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(54) **Reflective line source**

(57) There is provided a reflective line source 100 for an antenna system. The reflective line source 100 comprises at least one region 104 adapted to receive an electromagnetic field and to expand the field in at least one dimension. The reflective line source 100 further comprises a reflective phase compensator 108 that is coupled to the region 104. The reflective phase compensator 108 is adapted to correct a phase error resulting from propagation of the field through the region 104 as well as to fold a direction of propagation of the field. For this purpose, the reflective phase compensator 108 comprises at least two reflective phase compensating surfaces oriented at ninety degrees relative to one another.

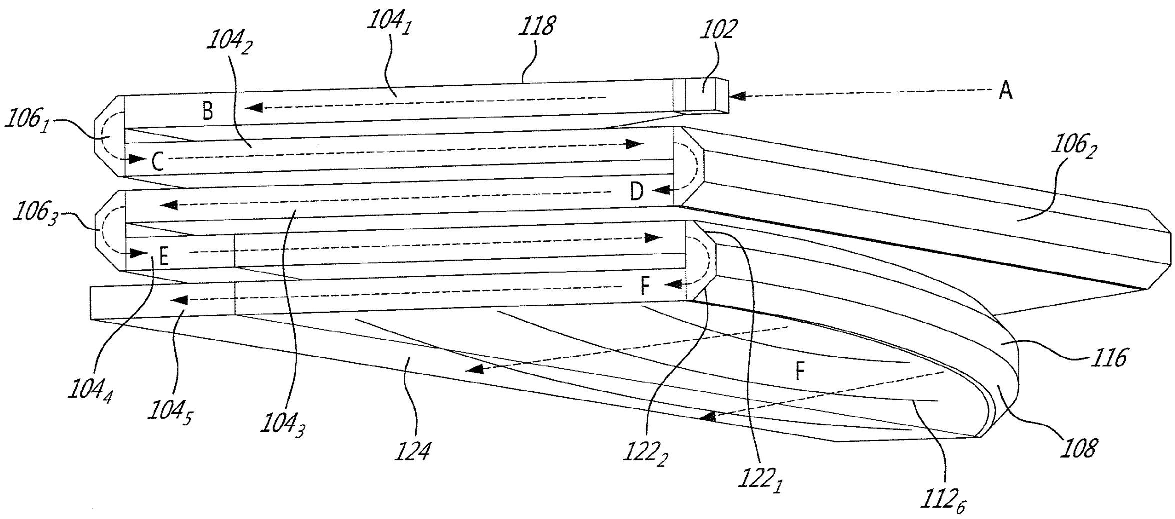

FIG. 3a

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Description

TECHNICAL FIELD

[0001] The present invention relates to the field of line sources.

BACKGROUND OF THE ART

[0002] A line source may be used in a waveguide antenna to expand a point source in one direction. Such a line source can be used as an input source to feed a larger two-dimensional aperture antenna, such as a sectoral horn. The line source may also be used solely as a line source emitter.

[0003] When used to expand an input electromagnetic field over a large frequency bandwidth, structures used to create conventional line sources typically introduce arbitrary phase errors and ohmic losses. Complex assembly is also required, making it difficult to achieve a low weight and compact size antenna, as desired for aeronautical applications and the like.

[0004] There is therefore a need for an improved line source.

SUMMARY

[0005] In accordance with a first broad aspect, there is provided a reflective line source comprising at least one region adapted to receive thereat an input electromagnetic field and to expand the input electromagnetic field in at least one dimension and at least one reflective phase compensator coupled to the at least one region, the at least one reflective phase compensator adapted to fold a direction of propagation of the expanded electromagnetic field and correct a phase error thereof.

[0006] In accordance with a second broad aspect, there is provided a method for manufacturing a reflective line source, the method comprising providing at least one region adapted to receive thereat an input electromagnetic field and to expand the input electromagnetic field in at least one dimension and coupling at least one reflective phase compensator to the at least one region, the at least one reflective phase compensator adapted to fold a direction of propagation of the expanded electromagnetic field and correct a phase error thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

[0008] Figure 1 is a perspective view of a folded reflective line source in accordance with an illustrative embodiment of the present invention;

[0009] Figure 2a is a schematic diagram of a taper region of Figure 1;

[0010] Figure 2b is a bottom view of the folded reflective line source of Figure 1;

[0011] Figure 2c is a schematic diagram of a reflective phase compensator of Figure 1;

[0012] Figure 3a is a perspective cross-sectional view of the folded reflective line source of Figure 1;

[0013] Figure 3b is a perspective view of the folded reflective line source of Figure 1 with an input beam propagating through a first taper region;

[0014] Figure 3c is a schematic diagram of a reflector of Figure 3a;

[0015] Figure 3d is a perspective view of the folded reflective line source with the input electromagnetic field of Figure 3b propagating through the first and a second taper region;

[0016] Figure 3e is a perspective view of the folded reflective line source with the input electromagnetic field of Figure 3b propagating through a second, a third and a fourth taper region;

[0017] Figure 4a is a plot of the phase error for the folded reflective line source of Figure 1 prior to compensation using the reflective phase compensator;

[0018] Figure 4b is a plot of the phase error for the folded reflective line source of Figure 1 after compensation;

[0019] Figure 5a is a bottom perspective view of a folded reflective line source integrated with an E-plane sectoral horn in accordance with an illustrative embodiment of the present invention;

[0020] Figure 5b is a front perspective view of the folded reflective line source integrated with the E-plane sectoral horn of Figure 5a;

[0021] Figure 6 is a plot of modeled and measured results of the azimuth far field gain pattern for the folded reflective line source integrated with the E-plane sectoral horn of Figure 5a; and

[0022] Figure 7 is a flow diagram of a method for manufacturing a folded reflective line source in accordance with an illustrative embodiment of the present invention.

[0023] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION

[0024] Referring to Figure 1, a folded reflective line source 100 in accordance with an illustrative embodiment will now be described. As will be discussed further below, the line source 100 may be used to expand in one direction, e.g. the X direction, a point source fed thereto. As such, the line source 100 may be used as an input source to feed an antenna (not shown), such as an aperture antenna, e.g. a horn, waveguide aperture, reflector, or the like, that emits electromagnetic waves through an opening or aperture. The line source 100 illustrative comprises an input 102, a plurality of expansion regions 104 used to guide therethrough an electromagnetic field received at the input 102, a plurality of 180 degrees elongate reflectors 106 used to fold the direction of propagation of the field by 180 degrees, and a reflective phase compensator 108.

[0025] In particular, as illustrated in Figure 2a, in some embodiments, each expansion region 104 flares away from a first edge 110_1 towards a second edge 110_2 opposite to the first edge 110_1. In this manner, a field 112_1 that has a width w_1 and enters the expansion region 104 at the first edge 110_1 is expanded when propagating down the expansion region 104 towards the second edge. As such, the width w_2 of the field 112_2 exiting the expansion region 104 is illustratively greater than the width w_1 of the field 112_1 entering the expansion region 104. The flare angle θ may be adjusted to achieve the desired flare in the expansion region 104. By increasing the flare angle θ, the rate of flare of the expansion region 104 may be increased, resulting in a faster expansion of the input electromagnetic field 112_1. The flare angle θ of the expansion regions 104 is illustratively comprised between zero and ninety (90) degrees. In one embodiment, one expansion region 104, and more particularly the last expansion region through which the field exits the line source 100, is a straight region that is provided with no taper.

[0026] In addition to expanding the field 112_1, propagation down each tapered one of the expansion regions 104 introduces a phase error between the field 112_1 entering the tapered expansion region 104 and the field 112_2 exiting the tapered expansion region 104. Indeed, the difference between the length d_1 from the center point of the first edge 110_1 of the tapered expansion region 104 to the center point of the second edge 110_2 and the length d_2 along each one of the side edges as in 114 of the tapered expansion region 104 results in a difference between the phase of the field 112_1 and the phase of the field 112_2. In particular, the length d_2 is substantially greater than the length d_1. It should be understood that the greater the flare angle θ of each expansion region 104, the greater the phase error and the higher the need for phase compensation. Indeed, a gentle width expansion would likely not require phase correction. Still, such a gentle expansion would result in the line source as in 100 being several meters in length so as to achieve a half-meter wide output field. In order to ensure the compactness of the line source 100, it is therefore desirable for the width expansion to be rapid and accordingly for phase compensation to be implemented using the reflective phase compensator 108. Although the expansion region 104 has been illustrated in Figure 2a as comprising side edges 114, e.g. metal walls, it should be understood that the expansion regions 104 may be provided without such edges 104.

[0027] Referring now to Figure 2b and Figure 2c, the reflective phase compensator 108 may be used to compensate for the above-mentioned phase error. For this purpose, the phase compensator 108 may be provided to couple a pair of consecutive expansion regions as in 104 of the line source 100. In the embodiment illustrated in Figure 2b, the phase compensator 108 is provided at the end of the second to last expansion region 104. Still, it should be understood that the phase compensator 108 may be provided at the end of any tapered one of the expansion regions 104 and thus may couple any pair of consecutive expansion regions 104. In such cases, the phase compensator 108 may be designed to overcompensate the phase error. In this manner, although the electromagnetic field exiting the phase compensator 108 will propagate through the remaining expansion regions 104, thereby introducing additional phase error, the overcompensation initially effected by the phase compensator 108 illustratively results in an overall phase error cancellation. It should further be understood that multiple phase compensators 108 may be provided for coupling to more than one pair of expansion regions 104.

