(1)

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NOTICE

The Government-owned invention described herein is available for licensing. Irquires and requests for licensing information should be addressed to:

DEPARTMENT OF THE NAVY
Chief of Naval Research (Code 302)
Arlington, Virginia 22217

Navy Case No. 66,531

APPLICATION FOR LETTERS PATENT

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT J. Paul Shelton & James K. Hsiao

are citizens of the United States of America,

and residents of Arlington, Virginia and Vienna, Virginia, respectively

have invented certain new and useful improvements in COMPACT PHASED ARRAY FED DUAL REFLECTOR ANTENNA SYSTEM

of which the following is a specification:

Prep: JLForrest:ne
Tel: 767-3428

Navy Case No. 66,531

COMPACT PHASED ARRAY FED DUAL REFLECTOR ANTENNA SYSTEM

SPECIFICATION

Background of the Invention

The present Invention relates, in general, to a novel antenna system and, more particularly, to a novel phased array fed dual reflector microwave antenna system.

In various radar and communication applications, it is required to provide an electronically scanned microwave antenna with large aperture and limited angular coverage. A typical example of such an application is an orbiting spacecraft with an antenna which is viewing some portion of the earth, and either because of the orbit altitude or because of the size of the viewed region the angular coverage is small -- less than 20 degrees. The use of a conventional phased array with individual radiators spaced about one half wavelength apart is to be avoided because of the excessively large number of radiators that would be required, with attendant high cost and weight.

Figure 1 illustrates a prior art solution to this problem. In the antenna system 10 of Figure 1 a parabolic main reflector 12 and a parabolic sub-reflector 14 are positioned about a common axis. The main reflector 12 and the sub-reflector 14 are further positioned such that their respective focal points are co-located along the axis 16, as for example at point 18. This arrangement of reflectors is commonly referred to as "confocal".

A small phased array 20 emits radiation directed toward the sub-reflector 14. This radiation is reflected by the sub-reflector 14 toward the main reflector 12 from which it is reflected away from the antenna system 10 toward the subject to be scanned. For example, rays 22 and 24 emitted by the array 20 are reflected by the sub-reflector 14 as rays 26 and 28, respectively. The reflected rays 26 and 28 cross each other at the common focal point 18 and are subsequently reflected as respective rays 30 and 32 by the main reflector. The antenna is a reciprocal device, and thus the reverse process occurs in the receive mode.

The array 20 directs radiation to various locations on the surface of the sub-reflector 14 and, as a result, the angle of the radiation leaving the main reflector 12 may be varied thereby allowing the antenna system 10 to scan over a given area within the angular design limits of the system. The reflectors 12 and 14 and the array 20 must be arranged in an offset configuration as shown so that energy is not lost through the unwanted interception of rays by the sub-reflector 14 or the array 20, commonly referred to as "blockage".

The primary disadvantage of the prior art confocal antenna system of Figure 1 is the size of the reflectors necessary to provide reasonable angular scanning coverage. In the confocal antenna system an incoming plane wave reflected from the main reflector will concentrate in the vicinity of the focal point of the reflector. If the sub-reflector is located close to this focal point, a small sub-reflector is all that is theoretically required to reflect these waves into a parallel plane wave again. Thus a small feed array can be used without appreciable spill-over loss. Unfortunately, such a system is very sensitive to beam scanning. As soon as the beam is scanned slightly off the boresight, the reflected rays from the main reflector will be deflected and move away from the focal point. To avoid spill-over losses, both the sub-reflector size and array size must be increased. In fact, in many practical confocal systems, the sub-reflector must be very large and may approach the size of the main reflector.

The present Invention provides a novel solution to these problems in the form of a compact antenna design.

Summary of the Invention

Accordingly, one object of the present Invention is to provide a novel antenna system.

Another object is to provide a novel dual reflector microwave antenna system.

Still another object is to decrease the size of the sub-reflector in a dual reflector antenna system as compared to prior art systems.

Yet another object is to reduce the spacing between reflectors in a dual reflector antenna system as compared to prior art systems.

These and other objects and advantages are achieved in a novel dual reflector antenna system according to the present Invention which comprises a first reflector including a first concave specular surface having a substantially parabolic cross-section. The first concave surface includes a parabolic focal point. The system further comprises a second reflector including a second concave specular surface having a substantially elliptical cross-section. The parabolic focal point of the first concave surface lies along the second concave surface. The first concave surface is generally opposed to the second concave surface and is separated therefrom. The second concave surface includes first and second elliptical focal points. The first elliptical focal point lies along the first concave surface. Additionally, the system comprises a feed array means including a radiating surface directed toward the second concave surface for bidirectionally communicating electromagnetic radiation with locations external of the antenna system via reflection from the first and second concave surfaces.

Brief Description of the Drawings

A more complete appreciation of the Invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 illustrates a prior art confocal antenna system;

Figure 2 illustrates a cross-section of a dual reflector antenna system according to a preferred embodiment of the present Invention;

Figure 3 illustrates the formation of the maximum elevation beam by the antenna system shown in Figure 2 according to the present Invention;

Figure 4 illustrates the formation of the minimum elevation beam by the antenna system shown in Figure 2 according to the present Invention;

Figure 5 illustrates a method for determining the surface shape of the sub-reflector 58 of the antenna system according to the present Invention shown in Figure 2;

Figure 6 illustrates a method for determing the coordinates of the edge points of the sub-reflector 58 and the coordinates of the edge points of the phased array 68 of the antenna system according to the present Invention shown in Figure 2;

Figure 7 illustrates the blockage conditions for the antenna system shown in Figure 2 according to the present Invention;

Figure 8 illustrates a cylindrical embodiment of the antenna system according to the present Invention; and

Figure 9 illustrates a generalized three-dimensional embodiment of the antenna system according to the present Invention.

Description of the Preferred Embodiments

Referring now to drawing Figures 2 through 9, wherein like reference numerals designate identical or corresponding parts throughout the several views, and more particularly to Figure 2 thereof, a compact phased array fed dual reflector antenna system 50 is illustrated in cross-section according to a preferred embodiment of the present Invention.

The antenna system 50 includes a parabolic main reflector 52 having a focal point 54 positioned on the axis of the parabola 56. An elliptically-shaped sub-reflector 58 is positioned such that the focal point 54 is located along its inner reflective surface 60.

The elliptical sub-reflector 58 includes first and second focal points 62 and 64, respectively. The first focal point 62 is positioned approximately at the center of the inner reflective surface 66 of the main reflector 52. A phased array 68 is positioned such that the second focal point 64 of the sub-reflector 58 is located at its approximate center.

The antenna system 50 is shown in Figure 2 producing a beam in the direction of the parabolic axis 56. Thus rays 70 and 72 produced by the array 68 converge in the vicinity of the parabolic focal point 54 on the surface 60 of the elliptical sub-reflector 58. The rays 70 and 72 are reflected from the surface 60 as rays 74 and 76, respectively, which are directed toward the reflecting surface 66 of the main reflector from where they are reflected as the axially directed rays 78 and 80, respectively.

