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(54) Title: VARIABLE STAGGER REFLECTOR FOR AZIMUTH BEAM WIDTH CONTROLLED ANTENNA

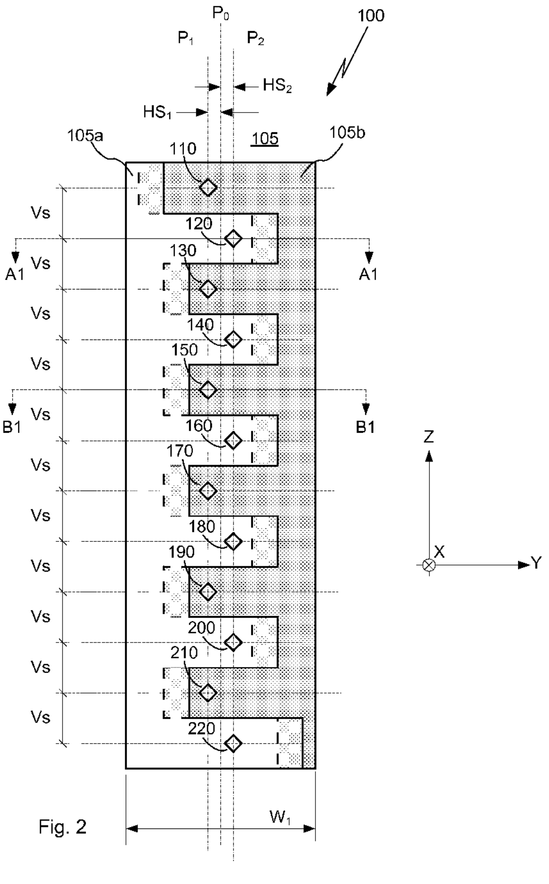

Fig. 2

(57) **Abstract:** An antenna array (100) with variably controlled reflector stagger is disclosed. The antenna array (100) contains a plurality of driven radiating elements (110, 120) that are spatially arranged having each radiating element or element groups orthogonally movable relative to a main vertical axis. This configuration provides a controlled variation of the antenna array's azimuth radiation pattern without excessive side lobe radiation over a full range of settings.

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VARIABLE STAGGER REFLECTOR FOR AZIMUTH BEAM WIDTH CONTROLLED ANTENNA

RELATED APPLICATION INFORMATION

The present application claims priority to US provisional patent application serial no. 61/002,635 filed November 9, 2007, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to communication systems and components. More particularly the present invention is directed to antennas and antenna arrays employed in wireless communications systems.

2. Description of the Prior Art and Related Background Information

Modern wireless antenna implementations generally include a plurality of radiating elements that may be arranged over a reflector plane defining a radiated (and received) signal beam width and azimuth scan angle. Azimuth antenna beam width can be advantageously modified by varying the amplitude and phase of an RF signal applied to respective radiating elements. Azimuth antenna beam width has been conventionally defined by Half Power Beam Width (HPBW) of the azimuth beam relative to a bore sight of such antenna array. In such an antenna array structure, radiating element positioning is important to the overall beam width control as such antenna systems rely on accuracy of amplitude and phase angle of RF signal supplied to each radiating element. This places a requirement for a great deal of tolerance and accuracy on a mechanical phase shifter to provide the required signal division between various radiating elements over various azimuth bandwidth settings.

Real world applications often call for an antenna array with beam down tilt and azimuth beam width control that may incorporate a plurality of mechanical phase shifters to achieve such functionality. Such highly functional antenna arrays are typically retrofitted in place of simpler, lighter and less functional antenna arrays while weight and wind loading of the newly installed antenna array can not be significantly increased. Accuracy of a mechanical phase shifter generally depends on its construction materials. Generally, highly accurate mechanical phase shifter implementations require substantial amounts of relatively expensive dielectric materials and rigid mechanical support. Such construction techniques result in additional size and weight not to mention being relatively expensive. Additionally, mechanical phase shifter configurations that have been developed utilizing lower cost materials may fail to provide adequate passive intermodulation suppression under high power RF signal levels.

Consequently, there is a need to provide a simpler method to adjust antenna beam width control.

SUMMARY OF THE INVENTION

In a first aspect the present invention provides an antenna for a wireless network comprising a first generally planar reflector having a first plurality of radiators mounted thereon and a second generally planar reflector having a second plurality of radiators mounted thereon, the second generally planar reflector configured in a variable partial overlapping relation with the first generally planar reflector. At least one of the first and second generally planar reflectors is movable relative to the other reflector in a direction generally parallel to the reflector plane and the radiators mounted on the reflectors are reconfigurable from a first configuration where the radiators are all aligned to a second configuration where the radiators are staggered relative to each other.

In a preferred embodiment of the antenna the first and second plurality of radiators comprise radiating elements extending perpendicular to the plane of the respective reflectors. At least one of the first and second reflectors has a comb-like structure having a plurality of notched portions configured in alignment with the radiators on the other reflector. The first and second plurality of radiators are arranged in first and second columns respectively on the first and second reflectors. The first and second plurality of radiators in each of the first and second columns are preferably equally spaced along the length direction of the columns. In the first configuration the first and second columns may be aligned along a centerline and the first and second plurality of radiators are equally spaced apart a distance Vs. In the second configuration the first and second columns are not aligned and the first and second plurality of radiators are spaced apart a stagger distance SD which is greater than Vs. More specifically, in the second configuration the first and second columns may be spaced in opposite directions from the centerline by a distance HS_1 and HS_2 respectively and the stagger distance SD of the radiators is given by

$$SD = \sqrt{HS^2 + \mathrm{VS}^2} \text{ where } \mathrm{HS} = \mathrm{HS}_1 = \mathrm{HS}_2 .$$

As one example, the operating frequency of the antenna may be between 1.7 GHz and 2.2 GHz and the spacing Vs is between about 75 to 125 mm. The spacing HS_1 and HS_2 may be variable between 0 and 40 mm.