[0028] The reflective phase compensator 108 illustratively has an arcuate profile and comprises an arcuate edge 116. The complex shape of the reflective phase compensator 108 illustratively introduces a complex phase correction factor, i.e. a non-uniform phase. It should be understood that the reflective phase compensator 108 may have a simple conic profile, may be of high order aspherical type, or any other suitable profile known to those skilled in the art. For example, the phase compensator 108 may be shaped as an arc of circle, a conic section, a polynomial surface, a parabola, or the like. It should also be understood that the shape of the phase compensator 108 may or may not be smooth continuous. For instance, the phase compensator 108 may have a discontinuous curvature, be piecewise arcuate, or otherwise segmented. Other profiles may also apply.

[0029] As shown in Figure 2c, when an expansion region 104 is provided with such a phase compensator 108 having the arcuate edge 116, the length along each one of the side edges 114 of the expansion region 104 is illustratively reduced from the value d_2 to the value d_3, with the length d_1 along the center line (not shown) of the expansion region 104 being longer than the length d_3 along the edges 114 thereof. Thus, the difference between the lengths d_1 and d_3 may be reduced, resulting in a compensation of the phase error.

[0030] Referring now to Figure 3a in addition to Figure 2a, in one embodiment, the reflective line source 100 may comprise five (5) connected expansion regions 104_1, 104_2, 104_3, 104_4, and 104_5. It should be understood that any suitable number of expansion regions may also apply. The expansion regions 104_1, 104_2, 104_3, 104_4, and 104_5 may be provided in a vertically, i.e. along the Z direction, stacked relationship and connected by the elongate reflectors 106 to create a compact folded structure. In particular, a first expansion region, as in 104_1, and a second expansion region, as in 104_2, are connected such that a first reflector, as in 106_1, is provided between the second edge 110_2 of the first expansion region and the first edge 110_1 of the second expansion region. In addition, in the embodiment of Figure 3a, expansion regions 104_1, 104_2, 104_3, and 104_4 are illustratively tapered waveguides with a flare angle θ while the fifth expansion region 104_5 through which the electromagnetic field exits the line source 100 is a straight waveguide, i.e. is not tapered. It should be understood that other configurations may apply. As the width of the electromagnetic field exiting each one of the tapered expansion regions 104_1, 104_2, 104_3, and 104_4 is illustratively expanded compared to the field received at the input 102, the tapered expansion regions 104_1, 104_2, 104_3, and 104_4 illustratively have an increasing size. Indeed, the width w2 of the second edge 110_2 of a first tapered expansion region, as in 104_1, is illustratively equal to the width w1 of the first edge 110_1 of the tapered expansion region, as in 104_2, which is connected and consecutive to the first tapered expansion region, as in 104_1.

[0031] Referring to Figure 3b in addition to Figure 3a, a guided electromagnetic field 112_1 illustratively enters the line source 100 at the input 102 along a direction A. The field 112_1 then travels along a direction B through the first expansion region 104_1 found on the top layer 118 of the line source 100. While traveling through the first expansion region 104_1, the field 112_1 gets expanded into a field 112_2. At the end of the first expansion region 104_1, the first reflector 106_1 redirects the expanded field 112_2 into the second expansion region 104_2 found below the top layer 118. For this purpose, and as illustrated in Figure 3c, the reflector 106_1 illustratively comprises a first angled facet 120_1 and a second angled facet 120_2. The first and the second angled facets 120_1 and 120_2 illustratively act as reflective surfaces oriented at forty-five (45) degrees to the incident field. As such, the field 112_2 incoming along the direction B is illustratively turned through 90 degrees by each one of the first angled facet 120_1 and the second angled facet 120_2. Thus, the field 112_3 exiting the first reflector 106_1 into the second expansion region 104_2 along direction C is illustratively turned by 180 degrees by the pair of angled facets 120_1 and 120_2, as illustrated in Figure 3d. It should be understood that the first reflector 106_1 may comprise more than two angled facets as in 120_1 and 120_2 and that the angled facets 120_1 and 120_2 may be oriented at angles other than forty-five (45) degrees. Still, regardless of the design of the first reflector 106_1 and remaining ones of the reflectors as in 106, it is desirable for the incoming field to be reflected by 180 degrees.

[0032] Referring to Figure 3e, the field 112_3 may then continue to travel down the second expansion region 104_2 of the reflective line source 100 along the direction C. The field 112_3 may get redirected by a second reflector 106_2 found at the end of the second expansion region 104_2. The second reflector 106_2 illustratively comprises a first and a second angled facet similar to the facets 120_1 and 120_2 of the first reflector 106_1 of Figure 3c. As such, the field 112_4 exiting the second reflector 106_2 is illustratively turned by 180 degrees upon entering into the third expansion region 104_3 along the direction D. When so redirected, the field 112_4 travels through the third expansion region 104_3 towards the end thereof. The field 112_4 may then be redirected as a field 112_5 towards the fourth expansion region 104_4 by a third 180 degree reflector 106_3 comprising angled facets similar to the facets 120_1 and 120_2 of the first reflector 106_1.

[0033] Referring back to Figure 3a in addition to Figure 3e, the field 112_5 may then travel through the fourth expansion region 104_4 along the direction E. When traveling through the fourth expansion region 104_4, the field 112_5 may further encounter the reflective phase compensator 108, which illustratively corrects errors induced by the finite length tapered expansion regions as in 104_1, 104_2, 104_3, 104_4. In particular and as discussed above with reference to Figure 2c, upon reaching the arcuate edge 116, the field 112_5 has illustratively traveled through an expansion region 104_4 where the length (reference d_1 in Figure 2c) along the center line is longer than the length (reference d_2 in Figure 2c) along the edges (reference 114 in Figure 2c). As such, it is desirable, using the reflective phase compensator 108, to achieve phase compensation for the distances traveled by the signal through the expansion regions 104_1, 104_2, 104_3, and 104_4. In particular, the phase compensator 108 may correct the phase error so that a planar phase front is achieved at an output of the line source 100. The phase compensator may alternatively correct the phase error so that a target value phase front is achieved.

[0034] The arcuate edge 116 illustratively comprises a first and a second reflective phase compensating surface 122_1 and 122_2. In one embodiment, the reflective phase compensating surfaces 122_1 and 122_2 are arcuate angled facets each oriented at substantially forty-five (45) degrees for turning an electromagnetic field impinging thereon by substantially ninety (90) degrees. It should be understood that the phase compensator 108 may comprise more than two reflective phase compensating surfaces 122_1 and 122_2 and that the latter may be oriented at angles other than forty-five (45) degrees. Upon reaching the arcuate edge 116, the field 112_5 thus successively encounters the first and the second reflective phase compensating surfaces 122_1 and 122_2. As such, the field 112_5 is folded by 180 degrees and redirected towards the fifth expansion region 104_5 found on the bottom layer 124 of the folded structure 100. The field 112_6 exiting the reflective phase compensator 108 may then propagate along the direction F through the fifth expansion region 104_5.

[0035] Figure 4a and Figure 4b illustrate results obtained by simulating a 600 mm by 700 mm reflective line source (reference 100 in Figure 1). Such a line source 100 is then used as an input source to feed an antenna (not shown). Simulations were performed using electromagnetic simulation software, such as CST Microwave Studio ™. It should be understood that any other suitable software known to those skilled in the art may be used. Figure 4a shows a plot 200 of the phase error in the reflective line source 100 without phase error compensation. Due to the periodic nature of electromagnetic waves, phase jumps 202 of substantially 360 degrees occur due to phase wrapping. The unwrapped total phase error of the uncompensated expansion regions (reference 104 in Figure 1) is in excess of 2600 degrees or approximately 7.2 wavelengths.

[0036] Figure 4b shows a plot 300 of the phase error after compensation using a reflective phase compensator (reference 108 in Figure 1). After the field propagates through the reflective phase compensator 108, a non-uniform and complex phase correction factor is introduced. As a result, the peak-to-peak phase error is reduced to less than five (5) degrees over half of the width of the antenna aperture. The phase correction factor being non-uniform, a residual phase error remains across the full width of the antenna aperture. Still, this phase error is reduced to approximately sixty (60) degrees or 0.17 wavelengths. A phase error less than one-quarter of a wavelength can therefore be achieved using the reflective line source architecture 100 described above. As known to those skilled in the art, a phase error of lambda/6, with lambda being the wavelength of the electromagnetic wave, or sixty (60) degrees is typically sufficient for most antenna applications.

[0037] As discussed above, the reflective line source 100 may be coupled to a plurality of antenna types. Figure 5a and Figure 5b show a proof-of-concept reflective line source 400 integrated with an E-plane sectoral horn 402. The proof-of-concept line source 400 and the sectoral horn 402 may be fabricated using any suitable manufacturing process, such as rapid prototyping. The rapid prototyping process illustratively uses a laser to cure polymer into a specific geometry. In the embodiment shown in Figure 5a and Figure 5b, the resulting polymer part is then metalized with copper. An input waveguide 404 as well as two (2) expansion regions 406_1 and 406_2 of the line source 400 can be seen in Figure 5a. Figure 5b shows the output radiator 408 of the sectoral horn 402 with the line source 100 attached on top and to the back of the horn 402.

[0038] Figure 6 illustrates a comparison between modeled and measured results of the azimuth far field gain pattern at 19.7 GHz for the folded reflective line source 400 and E-plane sectoral horn 402 of Figure 5a and Figure 5b. The gain pattern plot 500 shows the agreement of the integration of the line source 400 with the sectoral horn 402. Indeed, well-behaved and low sidelobe levels 502 are obtained due to the fact that the phase error is reduced to less than one-quarter of a wavelength using the reflective phase compensator (reference 108 in Figure 1).