Although the rays 70 and 72 appear to converge at a single point 54 on the surface 60 of the sub-reflector 58, in reality the defracting wavefront for the finite-wavelength case will be distributed over a region extending several wavelengths along the surface 60 of the sub-reflector 58. This is more clearly shown in Figures 3 and 4 which illustrate the formation of off-axis beams.

Figure 3 illustrates the formation of the highest elevation beam by the antenna system 50. Here the rays 70 and 72 from the array 68 are dispersed somewhat when arriving at the surface 60 of the sub-reflector 58. Thus ray 70 strikes the surface 60 at point 82 while the ray 72 strikes the surface at point 84. Points 82 and 84 are located near the lower edge 86 of the sub-reflector 58. The rays 78 and 80 emanate from the surface 66 of the main reflector 52 at an elevated angle with respect to the parabolic axis 56.

Similarly, Figure 4 illustrates the formation of the lowest elevation beam by the antenna system 50. Here the rays 70 and 72 are reflected at respective points 88 and 90 near the upper edge 92 of the sub-reflector 58. The rays 78 and 80 are ultimately reflected from the surface 66 of the main reflector 52 at a depressed angle with respect to the parabolic axis 56.

In each of the off-axis beam positions shown in Figures 3 and 4, the rays 70 and 72 are dispersed somewhat as they encounter the surface 60 of the sub-reflector 58. Nevertheless, the ray bundle has a very small cross-section upon reflection from the sub-reflector 58, and this is what allows the use of the smaller sub-reflector.

It should be noted that the rays 70 and 72 leaving the phased array 68 converge to a focus in the region of the surface 60 of the sub-reflector 58, in contrast to the parallel rays 22 and 24 emitted by the array 20 in the prior art confocal configuration shown in Figure 1. Thus, the phased array 68 of the present Invention must emit a convergent wavefront. This convergent wavefront may be easily generated by appropriate phasing of the signal used to drive the array 68, as is well-known in the art. Alternatively, it might be desirable to use a phased aray having a concave surface (not illustrated).

Additionally, it should be noted that the antenna system 50 of the present Invention is reciprocal such that it may operate equally well as either a transmitting or receiving antenna. The antenna system has been described herein above as a transmitting antenna; however, the system is fully capable of operating as a receiving antenna if the directions of beam propagation are reversed. Also, although the system is particularly useful when used in conjunction with a phased array transmitter or a phased array receiver, the present Invention is not limited to phased arrays and thus can be used with other types of active elements.

The mathematical equations necessary for construction of the antenna system 50 will now be presented. Since the geometry of the antenna is somewhat complicated, solving the relationships between the required main reflector, sub-reflector, and array parameters in closed form is nearly impossible. Therefore, a method for determining the various parameters will be presented simultaneously with the development of required formulae.

Referring to Figure 5, the antenna system 50 of Figure 2 is shown superimposed on a pair of rectangular coordinates (X, Y) such that the parabolic axis 56 lies along the X-axis. The focal length f of the main reflector 52 is assumed to be one unit, and thus the focal point 54 has the coordinates (1,0). The first focal point 62 of the sub-reflector 58 is designated as point F_1 having the coordinates (X_1, Y_1). Similarly, the second focal point 64 is designated as point F_2 having the coordinates (X_2, Y_2).

A far field incident ray 100 intercepts the main reflector 52 at a point P having coordinates (X_p, Y_p). The ray 100 reflects off the main reflector as a first reflected ray 102 which intercepts the sub-reflector 58 at a point I having coordinates (X_I, Y_I). The first reflected ray 102 is subsequently reflected by the sub-reflector as a second reflected ray 104.

The incident ray 100 intercepts point P at an angle θ_1 with respect to the horizonal. A first normal line 106 is normal to the surface 66 of the sub-reflector 52 at point P. The normal line 106 forms an angle of θ_2 with respect to the horizontal. The first reflected ray 102 reflects from point P at an angle of θ_3 with respect to the horizonal.

Similarly, the first reflected ray 102 strikes the sub-reflector 58 at point I at the same angle θ_3 with respect to the horizontal. A second normal line 108 is normal to the surface 60 of the sub-reflector 58 at point I. The second normal line 108 forms an angle θ_4 with respect to the horizontal. The second reflected ray 104 forms an angle θ_5 with respect to the horizontal.

The equation of the parabolic main reflector 52 having its focus at (1,0) is given by:

$$y^2 = 4x \qquad (1)$$

The end points A and B of the main reflector 52 will be determined later. The slope M_p of the first normal 106 taken from equation (1) is:

$$M_p = -1/\left(\frac{dy}{dx}\right) = -y_p/2 \qquad (2)$$

The equation of the elliptical sub-reflector 58 is given by:

$$\left[(x-x_1)^2+(y-y_1)^2\right]^{1/2}+\left[(x-x_2)^2+(y-y_2)^2\right]^{1/2}=L \qquad (3)$$

where:

$$L = \left[(1-x_1)^2+y_1^2\right]^{1/2} + \left[(1-x_2)^2+y_2^2\right]^{1/2}$$

Placing Equation (3) in the more general form for an ellipse, we obtain:

$$A_e x^2 + B_e xy + C_e y^2 + D_e x + E_e y + F_e = 0 \qquad (4)$$

Expanding Equation (3) allows the determination of the coefficients in Equation (4) as follows:

$$A_e = 4\left[(x_2 - x_1)^2 - L_2^2\right] \tag{5}$$

$$B_e = 8(x_2 - x_1)(y_2 - y_1) \tag{6}$$

$$C_e = 4\left[(y_2 - y_1)^2 - L_2^2\right] \tag{7}$$

$$D_e = 4\left[(x_2 - x_1)(L_2^2 - L^2) + 2L^2 x_2\right] \tag{8}$$

$$E_e = 4\left[(y_2 - y_1)(L_2^2 - L^2) + 2L^2 y_2\right] \tag{9}$$

$$F_e = L^4 + L_2^4 - 2L^2(x_1^2 + y_1^2 + x_2^2 + y_2^2) \tag{10}$$

where:

$$L_2^2 = x_1^2 - x_2^2 + y_1^2 - y_2^2 \tag{11}$$

The slope M_e of the second normal 108 taken from Equations (4) through (11) is:

$$M_e = -1\Big/\left(\frac{dy}{dx}\right) = \frac{B_e x + 2C_e y + E_e}{2A_e x + B_e y + D_e} \tag{12}$$

The slope M of the first reflected ray 102 is calculated as follows. The relationship of angles 0_1, 0_2, and 0_3 is from Figure 5:

$$\theta_1 - \theta_2 = \theta_2 - \theta_3 \tag{13}$$

$$\theta_3 = 2\theta_2 - \theta_1 \tag{14}$$

The slope M is thus:

$$M = \tan\theta_3 = \frac{\tan(2\theta_2) - \tan\theta_1}{1 + \tan\theta_1 \tan(2\theta_2)}$$

$$= \frac{2\tan\theta_2 - \tan\theta_1(1-\tan^2\theta_2)}{1-\tan^2\theta_2 + 2\tan\theta_1\tan\theta_2} \qquad (15)$$

where:

