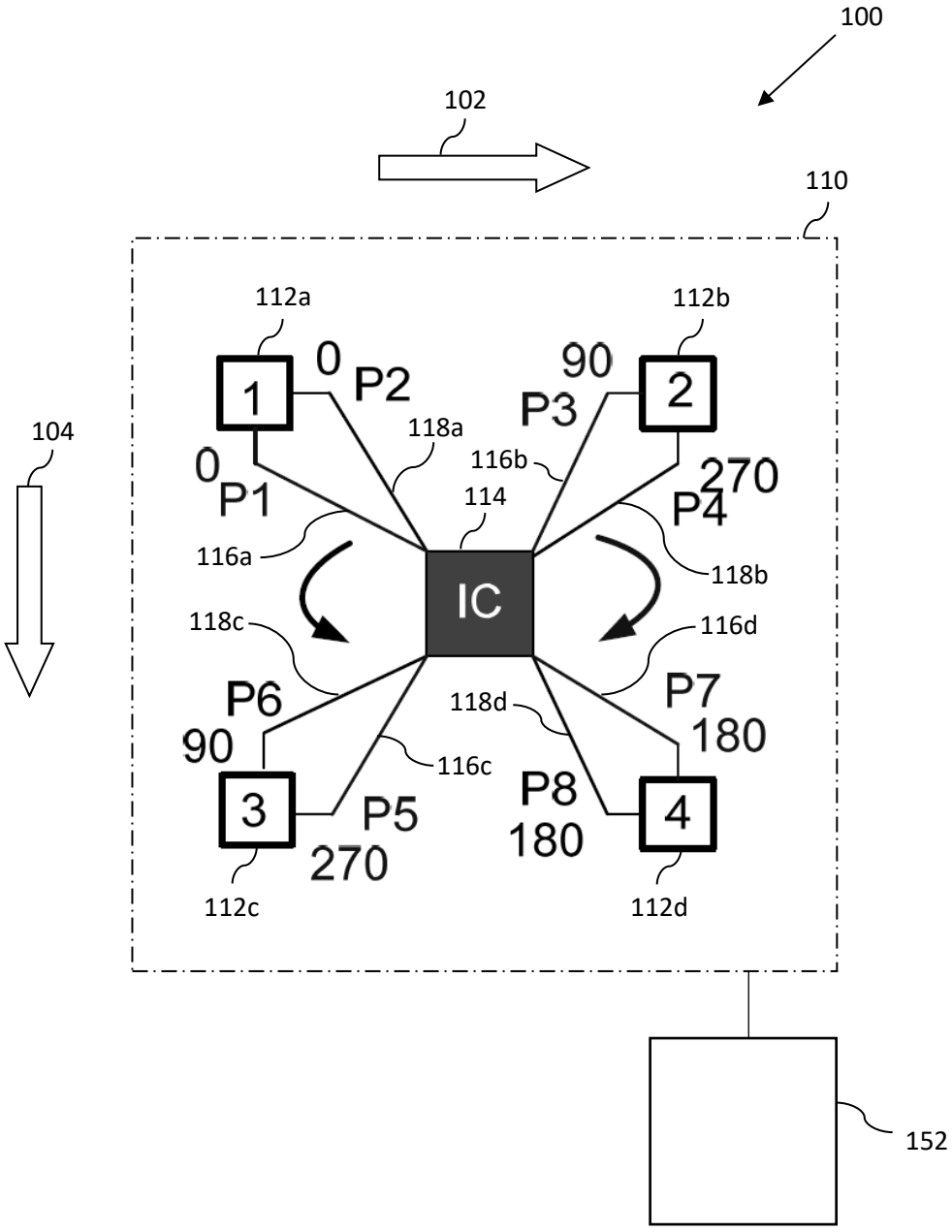

100
102
110
104
112a
112b
1
2
0
P2
90
P3
0
P1
270
P4
118a
116b
114
116a
118b
IC
118c
116d
P6
90
P7
180
118d
116c
3
P5
270
P8
180
4
112c
112d
152