In another aspect the present invention provides a variable azimuth beam width antenna comprising a reflector structure, the reflector structure comprising first and second generally planar reflector panels each having plural alternating extensions and notched portions forming a comb shape, wherein the first and second generally planar reflector panels are interdigitated to form a generally rectangular shape for the reflector structure and wherein one or both of the panels are movable relative to the other to provide a variable overlap. The antenna further comprises a first plurality of radiators mounted on the first reflector panel in the plural extensions thereof and a second plurality of radiators mounted on the second reflector panel in the plural extensions thereof. Signal azimuth beam width is variable based on variable relative positioning of the first plurality of radiators and the second plurality of radiators as the first and second reflector panel overlap is varied.

In a preferred embodiment of the antenna the reflector structure has a variable width as the first and second reflector panel overlap is varied. As one example, the operating frequency of the antenna may be between 1.7 GHz and 2.2 GHz and the reflector structure width is variable between about 120 mm and 200 mm. The beam width of the antenna may be variable between about 100 degrees and 47 degrees. The first plurality of radiators mounted on the first reflector panel are preferably arranged in a first column aligned perpendicular to the azimuth direction and the second plurality of radiators mounted on the second reflector panel are preferably arranged in a second column also aligned perpendicular to the azimuth direction and the spacing of the first and second columns is varied as the reflector panel overlap is varied.

In another aspect the present invention provides a method of adjusting signal beam width in an antenna having first and second generally comb shaped planar reflector panels each having a plurality of radiators mounted thereon. The method comprises adjusting the position of at least one of the panels by moving the panel in a direction generally parallel to the plane of the reflector to a first configuration having plural interdigitated first and second radiators on the first and second reflector panels with a first spacing to provide a first signal beam width. The method further comprises adjusting the position of at least one of the panels by moving the panel in a direction generally parallel to the plane of the reflector to a second configuration having interdigitated first and second radiators with a second different spacing to provide a second signal beam width.

In a preferred embodiment of the method, in the first configuration all radiators are aligned with a center line of the reflector and in the second configuration alternate radiators are offset from the center line of the reflector in opposite directions. In the first configuration the beam width is then greater than in the second configuration. The beam width of the antenna may be variable between about 100 degrees and 47 degrees. The first and second reflector panels together preferably form a rectangular reflector structure having a width which is variable, for example between about 120 mm and 200 mm.

Further features and advantages of the present invention will be appreciated from the following detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a front view of a variable reflector stagger antenna array in accordance with a preferred embodiment of the invention in wide azimuth beam width setting.

Figure 2 is a front view of a variable reflector stagger antenna array in accordance with a preferred embodiment of the invention in narrow azimuth beam width setting.

Figure 3A provides cross sectional view details along A-A and B-B datum detailing the motion of a dual polarized antenna element corresponding to wide azimuth beam width setting.

Figure 3B provides cross sectional view details along A1-A1 and B1-B1 datum detailing the motion of a dual polarized antenna element corresponding to narrow azimuth beam width setting.

Figure 4 is the simulated azimuth radiation pattern of an antenna in accordance with the invention configured for wide azimuth beam width ($97.6 \leq HPBW \leq 99.7$deg), minimum reflector stagger +/- 0.00mm.

Figure 5 is the simulated azimuth radiation pattern of an antenna in accordance with the invention configured for intermediate azimuth beam width ($73.8 \leq HPBW \leq 79.8$deg), reflector stagger +/- 20.0mm.

Figure 6 is the simulated azimuth radiation pattern of an antenna in accordance with the invention configured for intermediate azimuth beam width ($46.9 \leq HPBW \leq 57$deg), reflector stagger +/- 40.0mm.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides an azimuth beam width variable antenna array for a wireless network system and related methods of beam width control. Reference will be made to the accompanying drawings, which assist in illustrating the various pertinent features of the present invention. Also the teachings of U.S. provisional application serial no. 60/922,130 filed April 6, 2007 and utility patent application serial No. 12/080,483 filed April 3, 2008 are incorporated herein by reference in their entirety.

Figure 1 shows a front view of a dual polarization, staggerable reflector antenna array, 100, according to an exemplary implementation, which utilizes twin element staggerable reflector plates or panels 105a and 105b. As may be seen these panels each have a comb shape which together form an interdigitated structure. More specifically, the two reflector plates 105a and 105b are oriented in a vertical orientation (Z-dimension) of the antenna array together forming a rectangular shaped reflector 105. Reflector plates 105a and 105b may, for example, consist of electrically conductive plates suitable for use with Radio Frequency (RF) signals. Further, reflector plates 105a and 105b when combined together are shown as a featureless rectangle, but in actual practice additional details such as outer perimeter augmentation (not shown) may be added to aid reflector performance and HPBW control.

Continuing with reference to Figure 1 an antenna array, 100, contains a plurality of RF radiating (110, 120, 130, 140 -to- 220) elements preferably arranged both vertically and horizontally along operationally defined vertical axis P0 which corresponds to a minimum stagger distance O1. RF radiating (110, 120, 130, 140 -to- 220) elements are preferably equidistantly spaced a distance Vs as shown; alternatively unequal elements groupings and offset vertical arrangements can also be employed. The illustrated embodiment utilizes 12 radiating elements, however it shall be understood that the number of radiating elements can be greater or fewer depending on performance requirements and other implementation requirements.