$\tan\theta_1 = A =$ Slope of far field ray 100 (16)

$\tan\theta_2 = M_p = -y_P/2$ (17)

Therefore, by substituting Equations (16) and (17) in Equation (15) we obtain:

$$M = \frac{-y_p - A(1 - y_p^2/4)}{1 - (y_p^2/4) - y_p A} \qquad (18)$$

The equation for the first reflected ray 102 is:

$$y = Mx + B \qquad (19)$$

Solving for B at point P, we obtain:

$$B = y_p - M x_p \qquad (20)$$

Substituting the Equation (19) into Equation (4) we may obtain the coordinates of the point of intercept I of the first reflected ray 102 and the sub-reflector 58 as:

$$X_I = \frac{-B_I \pm \sqrt{B_I^2 - 4A_I C_I}}{2A_I} \qquad (21)$$

where:

$$A_I = A_e + MB_e + M^2 C_e \qquad (22)$$

$$B_I = BB_e + 2MBC_e + D_e + ME_e \qquad (23)$$

$$C_I = B^2 C_e + BE_e + F_e \qquad (24)$$

Combining the results of Equation (21) with Equations (19) and (20) we obtain:

$$y_I = M(x_I - X_P) + y_P \qquad (25)$$

The slope M_R of the second reflected ray 104 is calculated as follows. The relationship of the angles θ_3, θ_4, and θ_5 is from Figure 5:

$$\theta_5 - \theta_4 = \theta_4 - \theta_3 \qquad (26)$$

$$\theta_5 = 2\theta_4 - \theta_3 \qquad (27)$$

The slope M_R is thus:

$$M_R = \tan\theta_5 = \frac{\tan(2\theta_4) - \tan\theta_3}{1 + \tan\theta_3 \tan(2\theta_4)} = \frac{2\tan\theta_4 - \tan\theta_3(1 - \tan^2\theta_4)}{1 - \tan^2\theta_4 + 2\tan\theta_3 \tan\theta_4} \qquad (28)$$

where:

$$\tan\theta_3 = M \qquad (29)$$

$$\tan\theta_4 = M_e \qquad (30)$$

Therefore, by substituting Equations (29) and (30) into Equation (28) we obtain:

$$M_R = \frac{2M_e - M(1 - M_e^2)}{1 - M_e^2 + 2MM_e} \qquad (31)$$

The equation for the second reflected ray 104 is:

$$y = M_R x + B_R \qquad (32)$$

Solving for B_R at point I, we obtain:

$$B_R = y_I - M_R x_I \qquad (33)$$

Referring now to Figure 6, the edges of the sub-reflector 58 and of the array 68 will now be determined. In Figure 6, the respective lower and upper edges of the main reflector 52 are represented by points A and B. Points C and D represent the respective lower and upper edges of the sub-reflector 58, and points E and F represent the edges of the array 68.

A far field ray 110 intercepts the main reflector 52 at point B. The ray 110 has an angle of α with respect to the horizontal, where α is the maximum elevation angle of the antenna system 50. The ray 110 is reflected at point B as a reflected ray 112 which strikes the sub-reflector 58 at the lower edge point C. Subsequently the reflected ray 112 is reflected as ray 114 which ultimately strikes the array 68 at edge point E.

Similarly, a far field ray 116 intercepts the main reflector 52 at point B. The ray 116 forms an angle

β with the horizontal, where β is the minimum elevation (depression) angle of the system 50. The angular coverage of the system is thus the sum ($\alpha + \beta$). The ray 116 is reflected as ray 118 which strikes the sub-reflector at the upper edge point D and is subsequently reflected as ray 120. The ray 120 ultimately intercepts the array at point E.

From Equation (16), the slope A_1 of the incident ray 110 is:

$$A_1 = \tan \alpha \tag{34}$$

Similarly, the slope A_2 of the incident ray 116 is:

$$A_2 = -\tan \beta \tag{35}$$

The coordinates of points C and D may then be determined from Equations (15) through (25). Thus the edges of the sub-reflector 58 are determined.

The edge point E of the array 68 is located by the intersection of the rays 114 and 120 from the sub-reflector 58. The slope M_{R1} and intercept B_{R1} are determined for the reflected ray 114 from Equations (31) and (33), respectively. Similarily, the slope M_{R2} and intercept B_{R2} for the reflected ray are determined. From the general equation for a line:

$$y_E = \hat{m}_{R1} x_E + B_{R1} \tag{36}$$

and,

$$y_E = M_{R2} x_E + B_{R2} \tag{37}$$

Solving Equations (36) and (37) simultaneously we obtain:

$$X_E = \frac{B_{R2} - B_{R1}}{M_{R1} - M_{R2}} \tag{38}$$

and

$$y_E = \frac{M_{R1} B_{R2} - M_{R2} B_{R1}}{M_{R1} - M_{R2}} \tag{39}$$

Thus the coordinates of the edge point E of the array 68 are determined.

In a similar manner, the coordinates X_F and Y_F of the other edge point F of the array 68 may be determined by intercepting two far field rays (not illustrated) at angles α and β at the lower edge A of the main reflector 52. These rays, when traced through the antenna system 50, will intersect at point F. The coordinates of point F are then calculated, as described above for point E.

The blockage conditions will now be discussed with reference to Figure 7. There are two possible types of blockage for the offset reflector and array configurations of the present Invention. In the first type of blockage, the lowest elevation ray approaching the antenna system 50 from the far field strikes the sub-reflector 58 without reflecting off the main reflector 52. For example, in Figure 7 the sub-reflector 58 effectively "blocks" the far field ray 130. The ray 130 is assumed to have a slope of $-A_3$. Thus the equation for the path of the ray 130 is:

$$y = -A_3 x + y_A + A_3 x_A \qquad (40)$$

The distance by which the ray 130 is above the upper edge D of the sub-reflector 58 is given by:

$$B_S = -A_3 x_D + y_A + A_3 x_A - y_D \qquad (41)$$

There is no blockage of this type when:

$$B_S \geq 0 \qquad (42)$$

In the second type of blockage, the feed array 68 "blocks" rays traveling between the main reflector 52 and the sub-reflector 58. Thus, in Figure 7 a far field ray 132 is reflected from point A on the main reflector 52 as ray 134. The ray 134 strikes the array 68 and thus fails to arrive at the sub-reflector 58. The incident ray 132 is assumed to have a slope of A_4. From Equation (18), the slope of the reflected ray 134 is given by:

$$m_A = \frac{-y_A - A_4(1 - y_A^2/4)}{1 - y_A^2/4 - y_A A_4} \qquad (43)$$

From Equation (20), the intercept B_4 is given by:

$$B_4 = y_A - M_4 x_A \qquad (44)$$

Thus, the equation for the path of the reflected ray 134 is:

$$y = M_4 x + B_4 \qquad (45)$$

The distance by which the reflected ray 134 is above the upper edge F of the array 68 is given by:

$$B_F = M_4 x_F + B_4 - y_F \qquad (46)$$

There is no blockage of this type when:

$$B_F \geq 0 \qquad (47)$$

In the above analysis, the focal point of the main reflector 52 has been assumed to be a point having the coordinates (1, 0). Thus, all derived parameters are effectively normalized to the focal length of the main reflector. These parameters may thus be easily scaled up to a practical size, as should be apparent to the skilled practitioner.