[0039] Referring to Figure 7, a method 500 for manufacturing a folded reflective line source, such as the line source 100 of Figure 1, will now be described. The method 500 comprises providing at step 502 one or more expansion regions (reference 104 in Figure 1). As described above, each expansion region may be such that an input field may be received at a first end thereof and an output field output through a second end thereof opposite the first end. When a plurality of expansion regions are provided, the next step 504 may then comprise arranging the expansion regions in a vertically stacked relationship. In particular, the expansion regions may be arranged such that the second end of each expansion region is adjacent the first end of the consecutive expansion region.

[0040] When a plurality of expansion regions are provided, the method 500 may then comprise coupling at step 506 a reflector (reference 106 in Figure 1) to each consecutive pair of expansion regions. In particular, the step 506 may comprise, as discussed above, coupling the reflector between the second end of the first expansion region of each pair and the first end of the second expansion region of the pair. In this manner, any electromagnetic field exiting through the second end of the first expansion region of each pair may be redirected towards the first end of the second expansion region of the pair, thereby connecting the expansion regions. The step 506 may, for instance, comprise providing a reflector having a first and a second angled facet each oriented at forty-five (45) degrees to an incident electromagnetic field for folding the direction of propagation of a field incident on the reflector by 180 degrees.

[0041] The next step 508 may then be to couple at least one reflective phase compensator (reference 108 in Figure 1) to at least one of the expansion regions. It should be understood that the order of steps 506 and 508 may be interchanged. The phase compensator may be coupled to the second end of a first expansion region and the first end of the second expansion region consecutive to the first expansion region. The phase compensator may be provided with an arcuate or other suitable shape for compensating a phase error due to propagation of a field through the taper regions connected at step 506. In particular, the phase compensator coupled at step 508 to the expansion region(s) may be provided with at least two reflective phase compensating surfaces for folding by 180 degrees a field incident on the phase compensator.

[0042] Referring back to Figure 1, the folded reflective line source architecture illustratively compensates for arbitrary phase errors over a very large frequency bandwidth. In particular, broadband response over 50% of the bandwidth may be achieved and the design may be scalable from 5 GHz to 75 GHz operating frequency. The line source 100 may further allow for superior phase control and provide continuous and smooth phase responses as well as a symmetric and well controlled phase and amplitude field distribution. Moreover, a reduction of losses and a loosening of assembly tolerances may be achieved. Also, the reflective line source 100 illustratively enables a compactness and a reduction in the weight of the overall antenna structure. The design may further be compatible with conventional high speed machining, extrusion, injection molding, arc-machining, stamping, or other manufacturing processes known to those skilled in the art.

[0043] The embodiments of the invention described above are intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.

Claims

1. A reflective line source (100) comprising:

   at least one region (104) adapted to receive thereat an input electromagnetic field and to expand the input electromagnetic field in at least one dimension; and
   at least one reflective phase compensator (108) coupled to the at least one region (104), the at least one reflective phase compensator (108) adapted to fold a direction of propagation of the expanded electromagnetic field and correct a phase error thereof.

2. The line source of claim 1, wherein the at least one reflective phase compensator comprises at least a first reflective phase compensating surface (122_1) and a second reflective phase compensating surface (122_2), the second reflective phase compensating surface oriented at substantially ninety degrees to the first reflective phase compensating surface for folding the direction of propagation of the expanded electromagnetic field by substantially 180 degrees.

3. The line source of claim 1 or 2, wherein the at least one region has a first end adapted to receive thereat the input electromagnetic field and a second end opposite to the first end and adapted to output therethrough the expanded electromagnetic field, a first width of the input electromagnetic field smaller than a second width of the expanded electromagnetic field.

4. The line source of claim 3, wherein the at least one region comprises a plurality of regions (104) arranged in a vertically stacked relationship with the second end of each region positioned adjacent to the first end of a consecutive region.

5. The line source of claim 4, wherein the at least one reflective phase compensator couples the second end of a first one of the plurality of regions to the first end of a second one of the plurality of regions consecutive to the first region for redirecting a first electromagnetic field output at the second end of the first region towards the first end of the second region.

6. The line source of claim 5, further comprising a plurality of reflectors (106) coupled to remaining ones of the plurality of regions, each reflector coupling the second end of a first one of the remaining regions to the first end of a second one of the remaining regions, the second remaining region consecutive to the first remaining region, and optionally wherein each one of the plurality of reflectors comprises a first angled facet (120_1) positioned adjacent to the second end of the first remaining region and a second angled facet (120_2) oriented at substantially ninety degrees to the first angled facet and positioned adjacent to the first end of the second remaining region for redirecting a second electromagnetic field output at the second end of the first remaining region towards the first end of the second remaining region.

7. The line source of any of claims 4 to 6, wherein a first one of the plurality of regions is adapted to receive the input electromagnetic field and a last one of the plurality of regions is adapted to output an output electromagnetic field, and further wherein the last region is straight while remaining ones of the plurality of regions are each tapered with a flare angle comprised between zero and ninety degrees.

8. The line source of any preceding claim, wherein the at least one reflective phase compensator corrects the phase error to achieve one of a planar phase front and a target value phase front.

9. The line source of any preceding claim, wherein the at least one phase compensator has a profile selected from the group consisting of an arc of circle, a conic section, a parabola, a polynomial surface, a high order aspherical shape, a discontinuous curvature, and a piecewise arcuate shape, and optionally wherein the profile of the at least one phase compensator introduces a non-uniform phase correction factor for correcting the phase error.

10. A method for manufacturing a reflective line source (100), the method comprising:

    providing at least one region adapted to receive thereat an input electromagnetic field and to expand the input electromagnetic field in at least one dimension (502); and
    coupling at least one reflective phase compensator to the at least one region (506), the at least one reflective phase compensator adapted to fold a direction of propagation of the expanded electromagnetic field and correct a phase error thereof.

11. The method of claim 10, wherein coupling the at least one reflective phase compensator to the at least one region comprises coupling at least a first reflective phase compensating surface and a second reflective phase compensating surface to the at least one region (508), the second reflective phase compensating surface oriented at substantially ninety degrees to the first reflective phase compensating surface for folding the direction of propagation of the expanded electromagnetic field by substantially 180 degrees.

12. The method of claim 10 or 11, wherein providing the at least one region comprises providing the at least one region having a first end adapted to receive thereat the input electromagnetic field and a second end opposite to the first end and adapted to output therethrough the expanded electromagnetic field, a first width of the input electromagnetic field smaller than a second width of the expanded electromagnetic field.

13. The method of claim 12, wherein providing the at least one region comprises arranging a plurality of regions in a vertically stacked relationship (504) with the second end of each region positioned adjacent to the first end of a consecutive region; and optionally wherein providing the at least one region comprises providing a first one of the plurality of regions for receiving the input electromagnetic field and a last one of the plurality of regions for outputting an output electromagnetic field, the last region being straight while remaining ones of the plurality of regions are each tapered with a flare angle comprised between zero and ninety degrees.

14. The method of claim 13, wherein coupling the at least one reflective phase compensator to the at least one region comprises coupling the at least one reflective phase compensator between the second end of a first one of the plurality of regions and the first end of a second one of the plurality of regions consecutive to the first region for redirecting a first electromagnetic field output at the second end of the first region towards the first end of the second region.

15. The method of claim 14, further comprising coupling a plurality of reflectors to remaining ones of the plurality of regions, each reflector coupling the second end of a first one of the remaining regions to the first end of a second one of the remaining regions, the second remaining region consecutive to the first remaining region, and optionally wherein coupling a plurality of reflectors comprises positioning a first angled facet of each one of the plurality of reflectors adjacent to the second end of the first remaining region and positioning a second angled facet of the reflector adjacent to the first end of the second remaining region, the second angled facet oriented at substantially ninety degrees to the first angled facet for redirecting a second electromagnetic field output at the second end of the first remaining region towards the first end of the second remaining region.

