.35)$ λ, with $n = 1, 2, 3 \ldots$ and λ equal to the wavelength.

3. A reflector antenna as described in claim **2** wherein said reflector is curved.

4. A reflector antenna as described in claim **2** wherein said reflector is circular.

5. A reflector antenna as described in claim **1** wherein said means for adjusting said width of said rim is comprised of said rim pressure fitted on said reflector thereby permitting movement of said rim toward the direction of radiation by exerting a pressure on said rim.

6. A reflector antenna as described in claim **1** wherein said means to adjust the width of said rim is comprised of telescoping cylinders.

7. A reflector antenna as described in claim **1** wherein said feed radiator is comprised of a dipole.

8. A reflector antenna as described in claim **1** wherein said feed radiator is comprised of an array of radiators.

9. A reflector antenna as described in claim **1** wherein said feed radiator is comprised of a combination of dipole and a secondary reflector, the sequence being said reflector, said dipole and said secondary reflector.

10. A reflector antenna as described in claim **1** wherein said feed radiator is comprised of a multiplicity of combinations, each combination consisting of a dipole and a secondary reflector, the sequence being said reflector, said dipole, and said secondary reflector.

11. A reflector antenna including a combination of first and second radiators to increase substantially the effective aperture of the antenna comprising a primary reflector having a predetermined area in accordance with the operating wavelength thereof, said primary reflector having a predetermined perimeter, a rim surrounding said perimeter, said rim having width and and edge, a feed radiator arranged in the center of said primary reflector and spaced from ¼ to ½ λ therefrom,

means to energize said feed radiator to simultaneously provide a first unidirectional pattern from said feed radiator and primary reflector, said feed radiator and said reflector acting as said first radiator, and a second unidirectional pattern resulting from excitation of said rim edge by way of said feed radiator and said primary reflector, said feed radiator, said primary reflector and said rim edge acting as said second radiator, and means to adjust the distance of said edge from said primary reflector such that the farfield unidirectional patterns of said first and second radiators are in phase coincidence in the direction normal to the plane of said primary reflector thus operating to provide a substantially increased effective aperture and an equivalent increased gain, the parameters of said primary reflector and said edge being arranged to permit said edge to operate exclusively as a second radiator.

12. A reflector antenna as described in claim **11** wherein said primary reflector is curved.

13. A reflector antenna as described in claim **11** wherein said reflector is circular.

14. A reflector antenna as described in claim **11** wherein said feed radiator is comprised of a combination of a dipole and a secondary reflector in the sequence of said primary reflector, said dipole, and said secondary reflector.

15. A reflector antenna as described in claim **14** including a multiplicity of said combinations.

16. A reflector antenna as described in claim **11** wherein the diameter of said edge is equal to $(n+0.35)$ λ where n equals 1, 2, 3, ... and λ equals operating wavelength.

17. An optimized reflector antenna including a combination of first and second radiators comprising a common reflector having a predetermined area in accordance with the operating wavelength thereof, said commond reflector having a predetermined perimeter and diameter, a feed raidator arranged in front of and approximately in the center of said common reflector and spaced ¼ to ½ λ therefrom, said feed radiator and common reflector forming said first radiator, a multiplicity of spaced rings in a parallel arrangement approximately of the same diameter as said common reflector, the first of said multiplicity of rings positioned at said perimeter and extending therefrom in front of said common reflector to the last of said multiplicity of spaced rings, said last ring operating in conjunction with said common reflector to form said second radiator, said last ring being at a predetermined distance from said common reflector such that the farfield unidirectional patterns of said first and second radiators are in phase coincidence in the direction normal to the plane of said common reflector thus operating to provide a substantially increased effective aperture and an equivalent increased gain.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,742,513 Dated 26 June 1973

Inventor(s) Hermann W. Ehrenspeck

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Add the three sheets of drawings containing Figures 2a - 2d, 5a - 5d, 6a, 6b and 7, photocopies of which are attached.