In order to design an antenna system using the above developed equations, certain input parameters must be known; i.e., the edge points A and B of the main reflector 52, the focus of the main reflector, and the focal points F_1 and F_2 of the sub-reflector 58. Generally, the known input parameter is the angular coverage of the system, defined above as the sum $(\alpha + \beta)$. The remaining input parameters must be estimated or assumed. The various other design parameters are then calculated as described above. Subsequently, using an iterative process each estimated or assumed input parameter may be altered in turn and its effects on the system may be calculated until ultimately a fixed design is realized.

The input parameters may be estimated in a logical manner. For example, point A must be selected such that the lowest elevation rays are not blocked by the sub-reflector 58. A reasonable estimate for Y_A is:

$$y_A = 2 \tan(\alpha + \beta) \qquad (48)$$

Then from Equation (1),

$$x_A = y_A^2 / 4 \qquad (49)$$

Similarly, a resonable estimate for point B is:

$$y_B = f + y_A = 1 + y_A \qquad (50)$$

$$x_B = y_B^2/4 \qquad (51)$$

As previously described, the first elliptical focal point 62 (F_1) should be located at the approximate center of the reflective surface 66 of the main reflector 52. Thus:

$$y_1 = (y_A + y_B)/2 \qquad (52)$$

$$x_1 = y_1^2/4 \qquad (53)$$

The coordinates of the second elliptical focal point 69 (F_2) can be determined from the magnification ratio of the antenna system. The magnification ratio (RM) is defined as the ratio of the phased array scan angle to the angular coverage of the system, or the ratio of the main reflector size to the array size, or the ratio of the main reflector focal length to the spacing between the array and sub-reflector. By similar triangles:

$$x_2 = 1 - (1 - x_1)/RM \qquad (54)$$

$$y_2 = -y_1/RM \qquad (55)$$

A practical example will now be presented. In this example, the desired angular coverage is 6.0 degrees. The magnification ratio was estimated to be 3.0. The following input parameters were estimated using Equations (48) through 55):

Point A: $Y_A = 0.19$

$X_A = 0.009$

Point B: $Y_B = 1.19$

$X_B = 0.354$

focus F_1: $X_1 = 0.119$

$Y_1 = 0.69$

focus F_2: $X_2 = 0.665$

$Y_2 = -0.164$

The sub-reflector 58 coefficients were then calculated from Equations (5) through (11):

$A_e = -7.71$

$B_e = -3.73$

$C_e = -5.98$

$D_e = 7.03$

$E_e \quad 4.61$

$F_e = 0.68$

The sub-reflector 58 edge points C and D were then computed from Equations (15) through (25):

Point C: $X_C = 0.97$

$Y_C = -0.12$

Point D: $X_D = 1.00$

$Y_D = 0.13$

The array 68 edge points E and F were then computed from Equations (36) and (39):

Point E: $X_E = 0.88$

$Y_E = -0.17$

Point F: $X_F = 0.51$

$Y_F = 0.012$

Finally, the blockage distances B_S and B_F were calculated from Equations (41) and (47):

$B_S = 0.004 > 0$

$B_F = 0.05 > 0$

Heretofore the antenna system 50 of the present Invention has been described in cross-section. A three-dimensional embodiment of this Invention can take any form which contains this central cross-section.

Figure 8 illustrates a cylindrical extension of the present Invention. Here the main reflector 52, the sub-reflector 58, and the array 68 take the form of segments of cylindrical surfaces having axes parallel to the Z-axis. Cross-sections of the system taken in planes parallel to the X-Y plane are identical to that shown in Figure 2. The feed array 68 may be made from an array of straight linear array elements 150, as is well-known in the art.

Figure 9 illustrates a more generalized three-dimensional embodiment of the present Invention. Here the main reflector 52 is a parabolid of revolution formed by rotating the parabolic cross-section of the main refelector 52 shown in Figure 2 about the parabolic axis 56. Similarly, the sub-reflector 58 is an ellipsoid of revolution formed by rotating the elliptical cross-section of the sub-reflector 58 shown in Figure 2 about the elliptical axis 152 joining the first elliptical focal point 62 and the second elliptical focal point 68. It should be noted that, in general, the parabolic axis 56 and the elliptical axis 152 are distinct.

The principal advantage of the present Invention is the reduction in the size of the sub-reflector of a dual reflector antenna system fed by a phased array. Another advantage is a reduction in the spacing between the main reflector and the sub-reflector of a dual reflector system. The separation between reflectors in the antenna system of the present Invention is the focal length f of the main reflector; whereas the separation between reflectors in the prior art confocal system shown in Figure 1 is f(1+1/RM), where RM is the magnification ratio of the system. Thus a reduction in spacing is achieved. As a consequence of this reduced spacing, the phased array of the present Invention may be located closer to the main reflector than has been possible in prior art systems.