FIG. 1

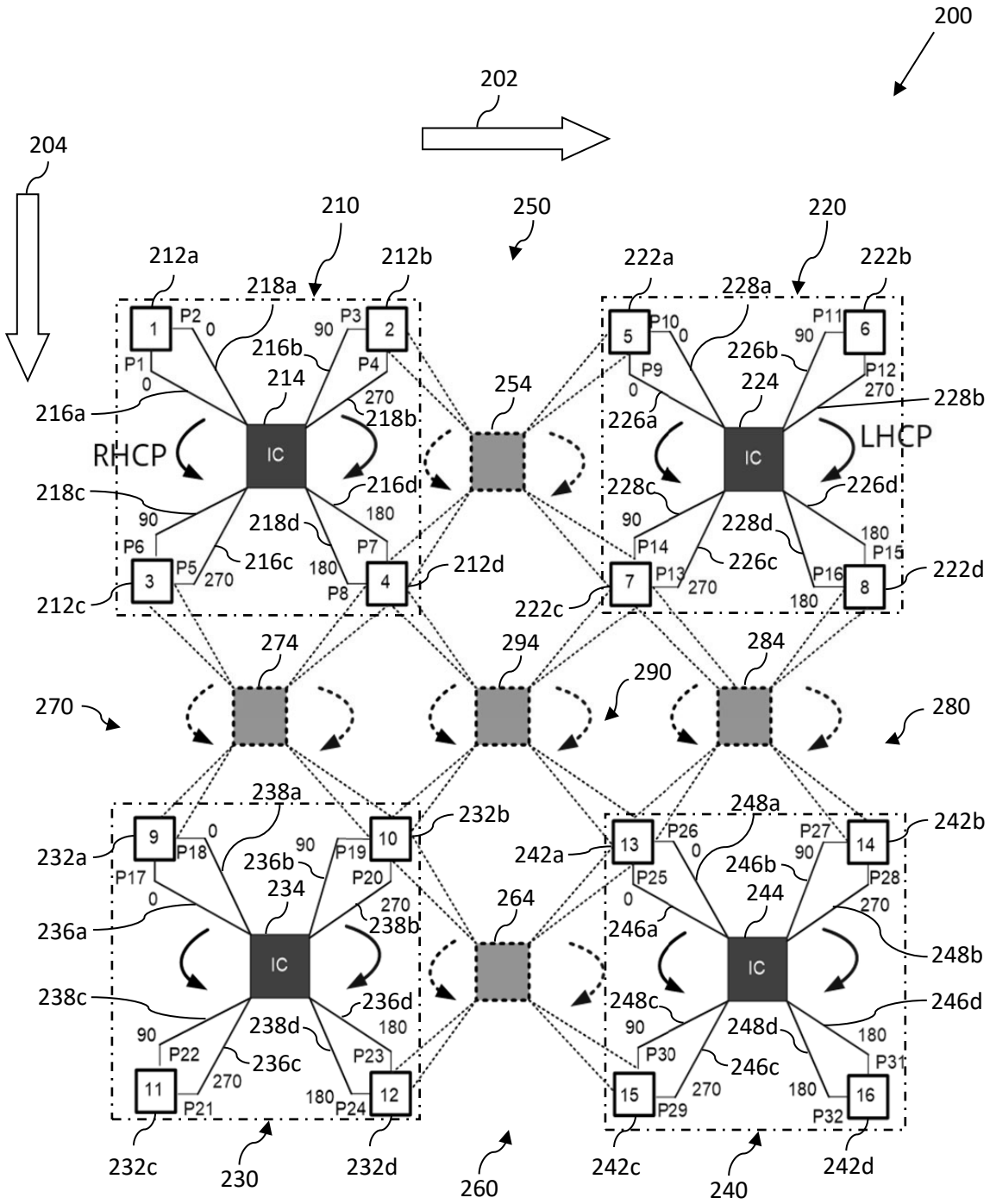

200
202
204
210
250
220
212a
212b
218a
222a
222b
228a
1
2
3
4
5
6
7
8
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
P16
0
90
180
270
216a
216b
214
218b
254
224
226a
226b
228b
RHCP
LHCP
IC
218c
216d
218d
216c
212d
212c
228c
226d
228d
226c
222d
222c
274
294
284
290
270
280
238a
232b
242b
248a
9
10
11
12
13
14
15
16
P17
P18
P19
P20
P21
P22
P23
P24
P25
P26
P27
P28
P29
P30
P31
P32
232a
236b
234
238b
264
242a
246b
244
246a
248b
238c
236d
238d
236c
246d
248c
248d
246c
232c
230
232d
260
242c
240
242d