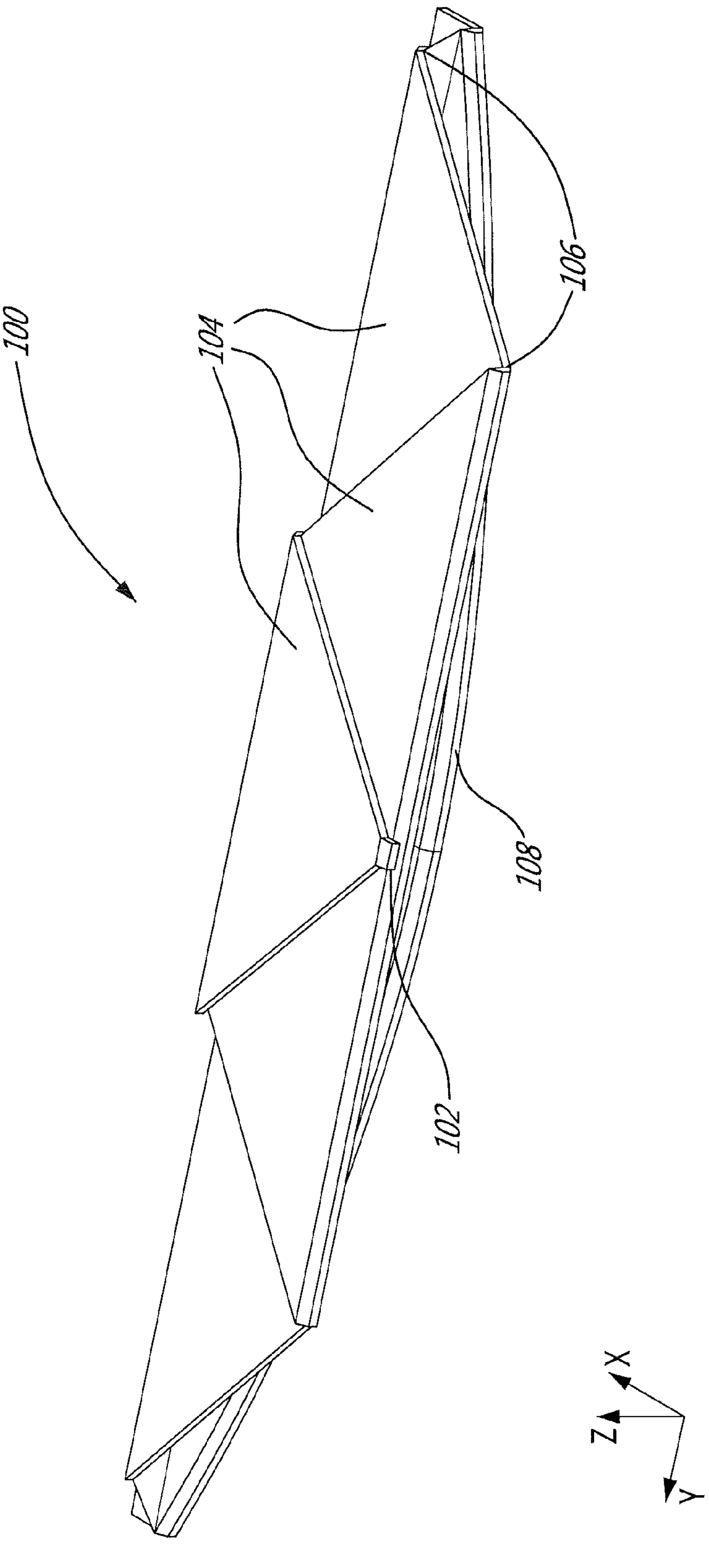


FIG. 1

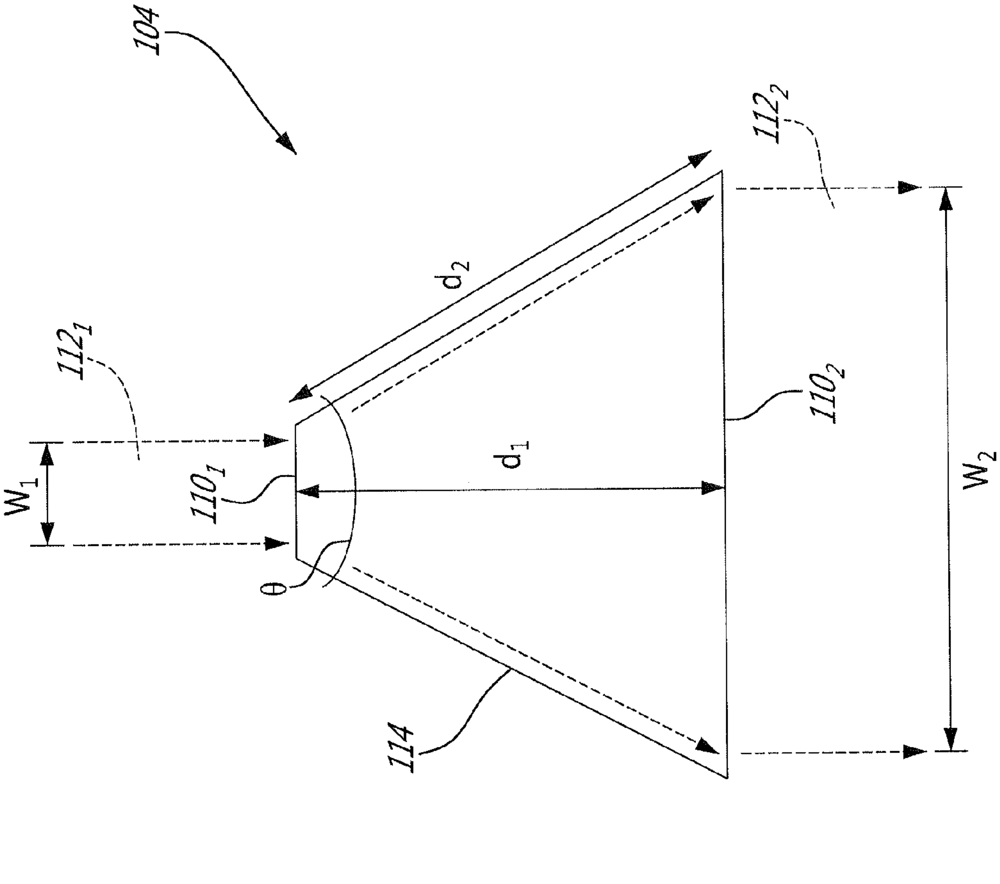


FIG - 2a

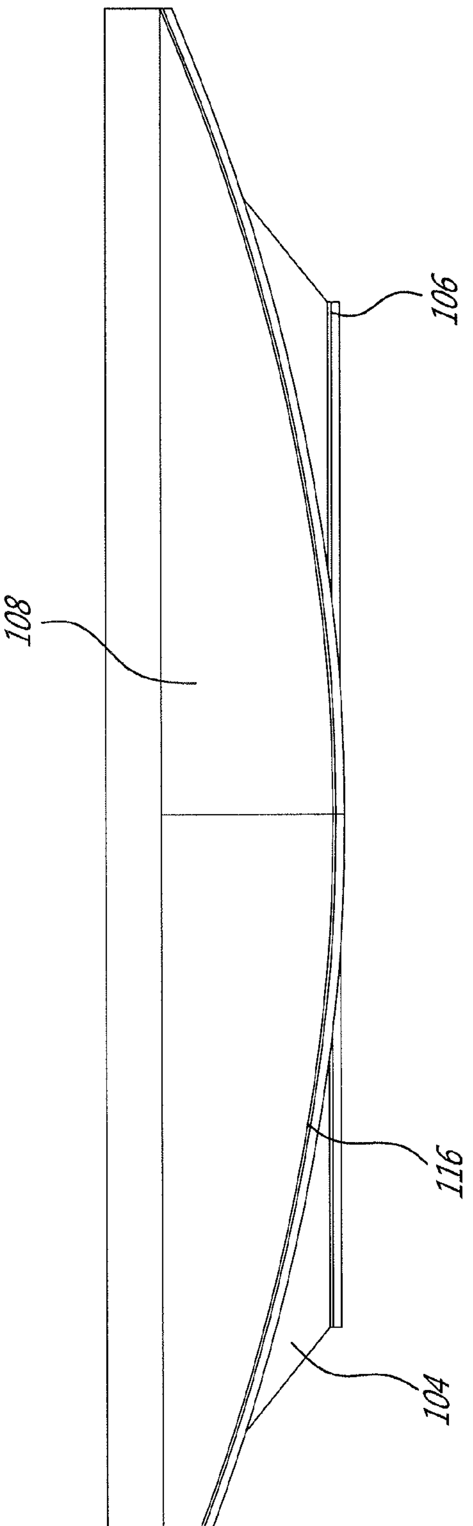


FIG - 7b

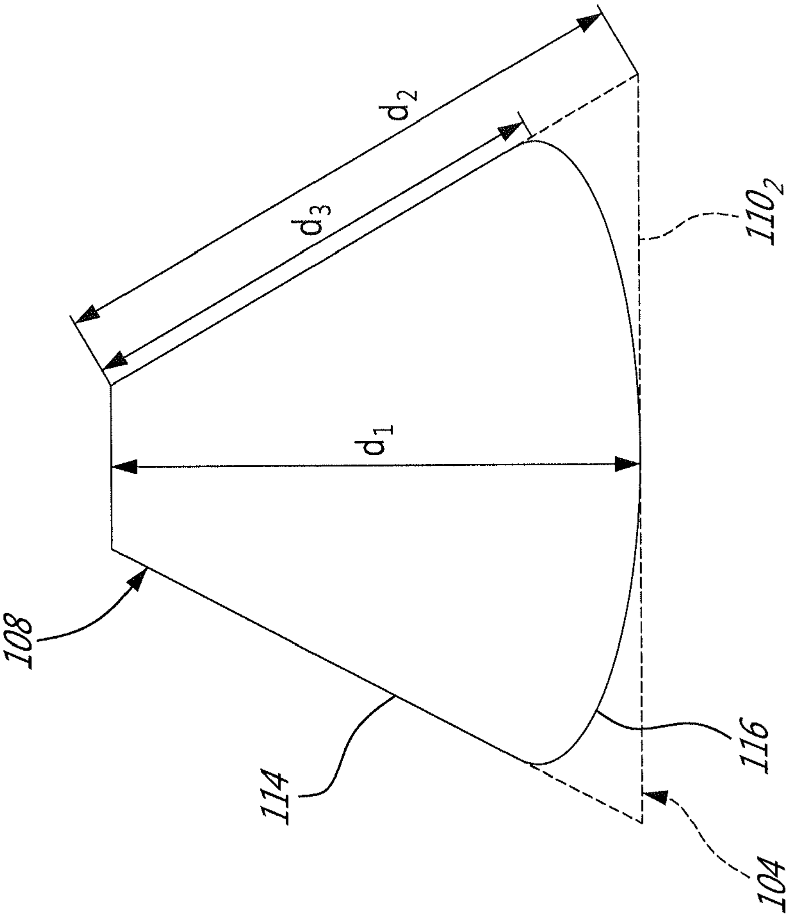
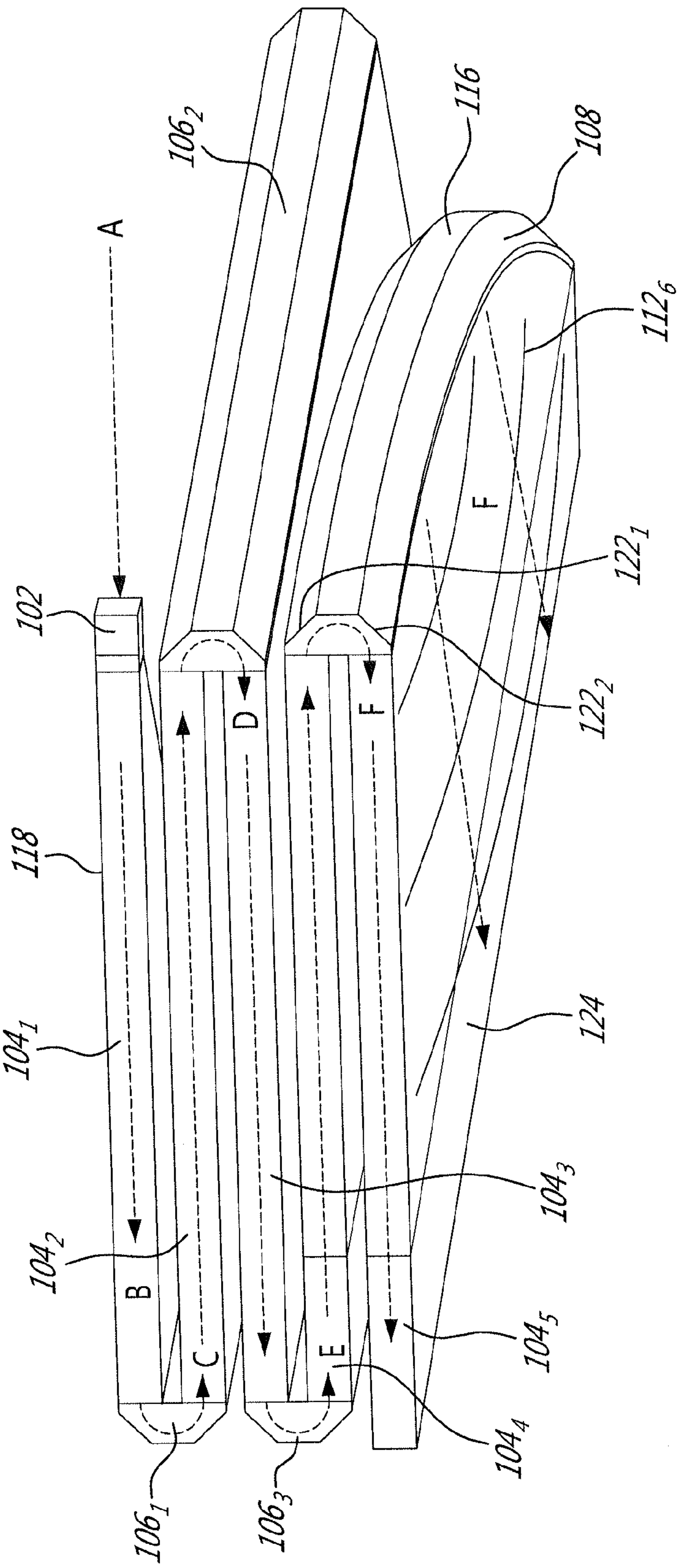


FIG-2c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104_3
124
E
104_5
104_4
106_1
106_3