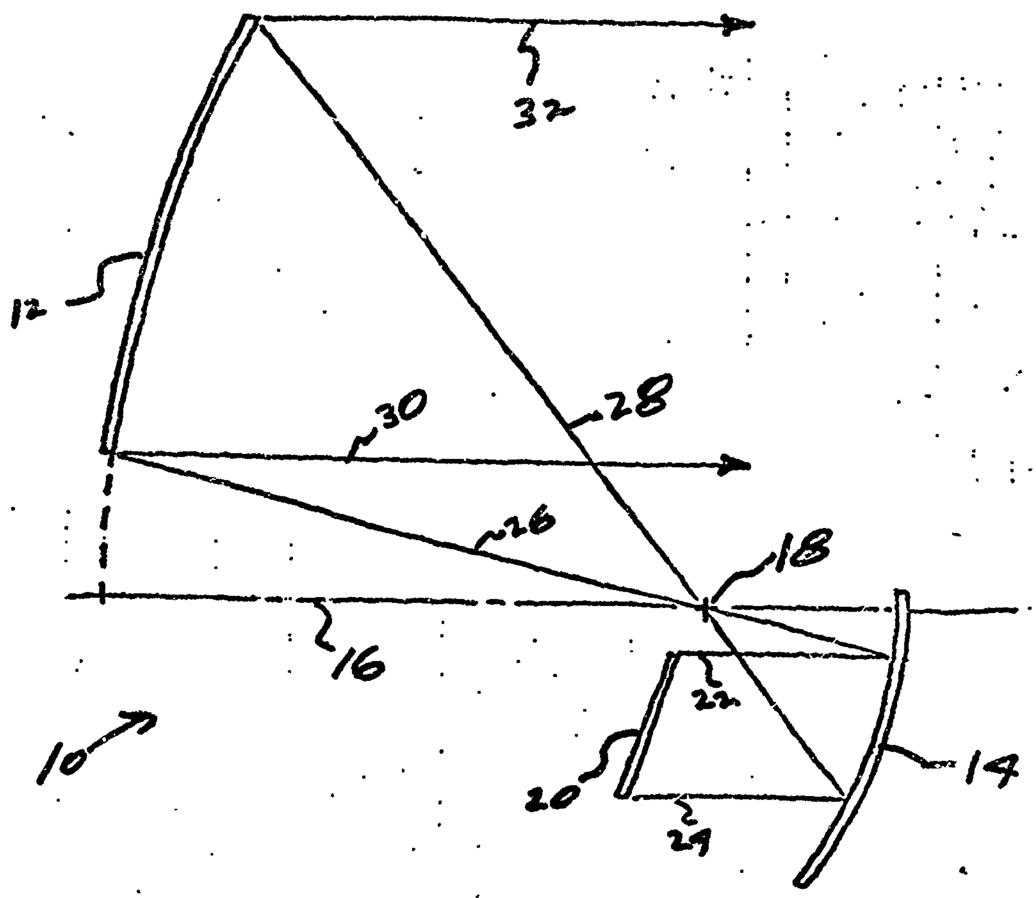
Further information regarding this present Invention may be obtained from "Ray Constraints on the Design of an Offset Feed Array for a Dual Reflector System Using a Guided Search Method" by J.K. Hsiao, NRL Memorandum Report 4744, May 2, 1982, Naval Research Laboratory, Washington, D.C., available from the National Technical Information Service (NTIS), Springfield, Virginia. The contents of this documents are specifically incorporated herein by reference.

Obviously, numerous (additional) modifications and variations of the present Invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the Invention may be practiced otherwise than as specifically described herein.

Navy Case No. 66,531

Abstract of the Disclosure

A compact phased array fed dual reflector antenna system. The antenna system includes a parabolic main reflector, an elliptical sub-reflector, and a phased feed array. The focal point of the parabolic main reflector is located on the elliptical surface of the sub-reflector. A first elliptical focal point of the sub-reflector is located on the parabolic surface of the main reflector while the second elliptical focal point is located on the radiating surface of the feed array.