The first group of RF radiating (120, 140, 160, 180, 200, and 220) elements are rigidly attached (122, 142, 162, 182, 202, and 222) to the left side reflector plate 105a along P1 axis common to the reflector plate 105a. The second group of RF radiating (110, 130, 150, 170, 190, and 210) elements are rigidly attached (112, 132, 152, 172, 192, and 212) to the right side reflector plate 105b along P2 axis common to the reflector plate 105b. Both left 105a and right reflector plates utilize a comb style shape with extensions and notched portions which are interdigitated to allow for interference free radiating element positioning while providing a substantially homogenous reflector plane. In the illustrated embodiment left reflector plate 105a is set to overlay right reflector plate 105b.

The two reflector plates 105a and 105b are equidistantly movable about vertical center axis P0, in opposite directions having identical lateral displacement HS1 & HS2. One skilled in the art can readily implement a simple electro-mechanical actuator (not shown) that can provide such controlled lateral movement. Alternatively, unequal shifting about center axis P0 is possible, such that displacement $|HS1| \neq |HS2|$.

Consider operational case HS1 = HS2 = 0 which is when all radiating (110, 120, 130, 140 -to- 220) elements are aligned vertically along center axis P0 - and respective common axis P1 and P2 are in alignment. P1 and P2 being the same as center axis P0 corresponds to a minimum overlap, O1= minimum, and overall combined antenna reflector W1=maximum dimension. Such reflector configuration corresponds to the widest possible azimuth HPBW (see Table 1). Inter-radiating element spacing SD is given by:

$$SD = VS$$

At another extreme consider operational case ABS(HS1) = ABS(HS2) = maximum when the two reflector plates 105a and 105b have maximum mutual overlap, O1= maximum, and overall combined antenna reflector 105 dimension W1=minimum dimension. Such reflector configuration corresponds to the narrowest possible azimuth HPBW (see Table 1). Inter-radiating element spacing SD is given by:

$SD = \sqrt{HS^2 + \mathrm{VS}^2}$ where HS = $HS_1 = HS_2$

Through computer simulations and direct EM field measurement it was determined that the azimuth radiation beam pattern can be deduced from the above formula. By varying the HS dimension desired azimuth beam width settings can be attained. VS dimension is defined by the overall length of the reflector 105 plane which defines the effective antenna aperture.

In the illustrative non-limiting implementation shown, RF radiator, 105, together with a plurality of folded dipole (110, 120, 130, 140 -to- 250) radiating elements forms an antenna array useful for RF signal transmission and reception. However, it shall be understood that alternative radiating elements, such as taper slot, horn, aperture coupled patches (APC), etc., can be used as well.

A cross section datum A-A and B-B will be used to detail constructional and operational aspects relating to reflector plates 105a and 105b relative movement with respect to each other. Drawing details of A-A and B-B datum can be found in Figure 3A. Minimum reflector overlap O1 dimension is preferably not 0mm, but has an additional mechanical safety margin to prevent reflector planes from disengaging each other at minimum overlap settings. Figure 3B provides cross sectional views along A1-A1 and B1-B1 datum of Figure 2.

Figures 4, 5, and 6 provide azimuth radiation patterns for different stagger settings. Preferred dimensions for a 1.7 GHz to 2.2 GHz embodiment are shown in Table 1. Other frequency ranges and dimensions are also possible, however.

Table 1

Element	Dimension	Min (mm)	Max (mm)	Typical (mm)
Vertical radiating element spacing	Vs	75	125	
Reflector Width	W1	120	200	
Reflector movement	HS1, HS2	0	40	
Overlap	O1	20	60	
HPBW	HPBW	99.7 deg	46.9 deg	

The present invention has been described primarily in solving aforementioned problems. However, it should be expressly understood that the present invention may be applicable in other applications wherein azimuth beam width control is required or desired. In this regard, the foregoing description of a reflector offset stagger, vertically and dually polarized antenna array equipped with stagger-able reflectors is presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Accordingly, variants and modifications consistent with the following teachings, and skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments described herein are further intended to explain modes known for practicing the invention disclosed herewith and to enable others skilled in the art to utilize the invention in equivalent, or alternative embodiments and with various modifications considered necessary by the particular application(s) or use(s) of the present invention.

WHAT IS CLAIMED IS:

1. An antenna for a wireless network, comprising:

a first generally planar reflector having a first plurality of radiators mounted thereon; and

a second generally planar reflector having a second plurality of radiators mounted thereon, said second generally planar reflector configured in a variable partial overlapping relation with said first generally planar reflector;

wherein at least one of the first and second generally planar reflectors is movable relative to the other reflector in a direction generally parallel to the reflector plane, wherein the radiators mounted on the reflectors are reconfigurable from a first configuration where the radiators are all aligned to a second configuration where the radiators are staggered relative to each other.

2. The antenna of claim 1, wherein the first and second plurality of radiators comprise radiating elements extending perpendicular to the plane of the respective reflectors.

3. The antenna of claim 1, wherein at least one of the first and second reflectors has a comb-like structure having a plurality of notched portions configured in alignment with the radiators on the other reflector.

4. The antenna of claim 1, wherein the first and second plurality of radiators are arranged in first and second columns respectively on the first and second reflectors.

5. The antenna of claim 4, wherein the first and second plurality of radiators in each of said first and second columns are equally spaced along the length direction of the columns.

6. The antenna of claim 5, wherein in said first configuration the first and second columns are aligned along a centerline and the first and second plurality of radiators are equally spaced apart a distance Vs.

7. The antenna of claim 6, wherein in said second configuration the first and second columns are not aligned and the first and second plurality of radiators are spaced apart a stagger distance SD which is greater than Vs.

8. The antenna of claim 7, wherein in the second configuration the first and second columns are spaced in opposite directions from the centerline by a distance HS_1 and HS_2 respectively and wherein said stagger distance SD of the radiators is given by

$$SD = \sqrt{HS^2 + \mathrm{VS}^2} \text{ where } HS = HS_1 = HS_2 .$$

9. The antenna of claim 8, wherein the operating frequency of the antenna is between 1.7 GHz and 2.2 GHz and wherein said spacing Vs is between about 75 to 125 mm.