FIG - 3a

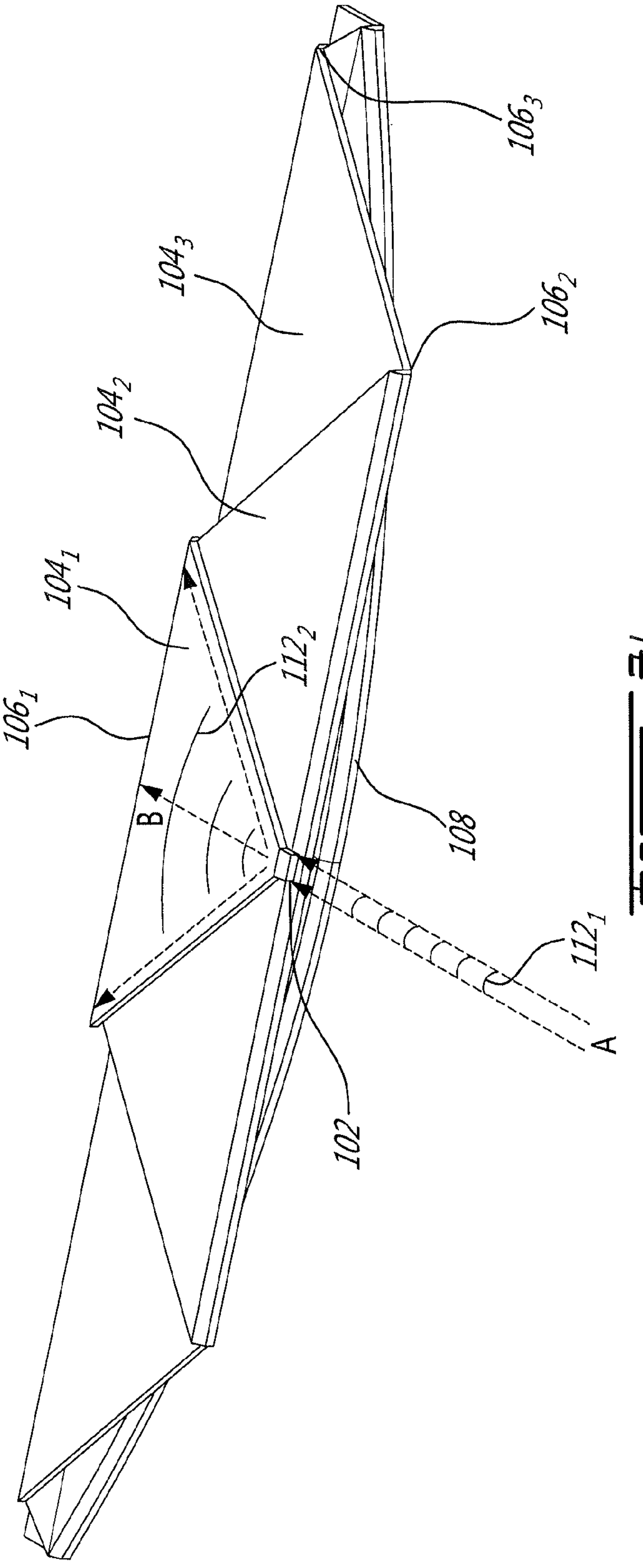

Fig - 3b

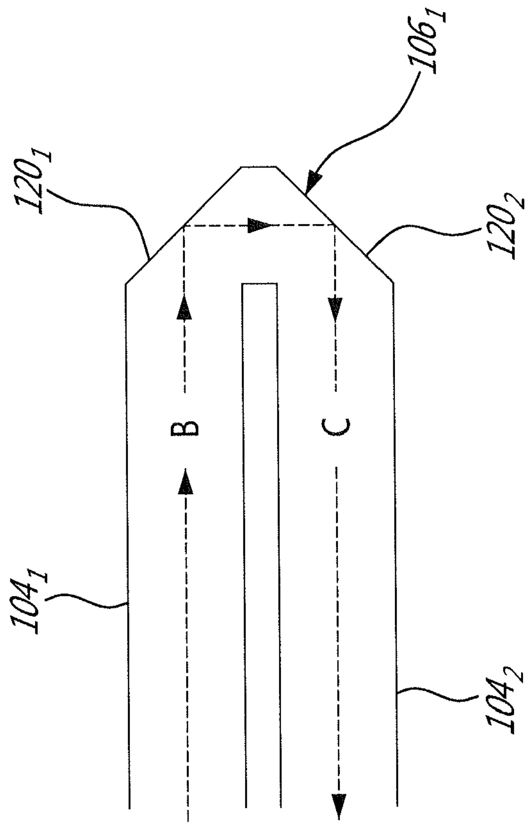

FIG. 3c

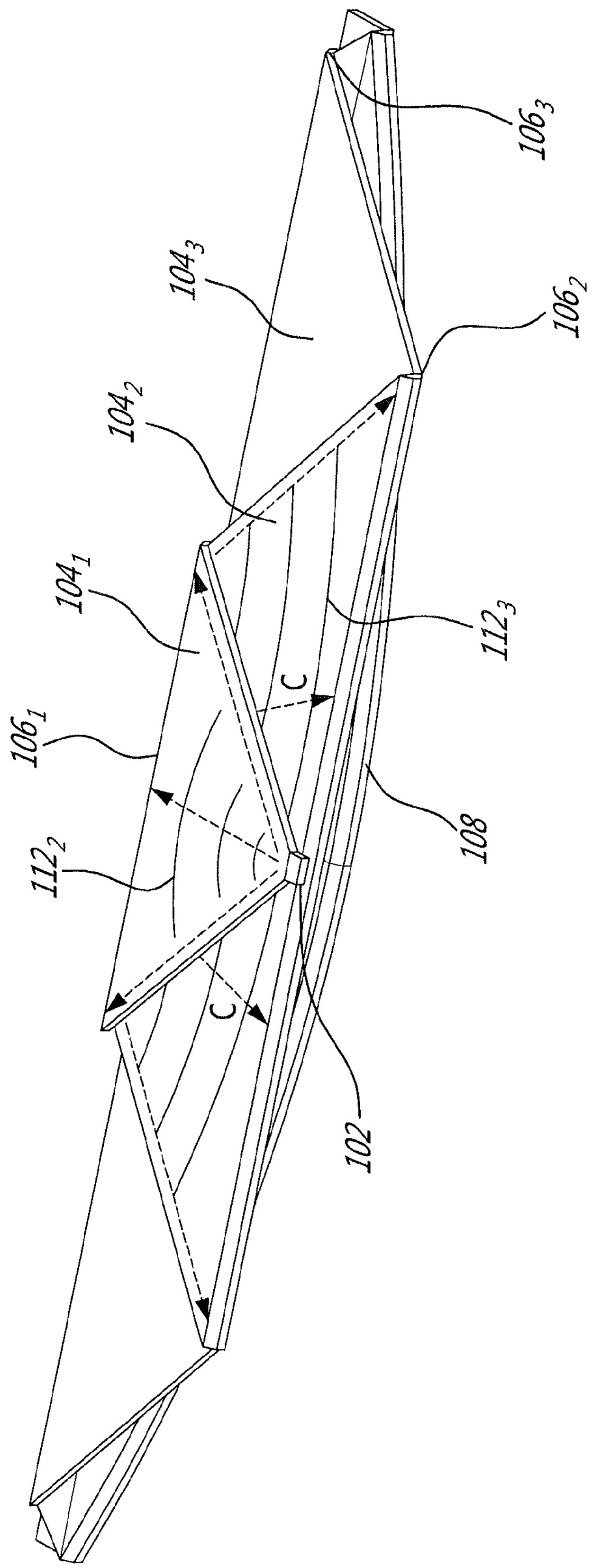

Fig. 1

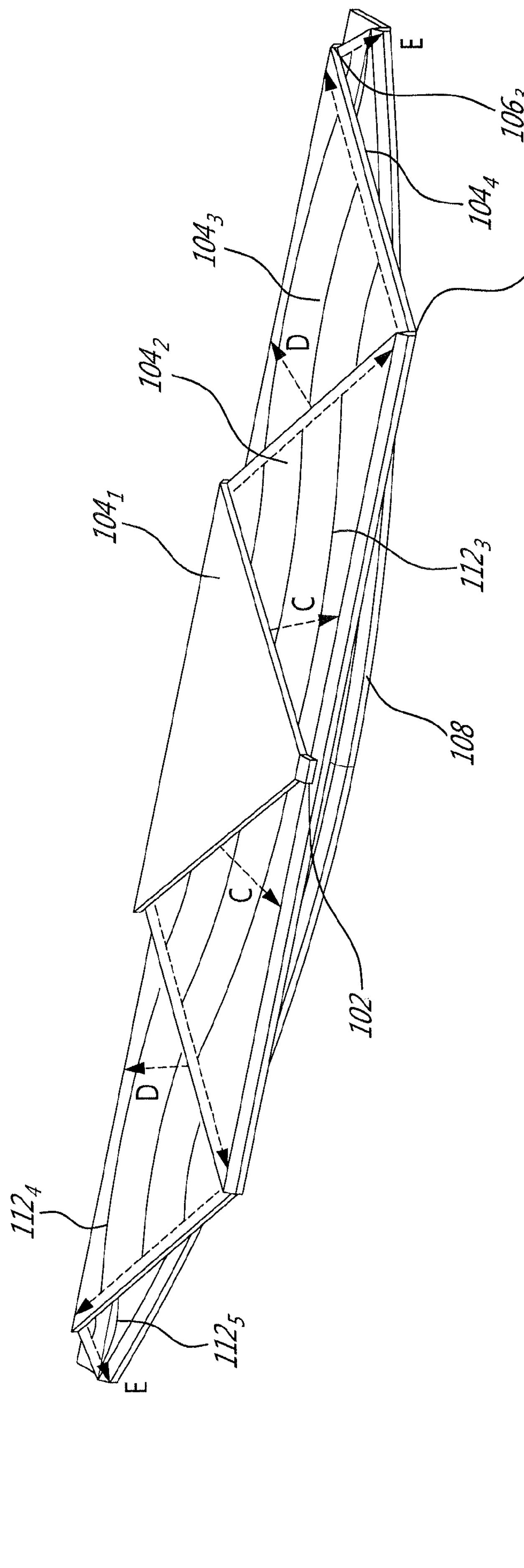

Fig - 3E

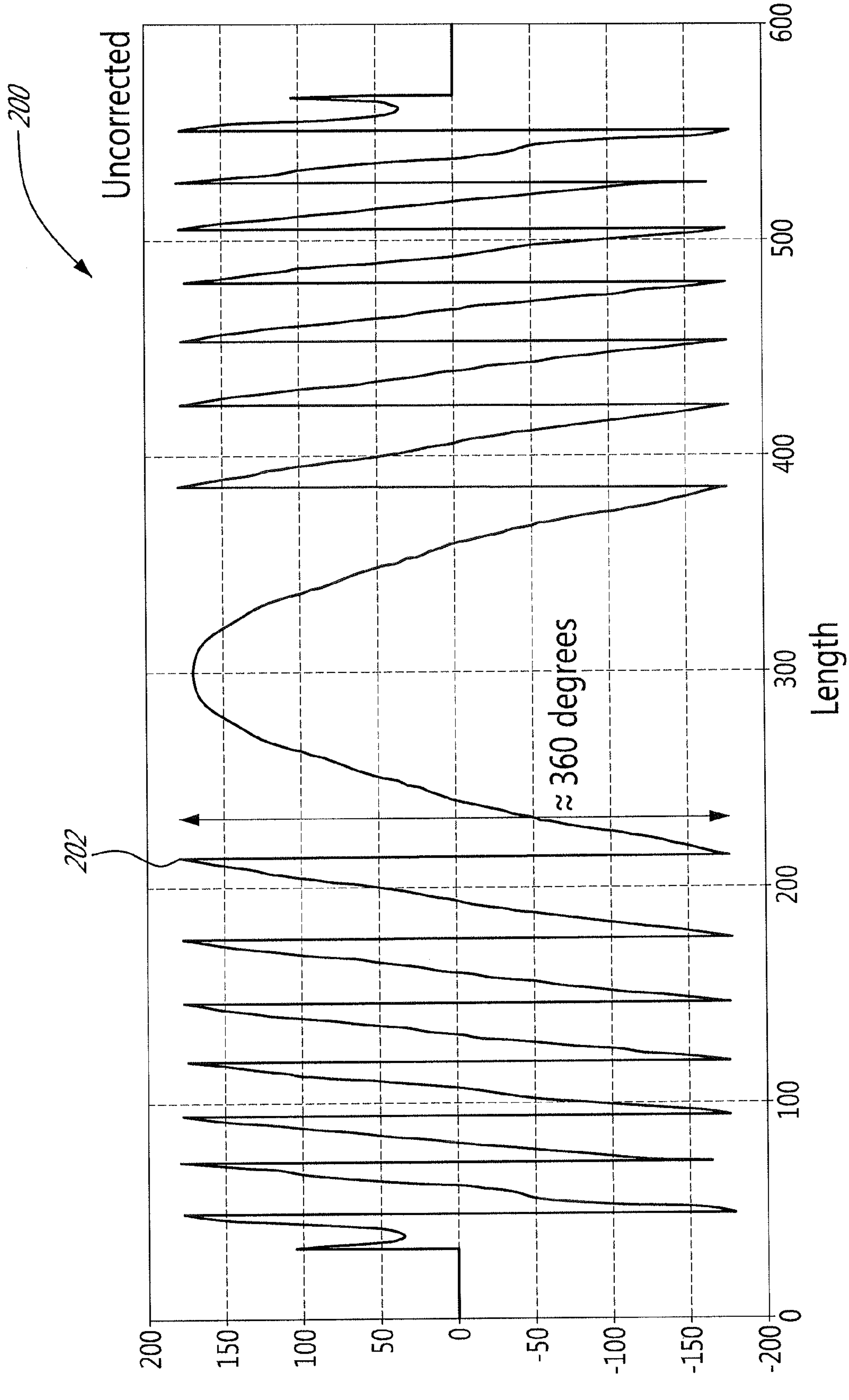
Uncorrected
200
202
≈ 360 degrees
Length
0
100
200
300
400
500
600
200
150
100
50
0
-50
-100
-150
-200