PRIOR ART

FIGURE 1

NAVY CASE 66,531

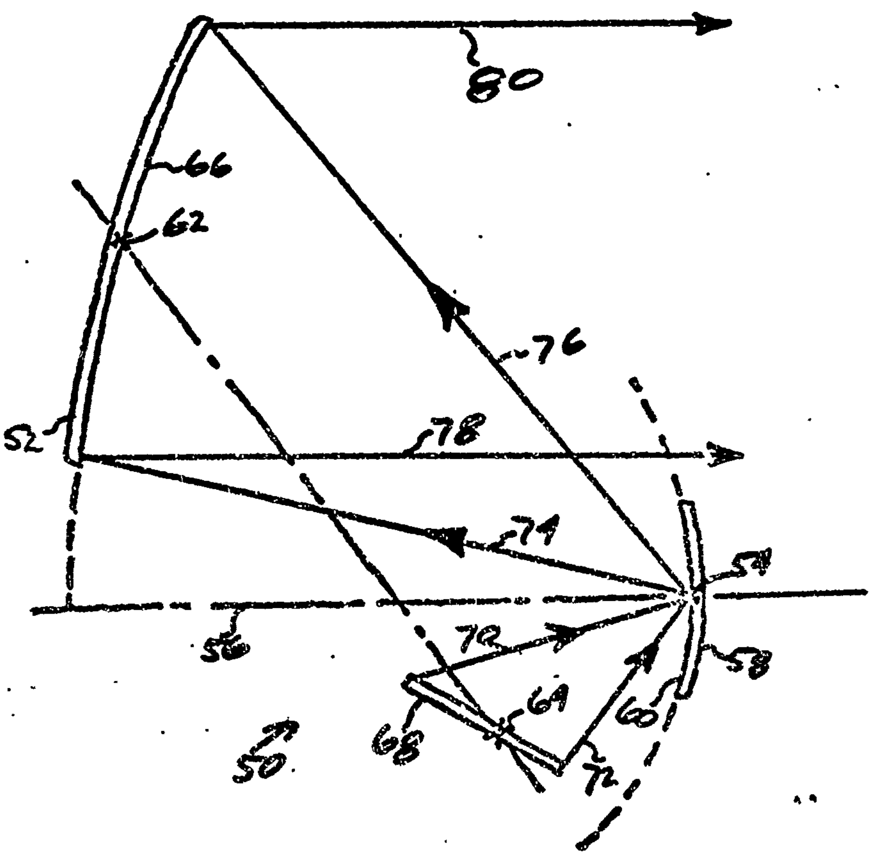


FIGURE 2

NAVY CASE 66,531

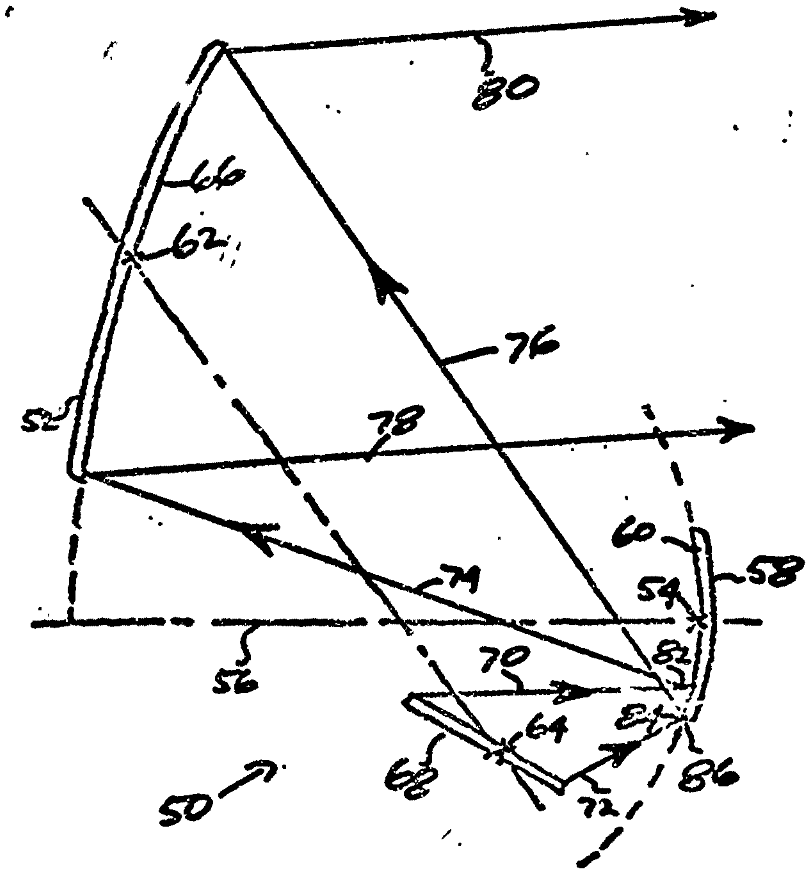


FIGURE 3

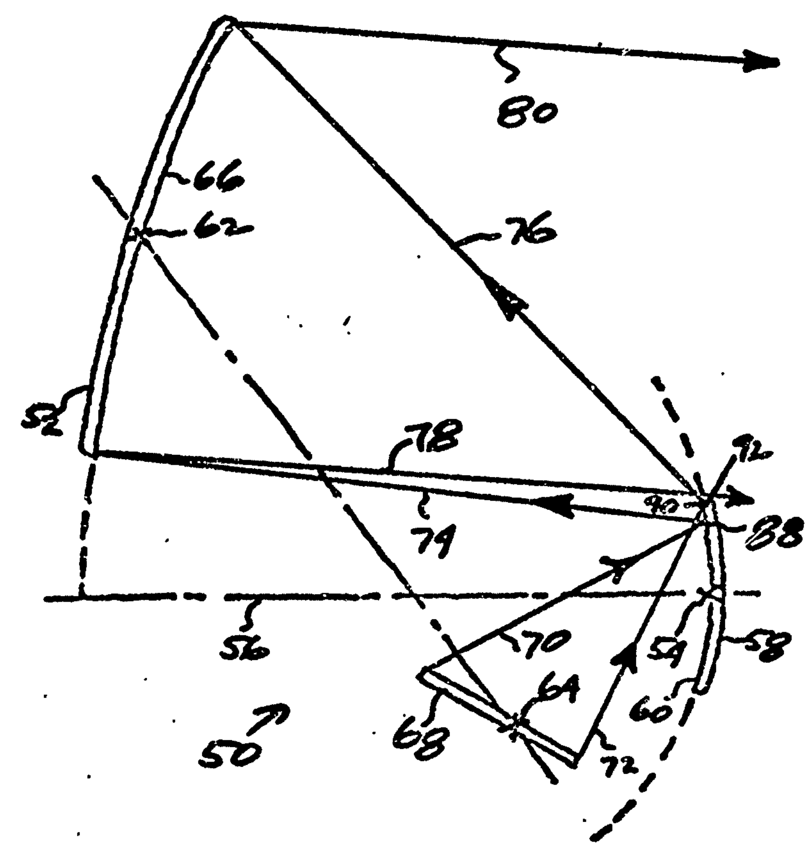