FIG. 2A

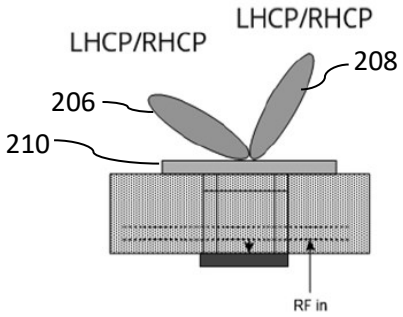


FIG. 2B

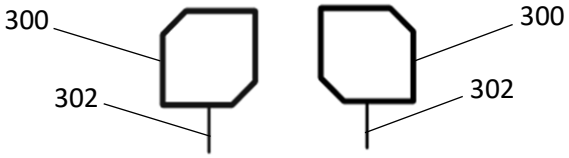


FIG. 3A

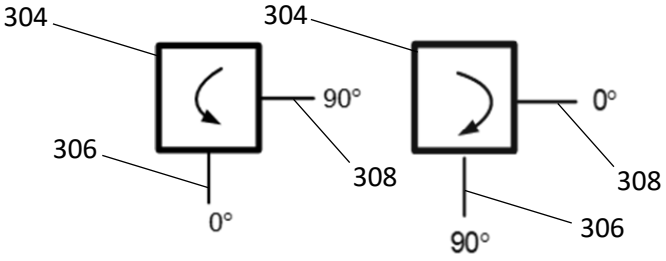


FIG. 3B

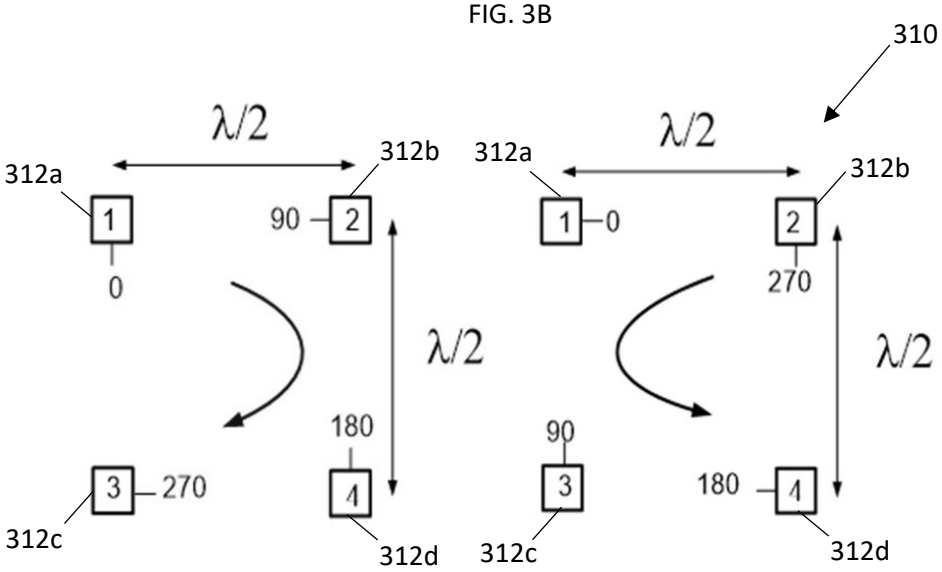


FIG. 3C