10. The antenna of claim 8, wherein the spacing HS_1 and HS_2 is variable between 0 and 40 mm.

11. A variable azimuth beam width antenna, comprising:

a reflector structure comprising first and second generally planar reflector panels each having plural alternating extensions and notched portions forming a comb shape, wherein the first and second generally planar reflector panels are interdigitated to form a generally rectangular shape for the reflector structure and wherein one or both of the panels are movable relative to the other to provide a variable overlap;

a first plurality of radiators mounted on the first reflector panel in the plural extensions thereof; and

a second plurality of radiators mounted on the second reflector panel in the plural extensions thereof;

wherein signal azimuth beam width is variable based on variable relative positioning of the first plurality of radiators and the second plurality of radiators as the first and second reflector panel overlap is varied.

12. The antenna of claim 11, wherein the reflector structure has a variable width as the first and second reflector panel overlap is varied.

13. The antenna of claim 12, wherein the operating frequency of the antenna is between 1.7 GHz and 2.2 GHz and wherein said reflector structure width is variable between about 120 mm and 200 mm.

14. The antenna of claim 12, wherein the beam width of the antenna is variable between about 100 degrees and 47 degrees.

15. The antenna of claim 11, wherein the first plurality of radiators mounted on the first reflector panel are arranged in a first column aligned perpendicular to the azimuth direction and the second plurality of radiators mounted on the second reflector panel are arranged in a second column aligned perpendicular to the azimuth direction and wherein the spacing of the first and second columns is varied as the reflector panel overlap is varied.

16. A method of adjusting signal beam width in an antenna having first and second generally comb shaped planar reflector panels each having a plurality of radiators mounted thereon, the method comprising:

adjusting the position of at least one of the panels by moving the panel in a direction generally parallel to the plane of the reflector to a first configuration having plural interdigitated first and second radiators on said first and second reflector panels with a first spacing to provide a first signal beam width; and

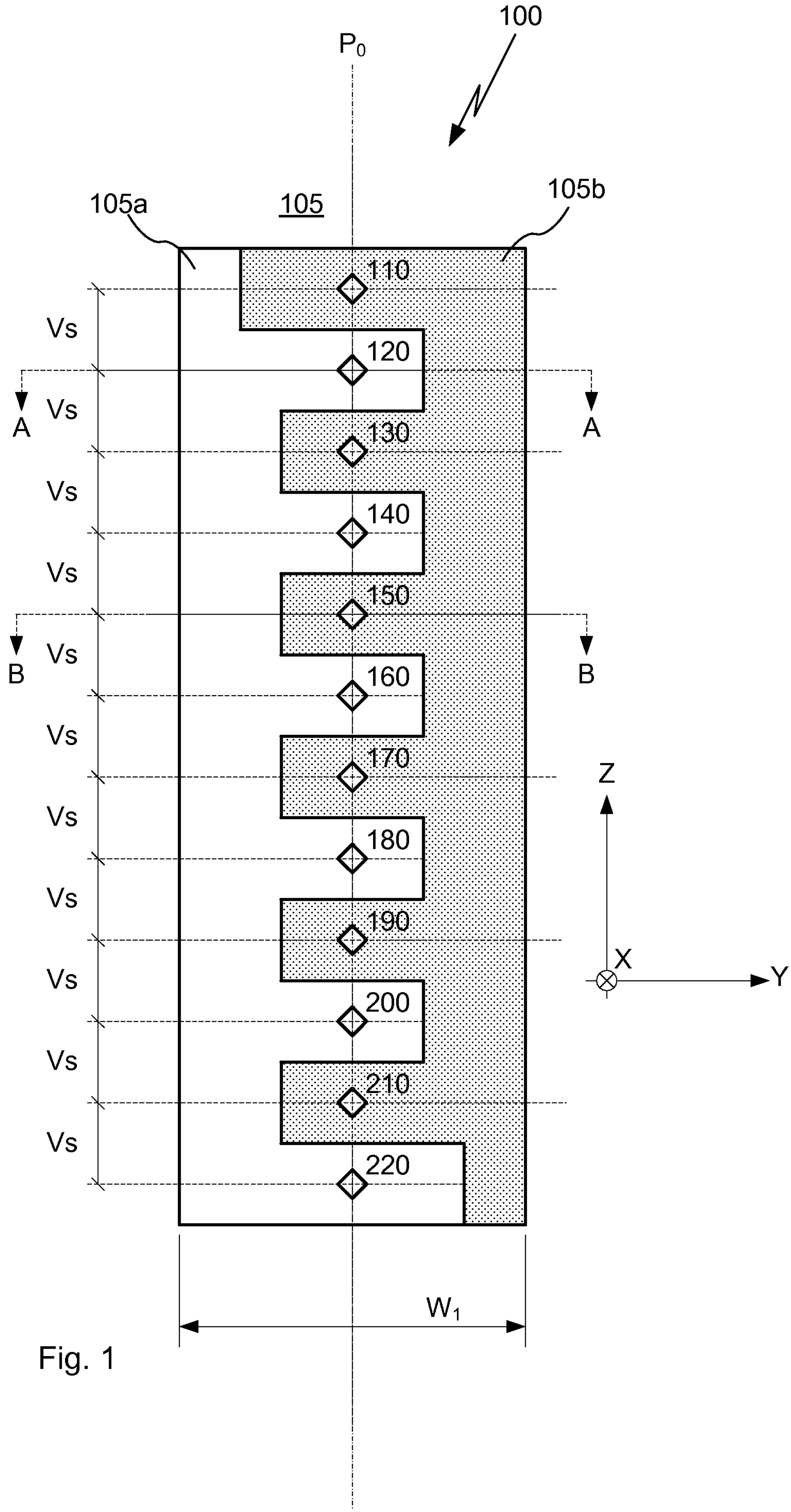
adjusting the position of at least one of the panels by moving the panel in a direction generally parallel to the plane of the reflector to a second configuration having interdigitated first and second radiators with a second different spacing to provide a second signal beam width.