Signed and sealed this 7th day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
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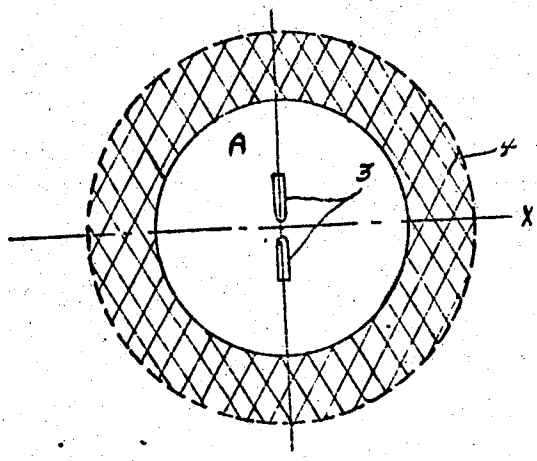


FIG. 2d

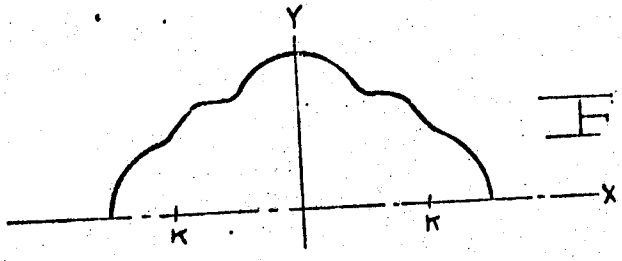


FIG. 2c

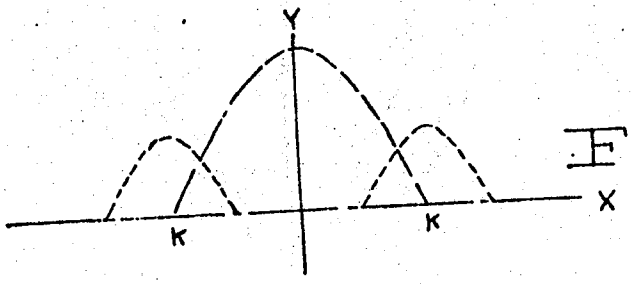


FIG. 2b

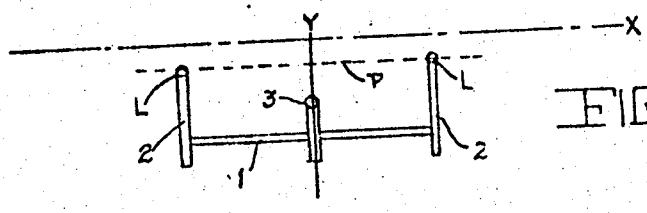


FIG. 2a