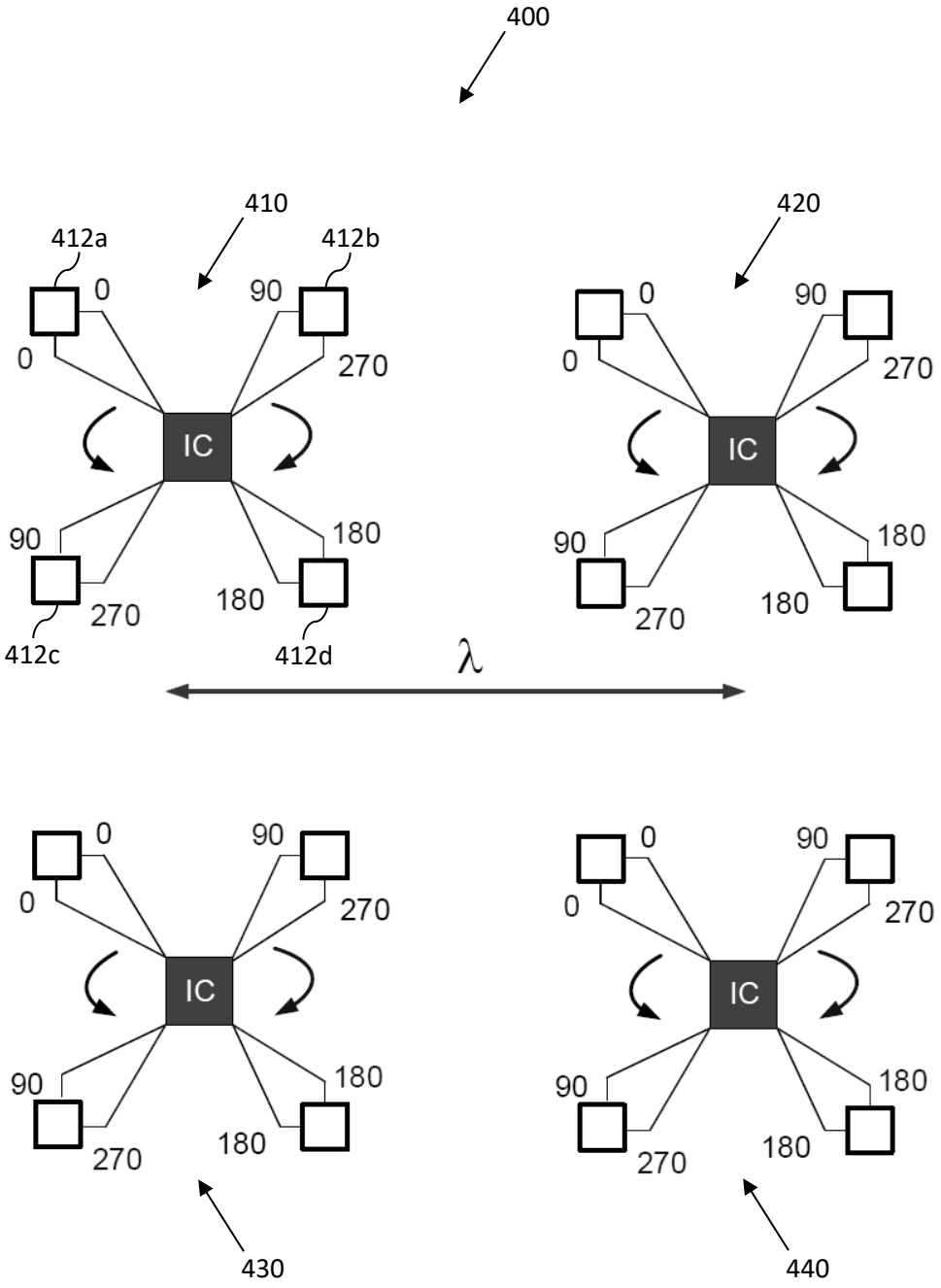

400
410
412a
412b
0
90
0
270
IC
90
180
270
180
412c
412d
420
λ
430
440

FIG. 4

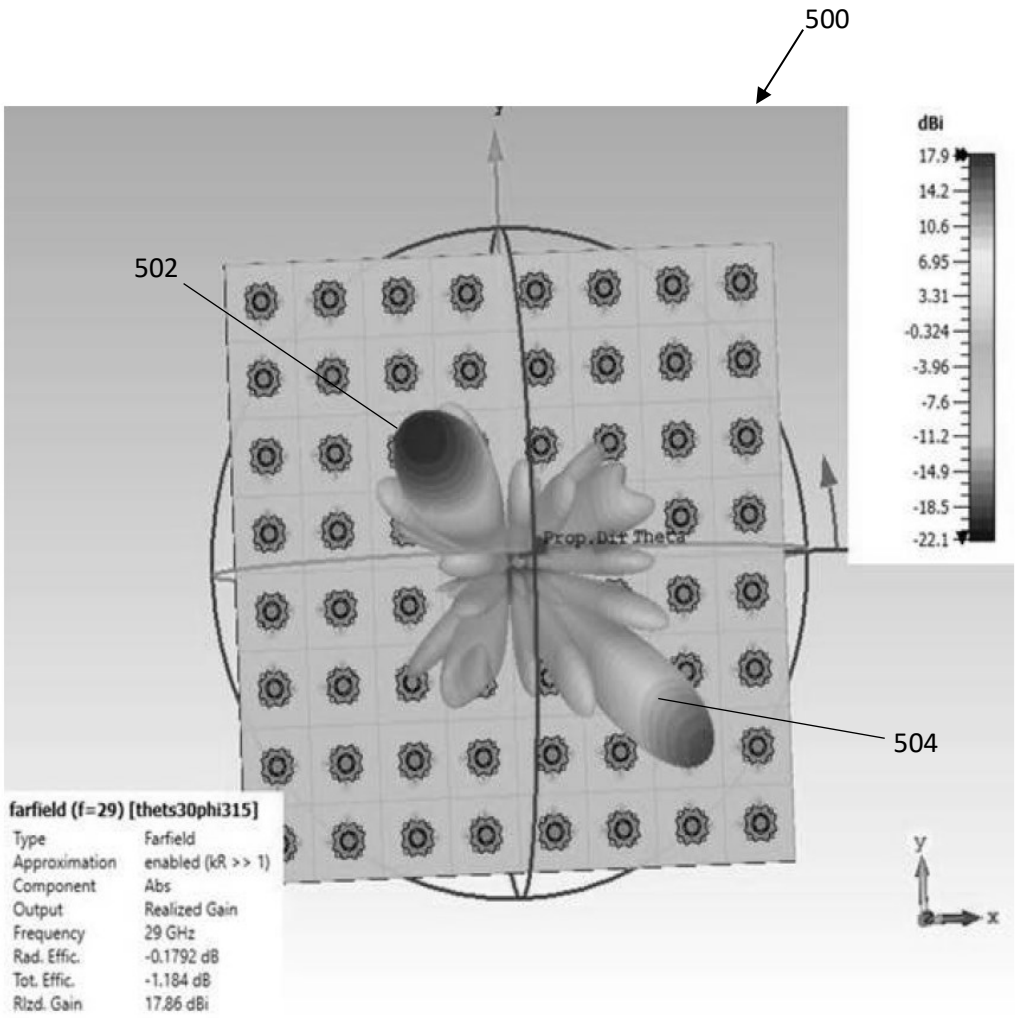

500
502
504
dBi
17.9
14.2
10.6
6.95
3.31
-0.324
-3.96
-7.6
-11.2
-14.9
-18.5
-22.1
Prop.Dir Theta
farfield (f=29) [thets30phi315]
Type Farfield
Approximation enabled (kR >> 1)
Component Abs
Output Realized Gain
Frequency 29 GHz
Rad. Effic. -0.1792 dB
Tot. Effic. -1.184 dB
Rlzd. Gain 17.86 dBi
y
x