17. The method of claim 16, wherein in the first configuration all radiators are aligned with a center line of the reflector and wherein in the second configuration alternate radiators are offset from the center line of the reflector in opposite directions.

18. The method of claim 17, wherein in the first configuration the beam width is greater than in said second configuration.

19. The method of claim 16, wherein the beam width of the antenna is variable between about 100 degrees and 47 degrees.

20. The method of claim 16, wherein the first and second reflector panels together form a rectangular reflector structure having a width which is variable between about 120 mm and 200 mm.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A
B
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X
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W_1

Fig. 1

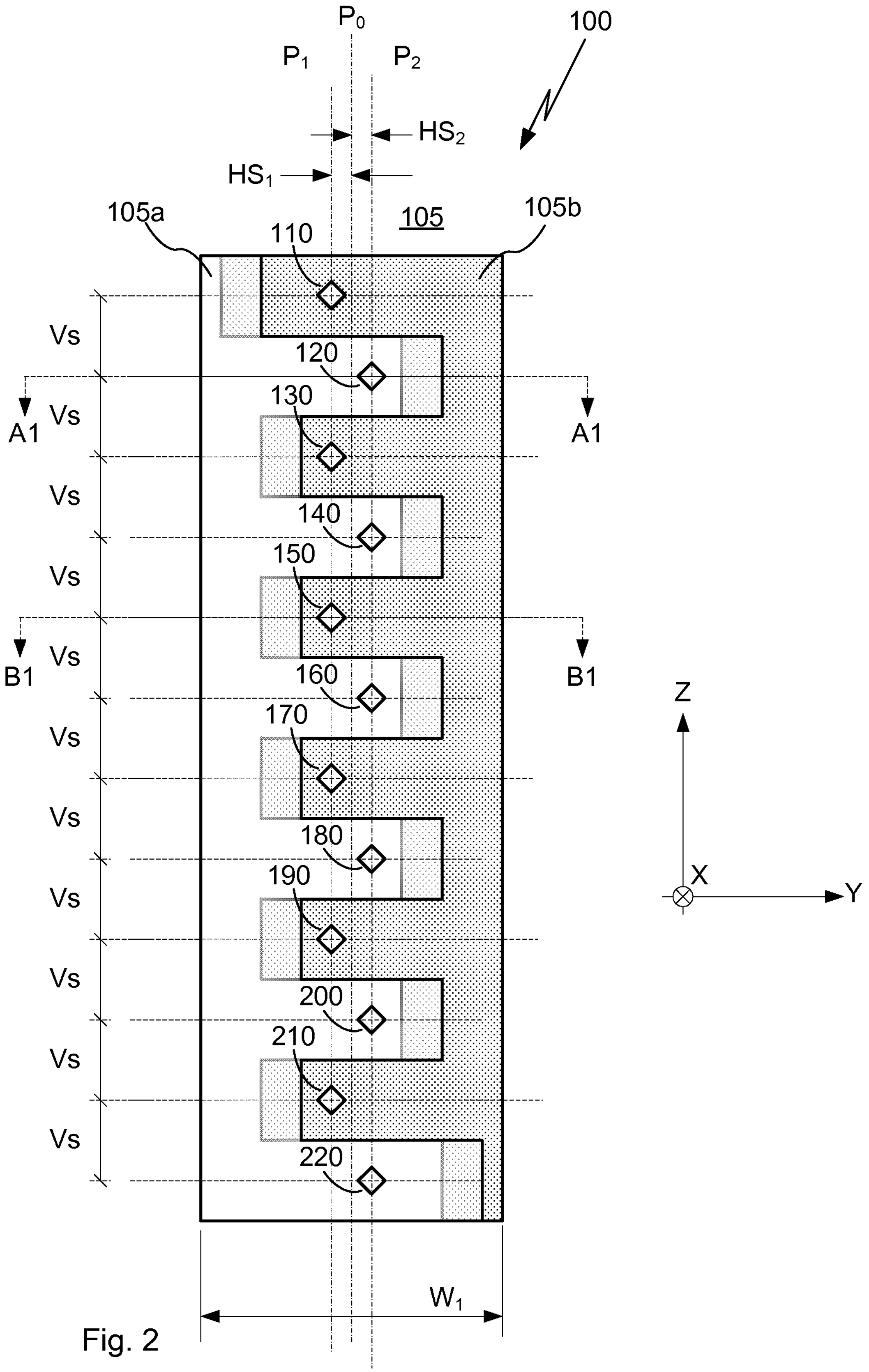
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Fig. 2