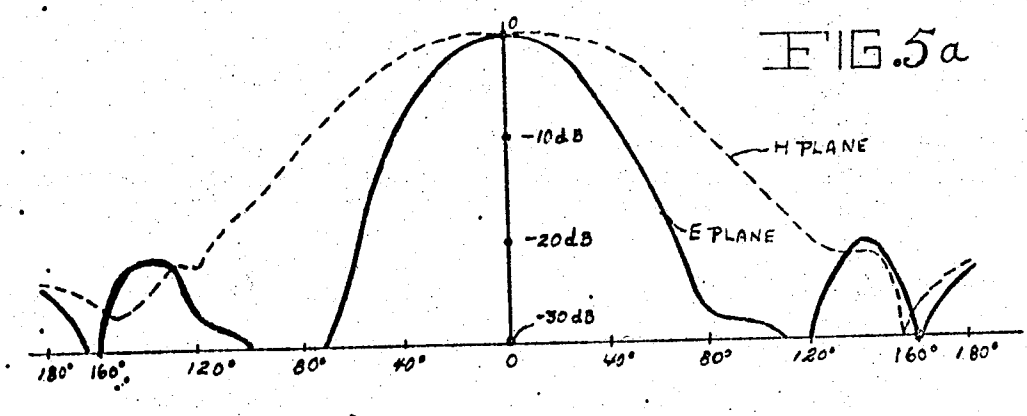


FIG.5a

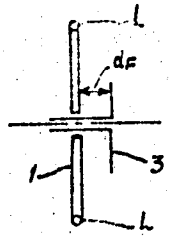


FIG.5c

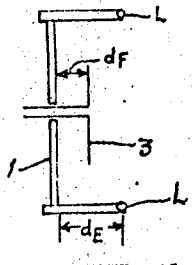


FIG.5d

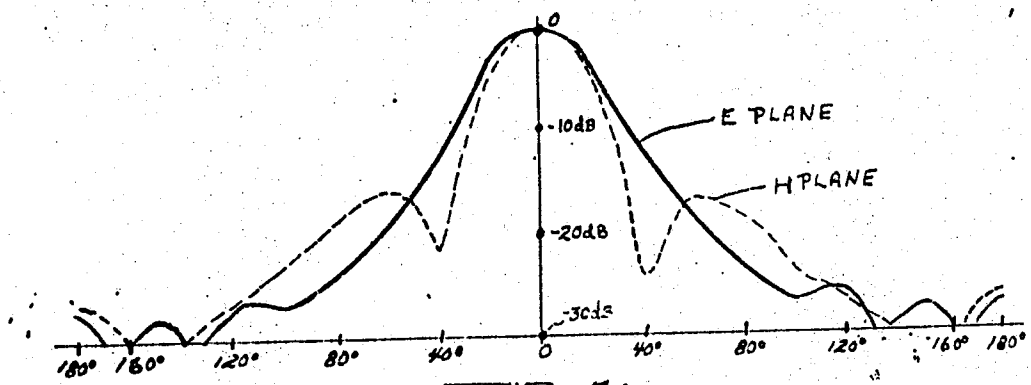


FIG.5b

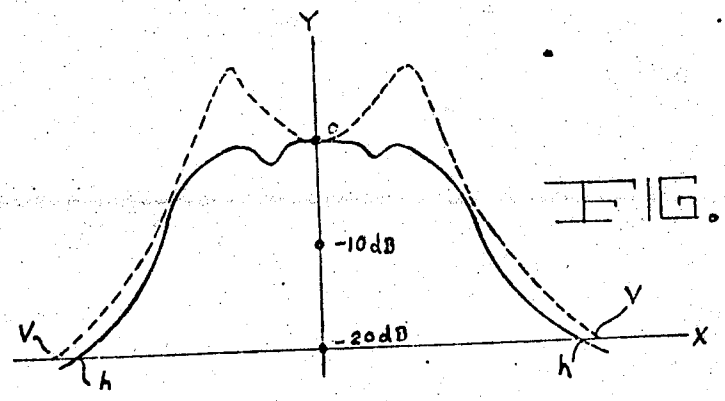


FIG. 6b

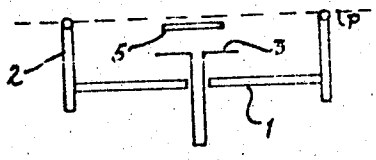


FIG. 6a

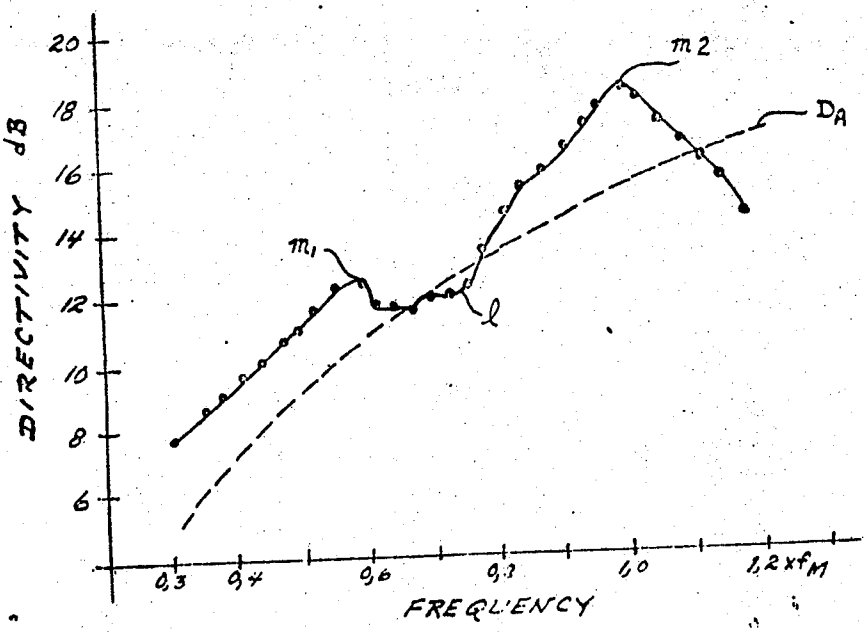


FIG. 7