FIG. 5

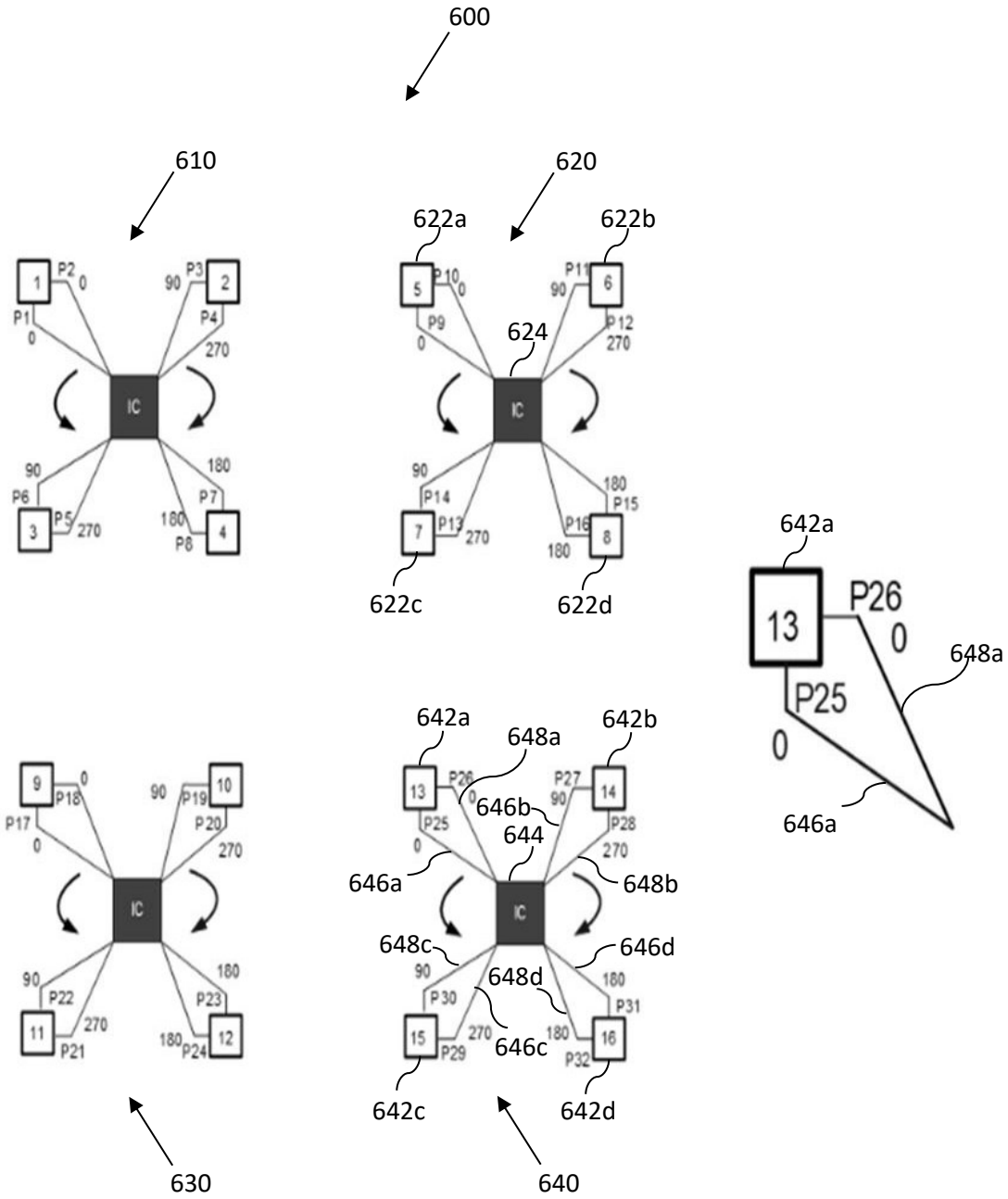

600
610
620
622a
622b
624
622c
622d
642a
13
P26
0
648a
P25
0
646a
642a
642b
648a
646b
644
646a
648b
648c
646d
648d
646c
642c
642d
630
640
IC