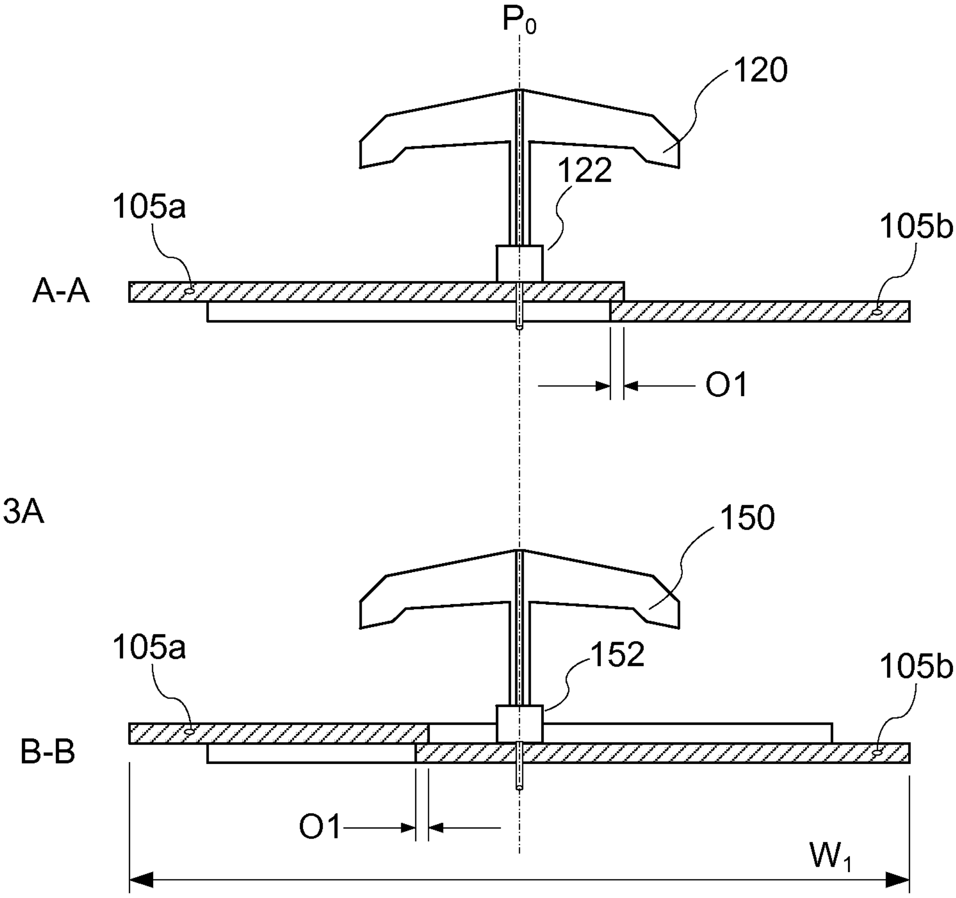
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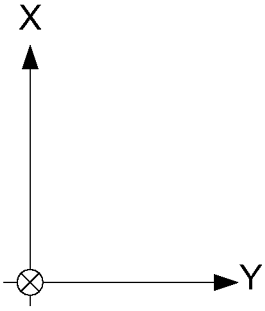
Fig. 3A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