FIGURE 4
NAVY CASE 66,531

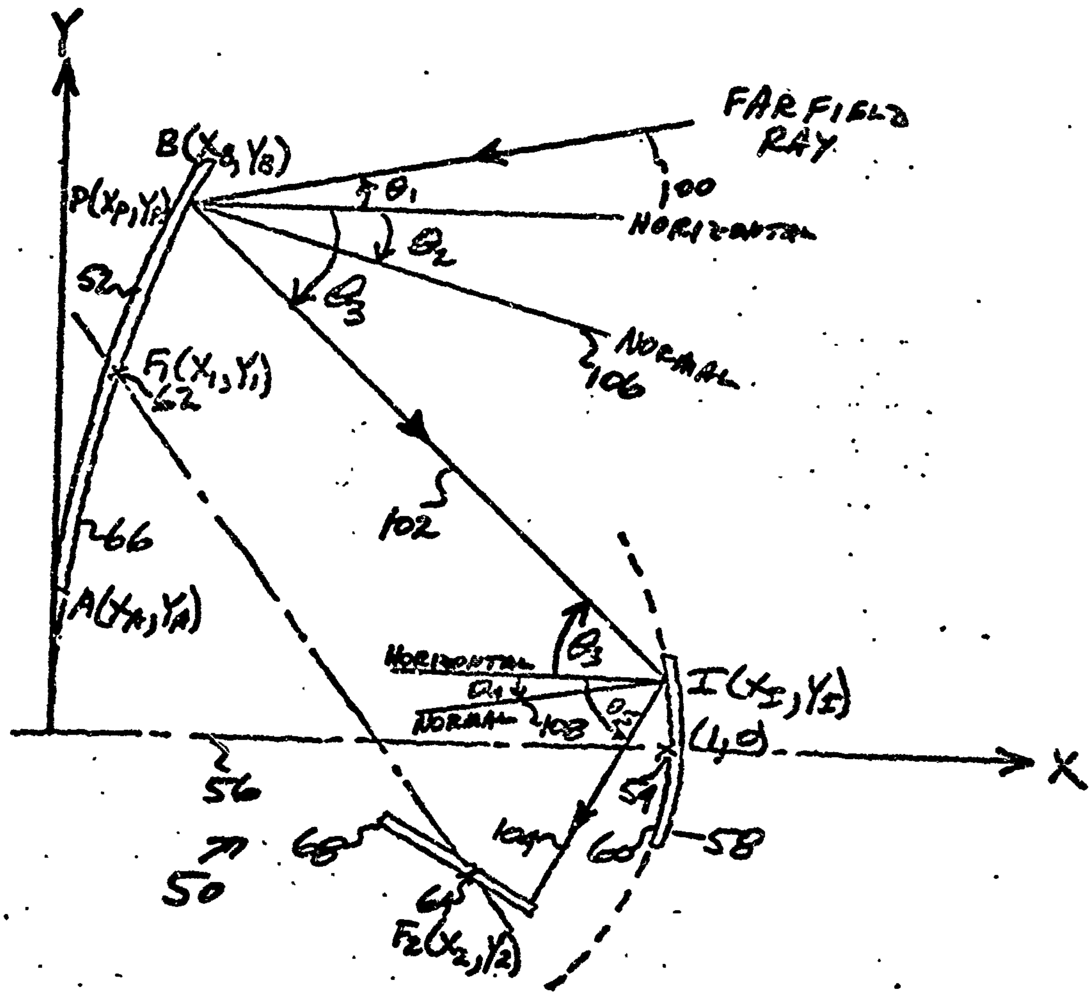


FIGURE 5

NAVY CASE 66,5

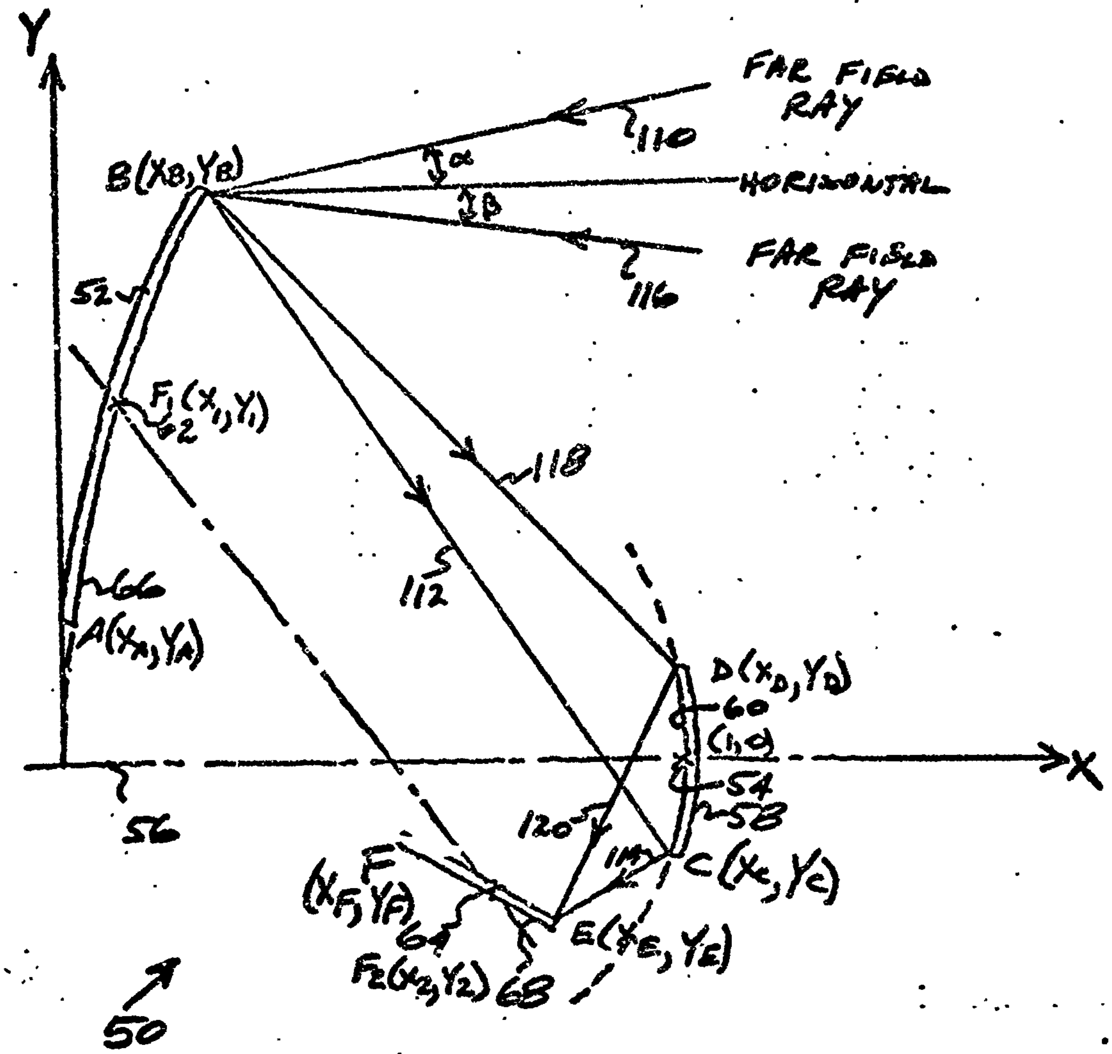


FIGURE 6

NAVY CASE 66,521