FIG. 6A

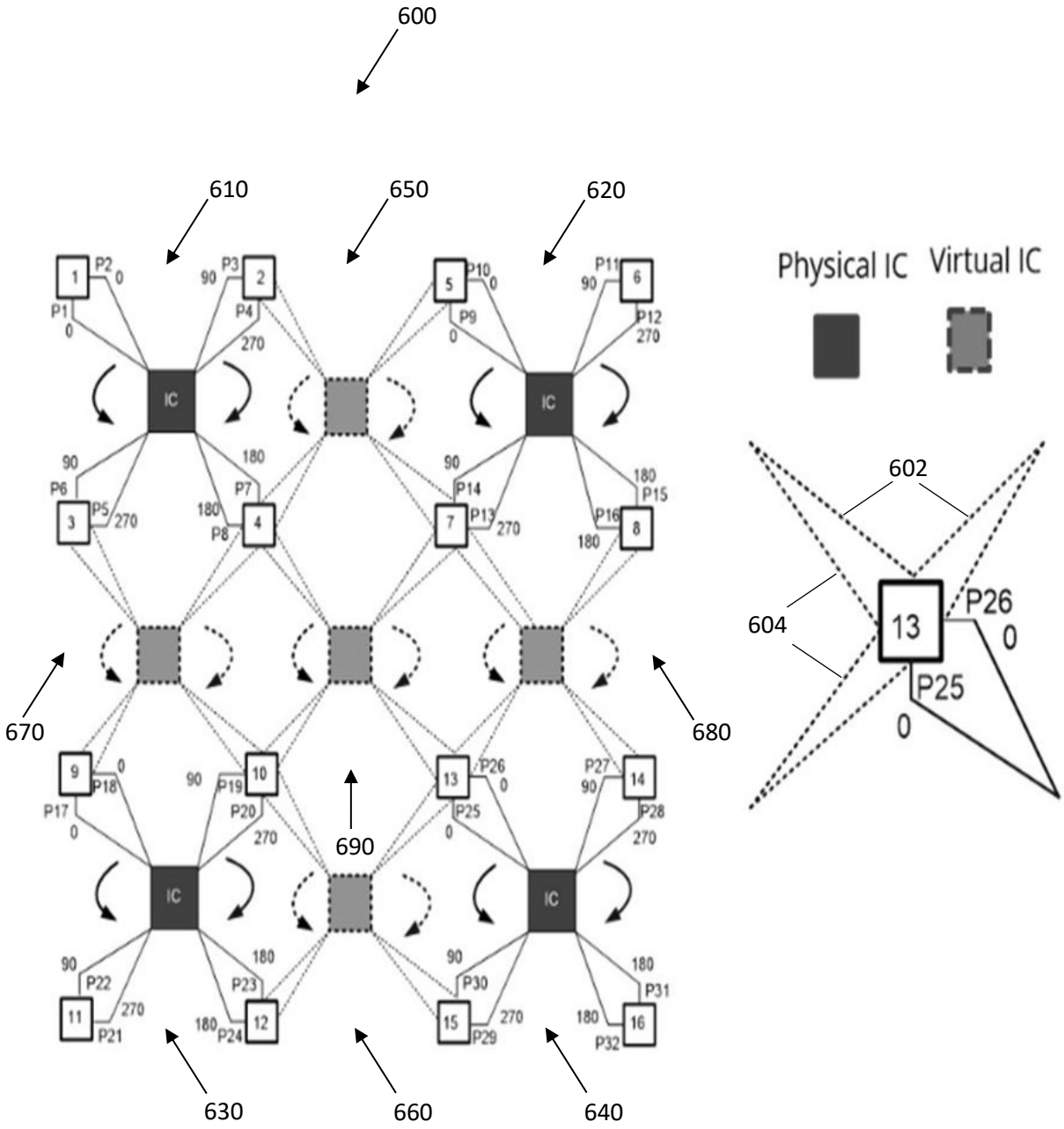

600
610
650
620
Physical IC
Virtual IC
602
604
13
P26
0
P25
0
670
680
690
630
660
640
IC
IC
IC
IC