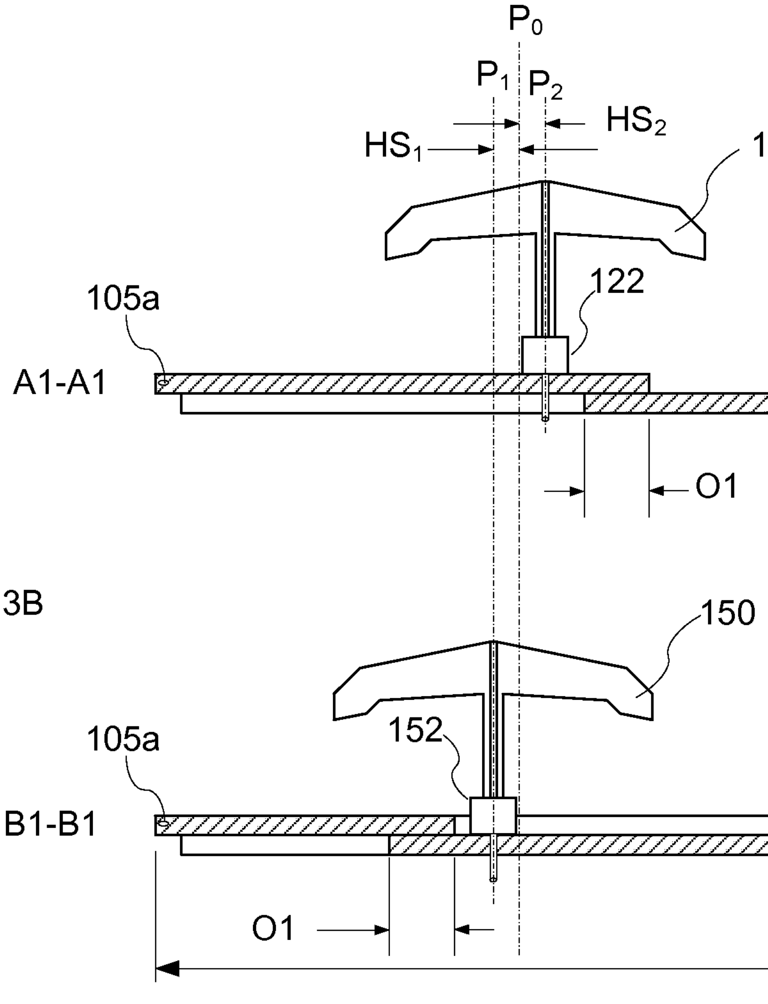
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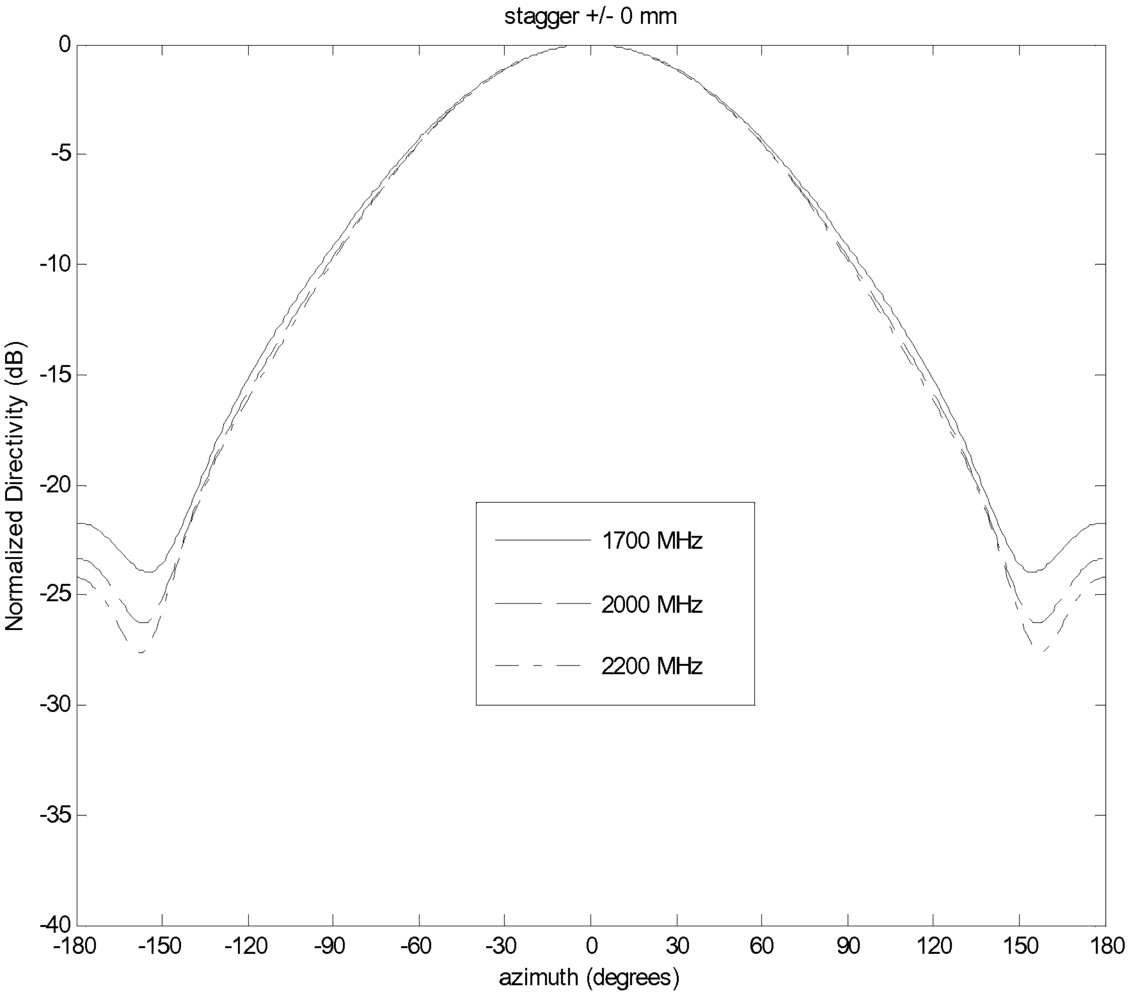
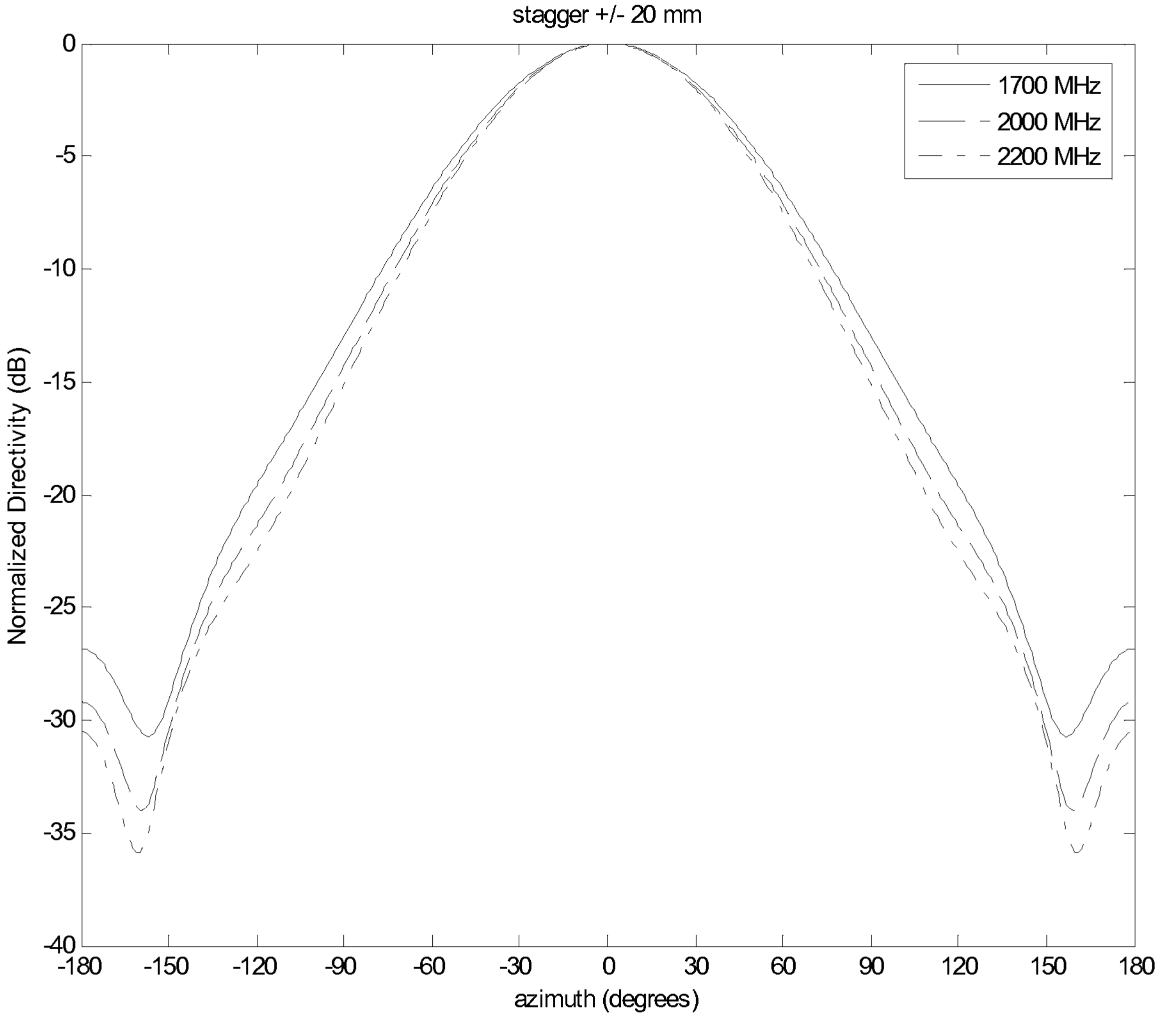
Fig. 3B