FIG. 4a

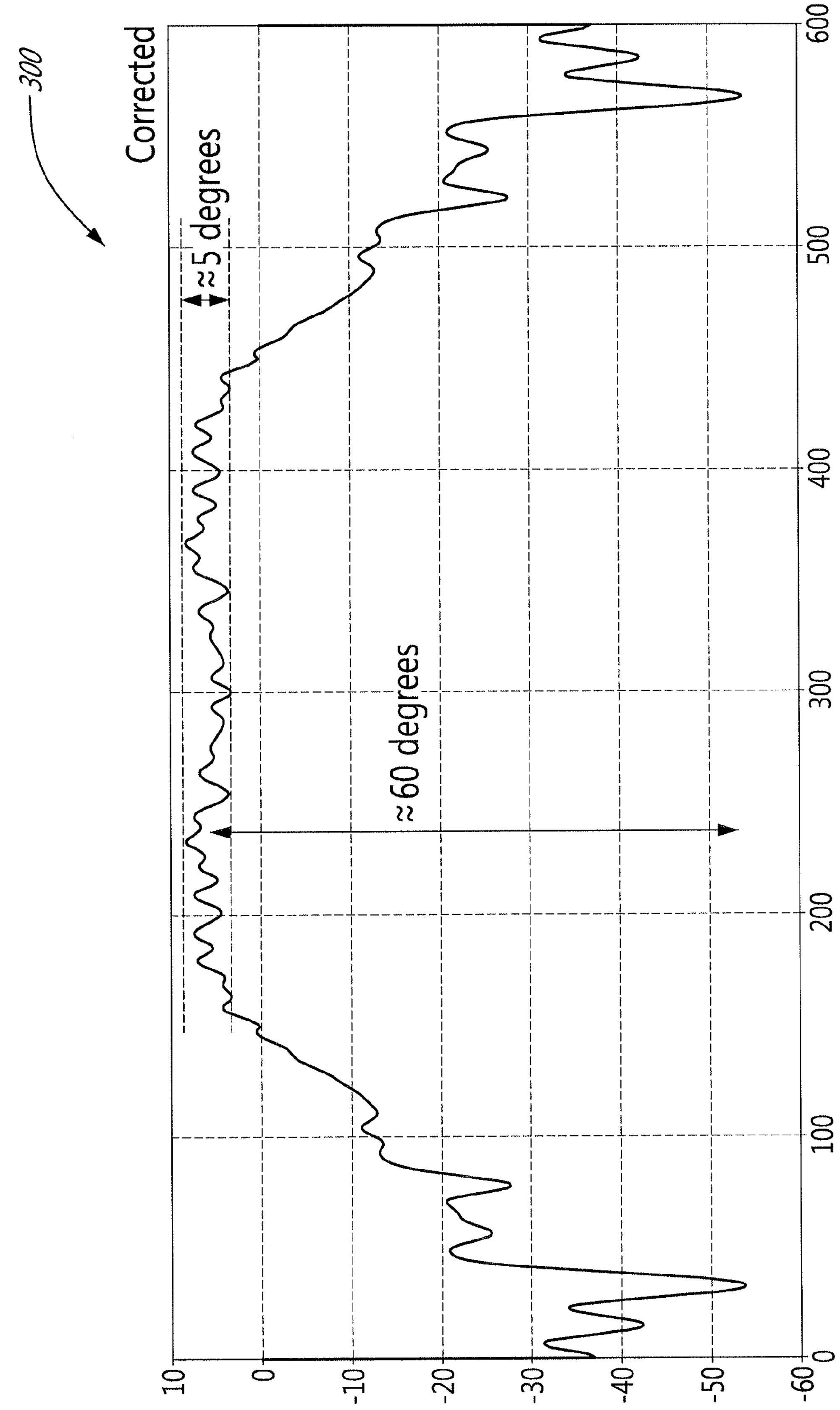
300
Corrected
≈5 degrees
≈60 degrees
Length
10
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600