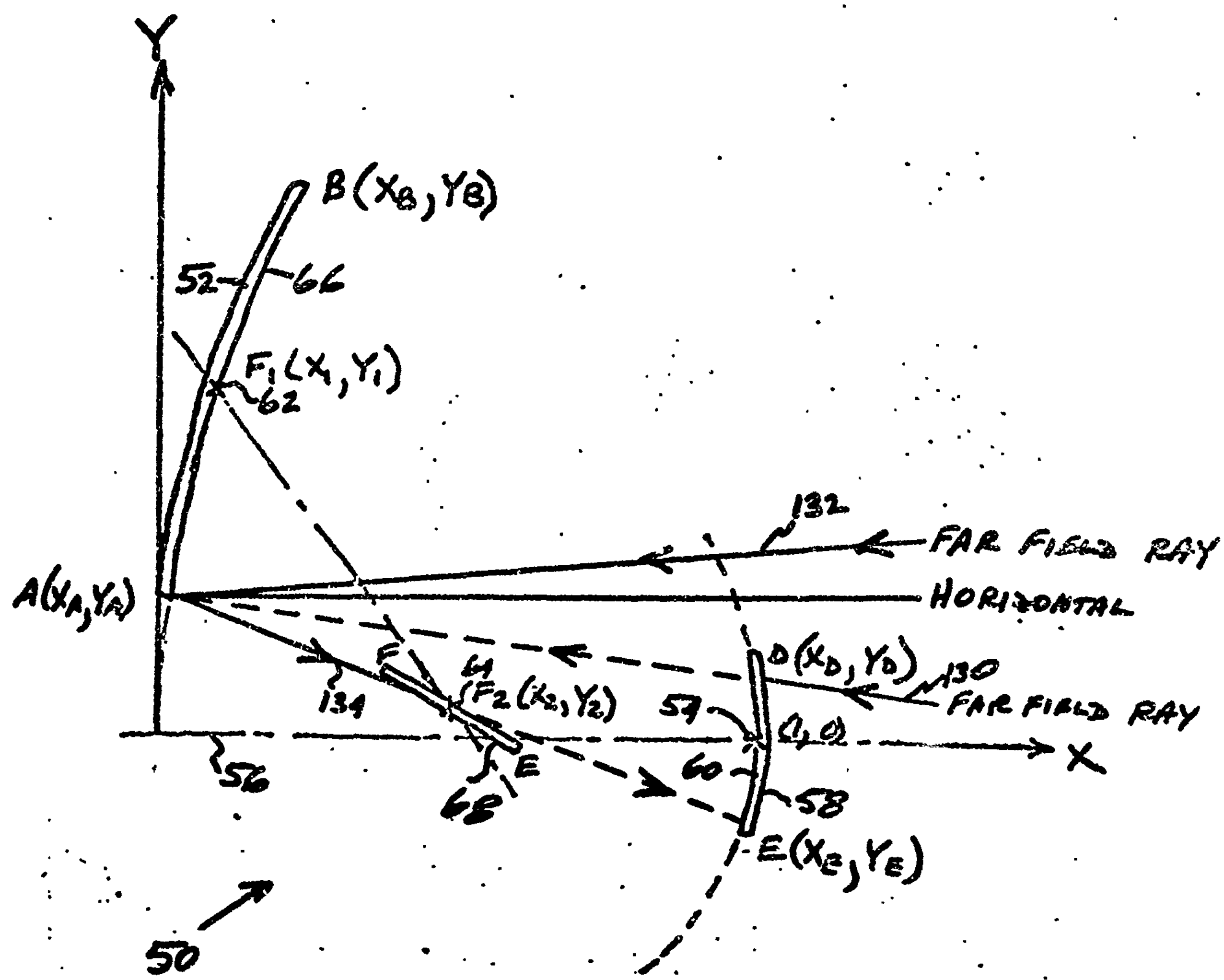


FIGURE 7

NAVY CASE 66,53,

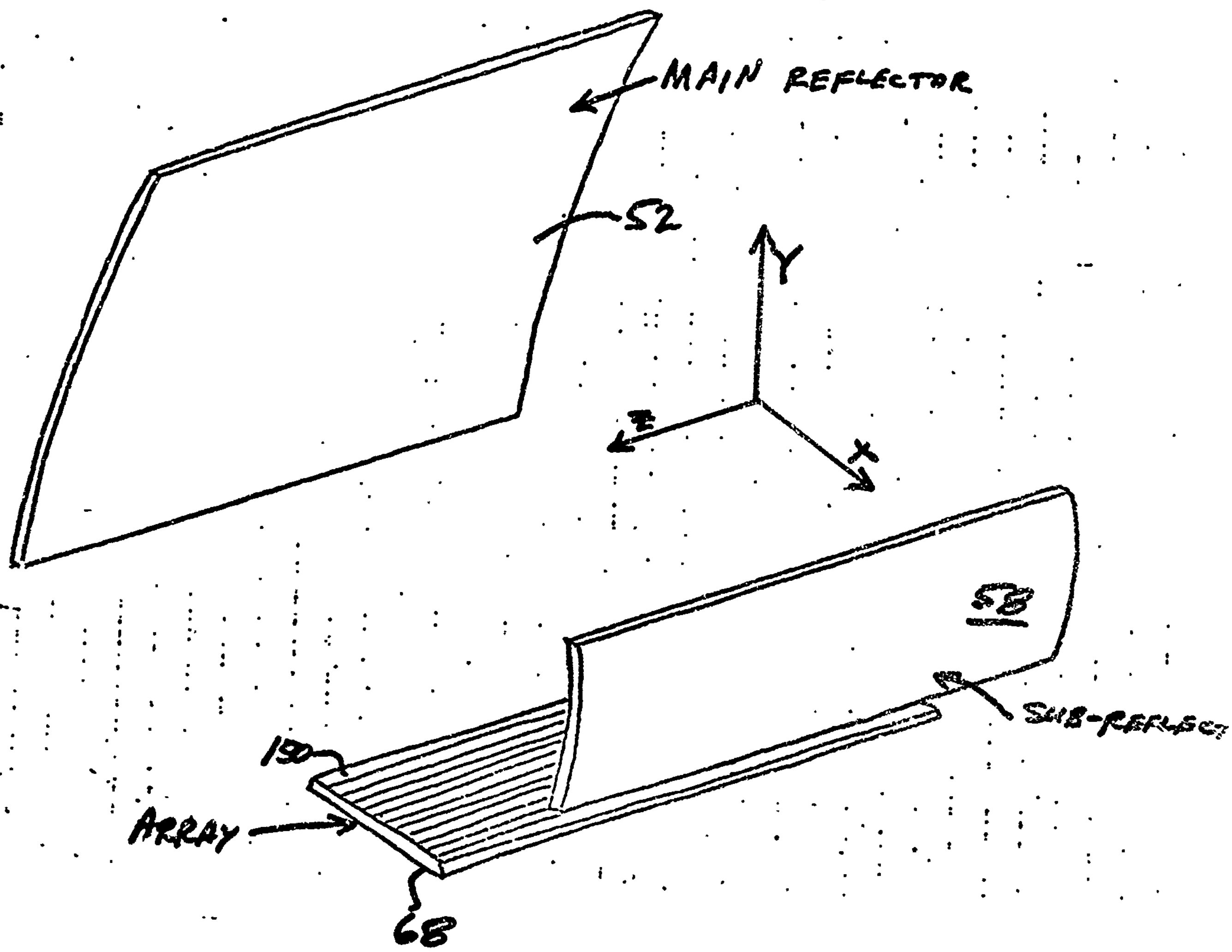


FIGURE 8

NAVY CASE 66,531

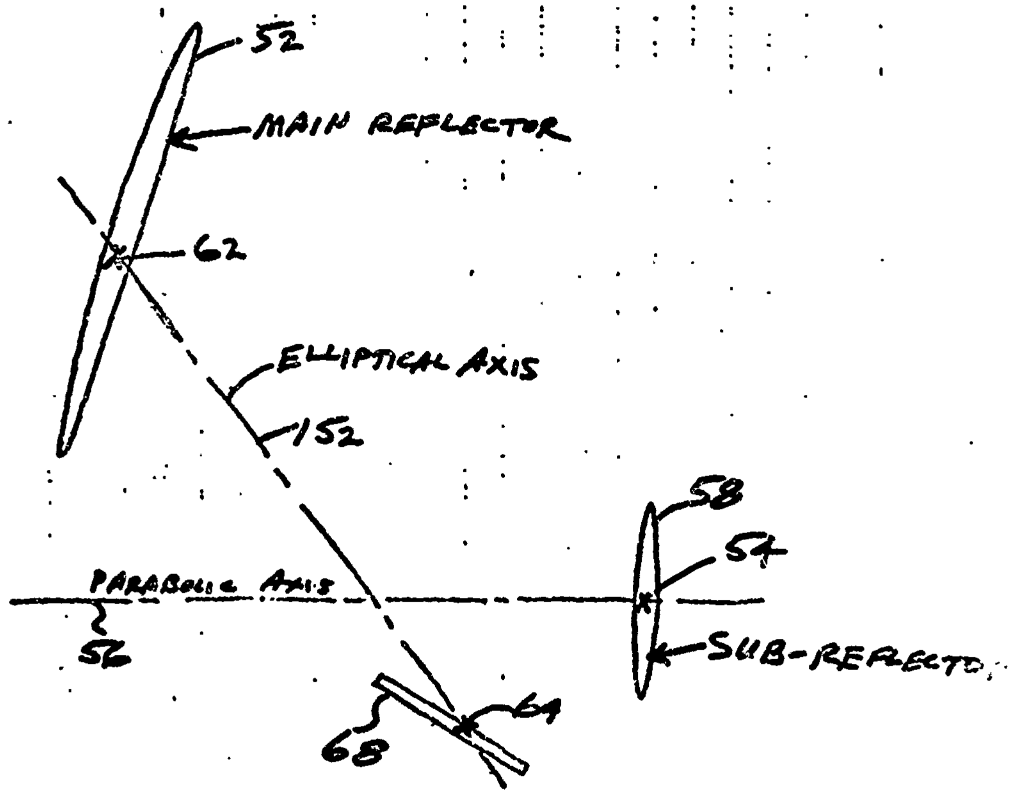


FIGURE 9

NAVY CASE 66,5