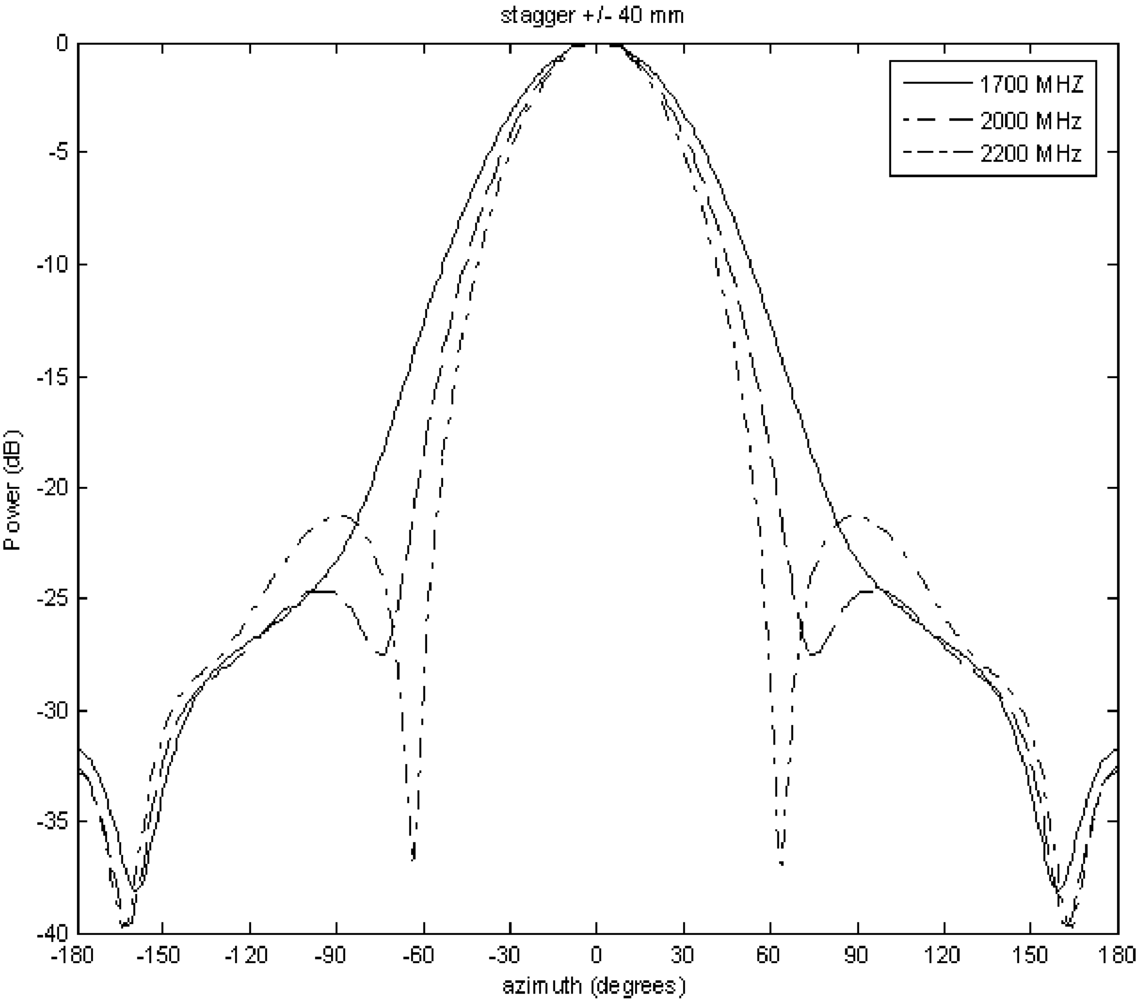
97.6° < HPBW < 99.7°

Fig. 4



73.8° < HPBW < 79.8°

Fig. 5



46.9° < HPBW < 57°

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/82697

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 35/00 (2008.04)
USPC - 343/700R
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 343/700R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 343/700R, 700MS, 824 keyword limited - see search terms below

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB,USPT,USOC,EPAB,JPAB), Google Scholar, Google Patent
Search terms: antenna, cellular, azimuth, beam width, reflector, variable, stagger, radiator, steering, mechanical, movable, reposition, array, column, element, wireless, changeable, adjustable, control, spacing, distance, pattern, align, separated

C DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0030249 A1 (GABRIEL et al.) 10 February 2005 (10.02.2005), para [0002-[0003], [0013]-[0014], [0028], [0053], [0057], Fig. 1	1-20
Y	US 2005/0057417 A1 (TEILLET et al.) 17 March 2005 (17.03.2005), para [0007], [0029]	1-10
Y	US 2006/0192716 A1 (KIM) 31 August 2006 (31.08.2006), para [0014], [0021], [0048]	11-20
Y	US 6,323,823 B1 (WONG et al.) 27 November 2001 (27.11.2001), col 4, ln 51-55, col 5, ln 62 to col 6, ln 4	9, 13

☐ Further documents are listed in the continuation of Box C. ☐

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Date of the actual completion of the international search
07 December 2008 (07.12.2008)

Date of mailing of the international search report
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