FIG. 4b

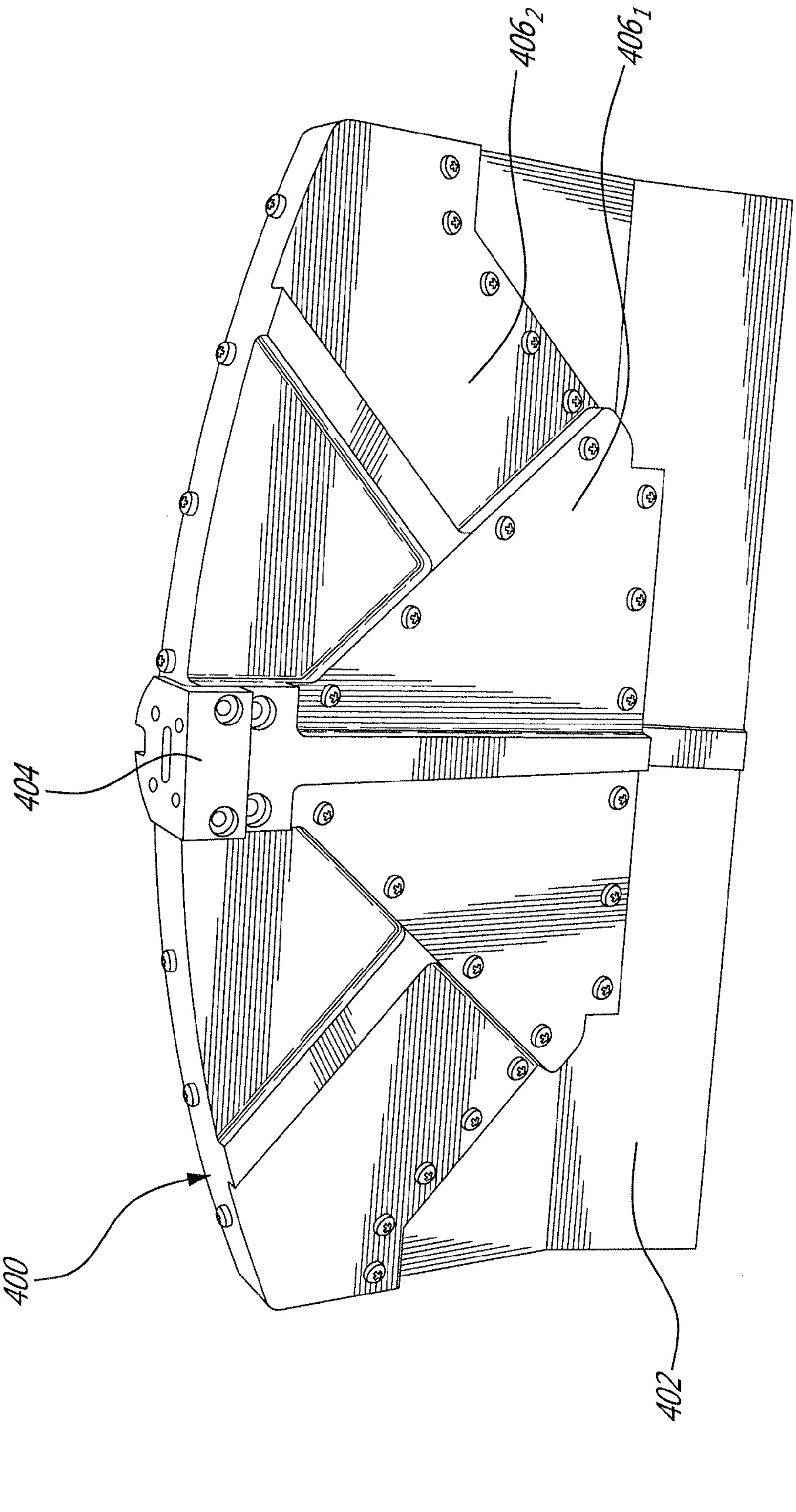

FIG. 5a

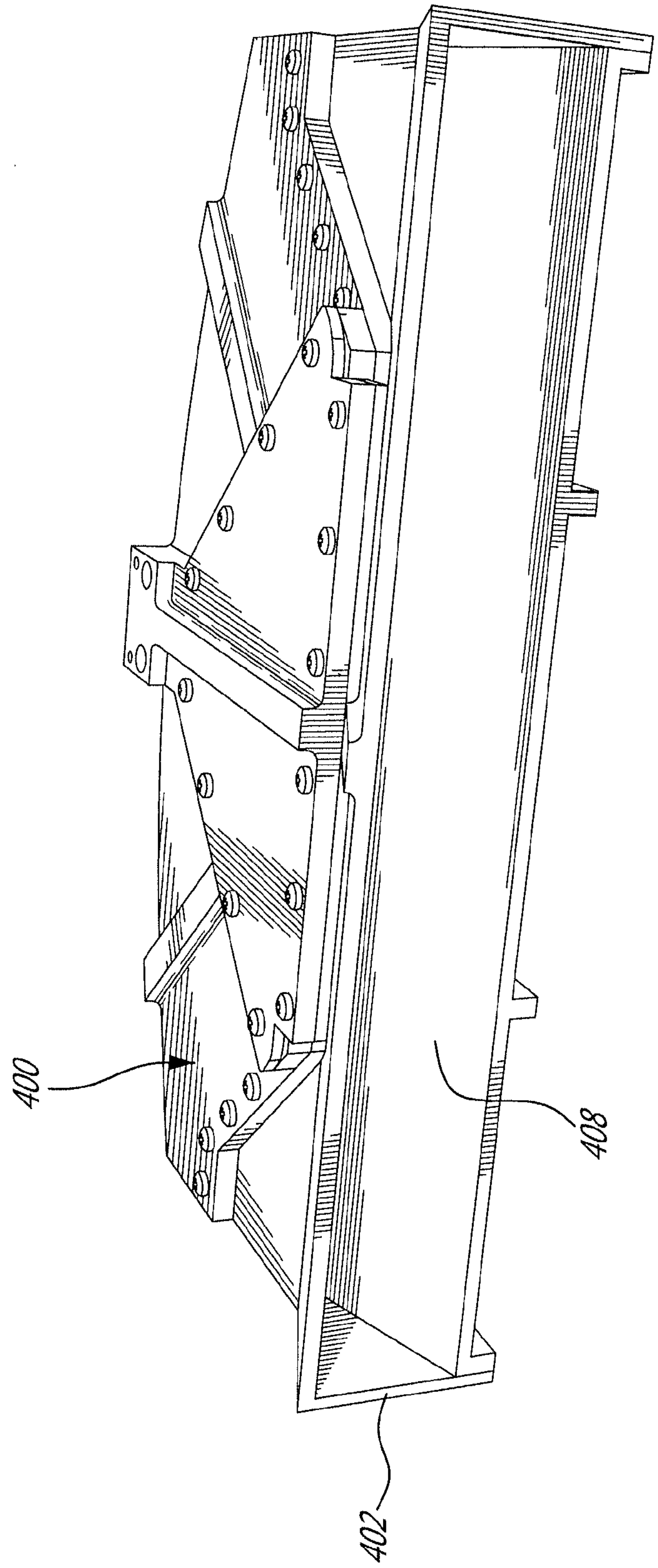

Fig - 5b

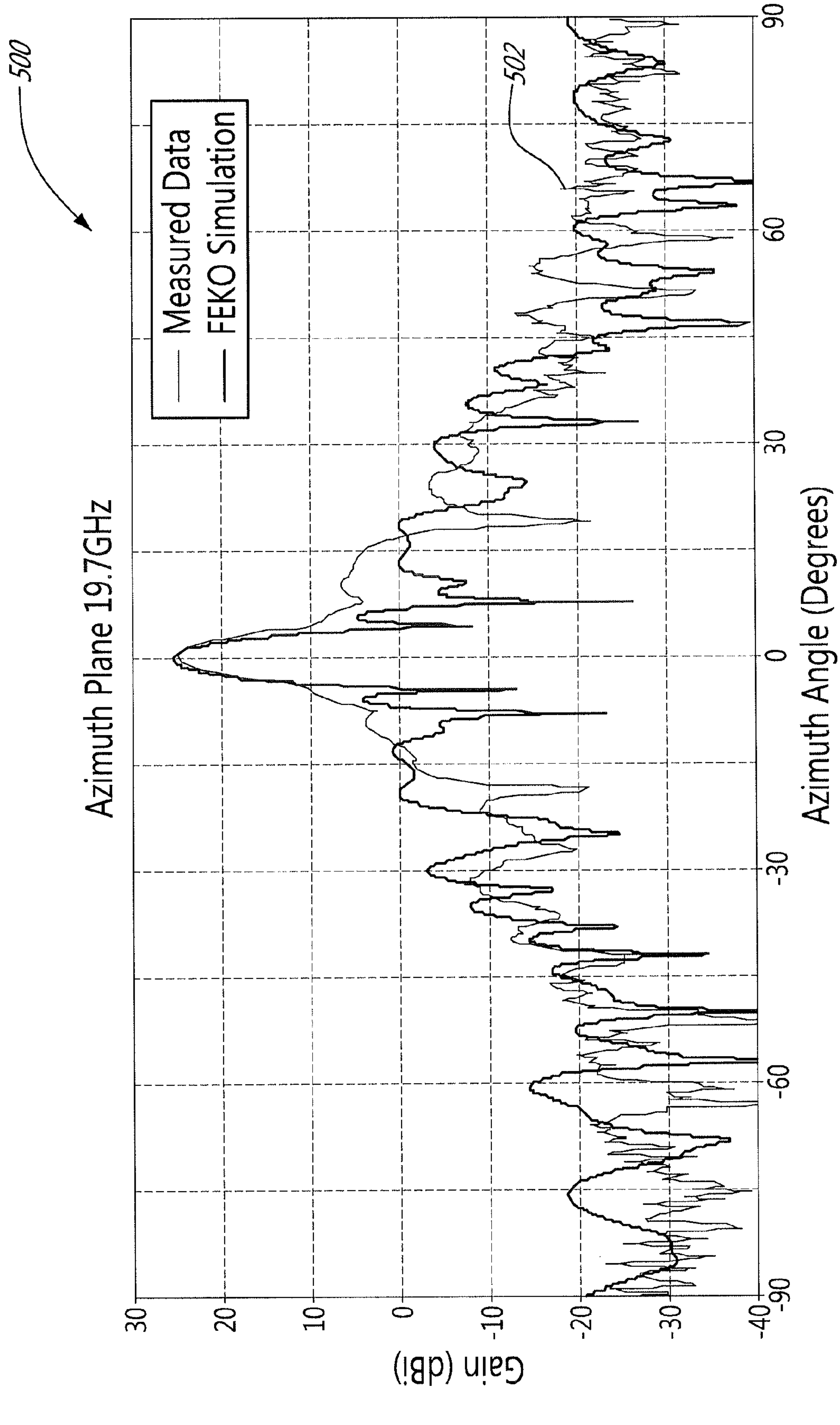
500
Azimuth Plane 19.7GHz
Measured Data
FEKO Simulation
502
Gain (dBi)
30
20
10
0
-10
-20
-30
-40
-90
-60
-30
0
30
60
90
Azimuth Angle (Degrees)

FIG - 6

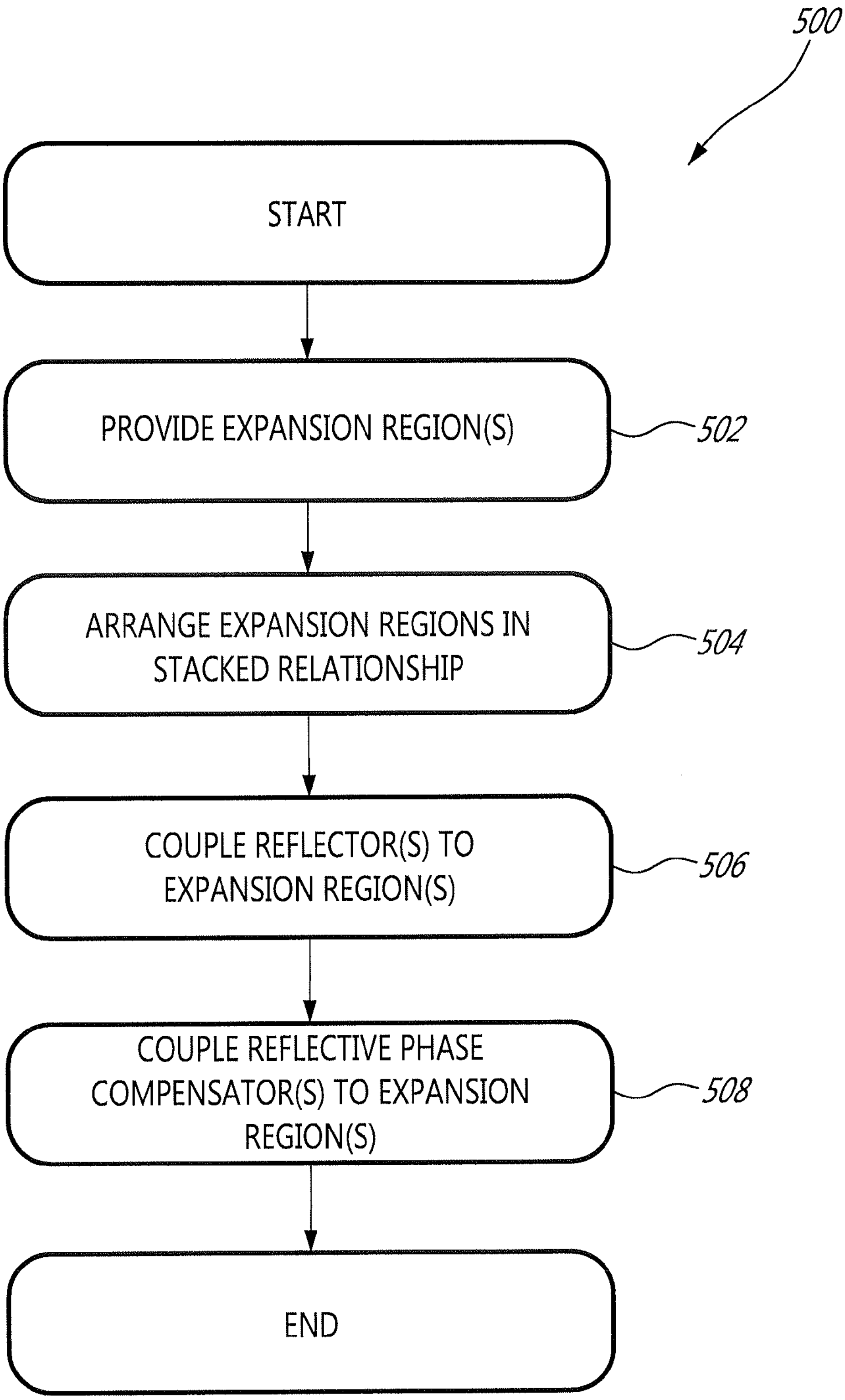
500
START
PROVIDE EXPANSION REGION(S)
502
ARRANGE EXPANSION REGIONS IN STACKED RELATIONSHIP
504
COUPLE REFLECTOR(S) TO EXPANSION REGION(S)
506
COUPLE REFLECTIVE PHASE COMPENSATOR(S) TO EXPANSION REGION(S)
508
END

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 13 15 1716

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/103489 A1 (JOHANSSON MARTIN [SE] ET AL) 18 May 2006 (2006-05-18) * abstract * * paragraphs [0002] - [0022], [0038] - [0057]; figures 9a, 9b, 5 * -----	1-15	INV. H01Q19/13
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H01Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 June 2013	Sidoti, Filippo

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20-06-2013

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