FIG. 6B

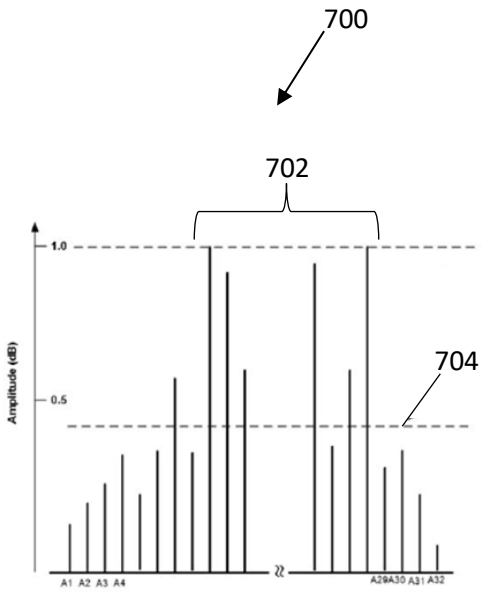


FIG. 7A

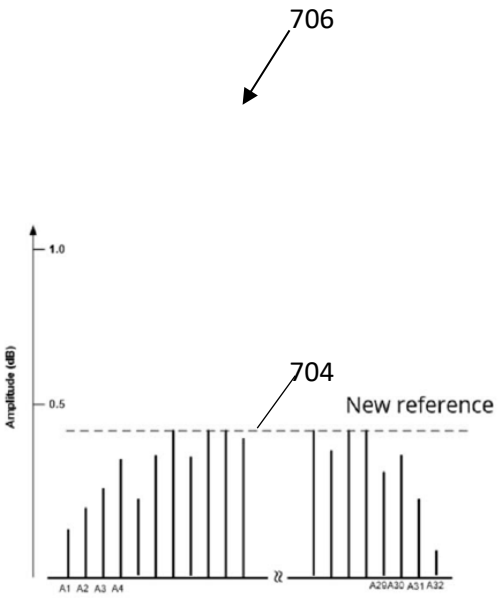


FIG. 7B

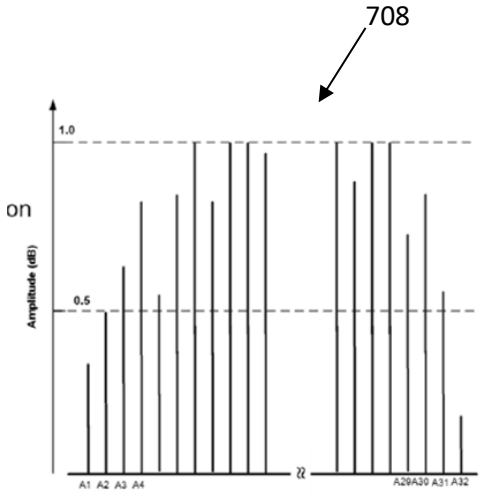


FIG. 7C

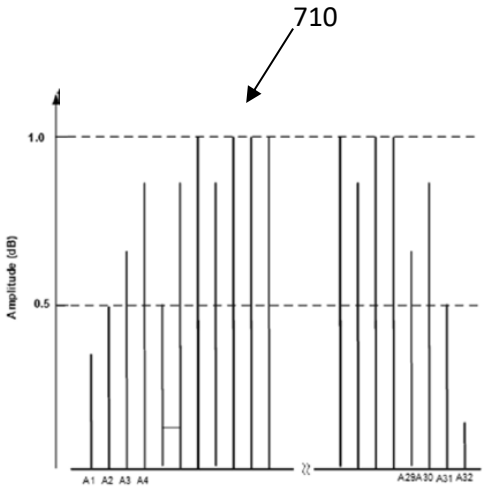


FIG. 7D

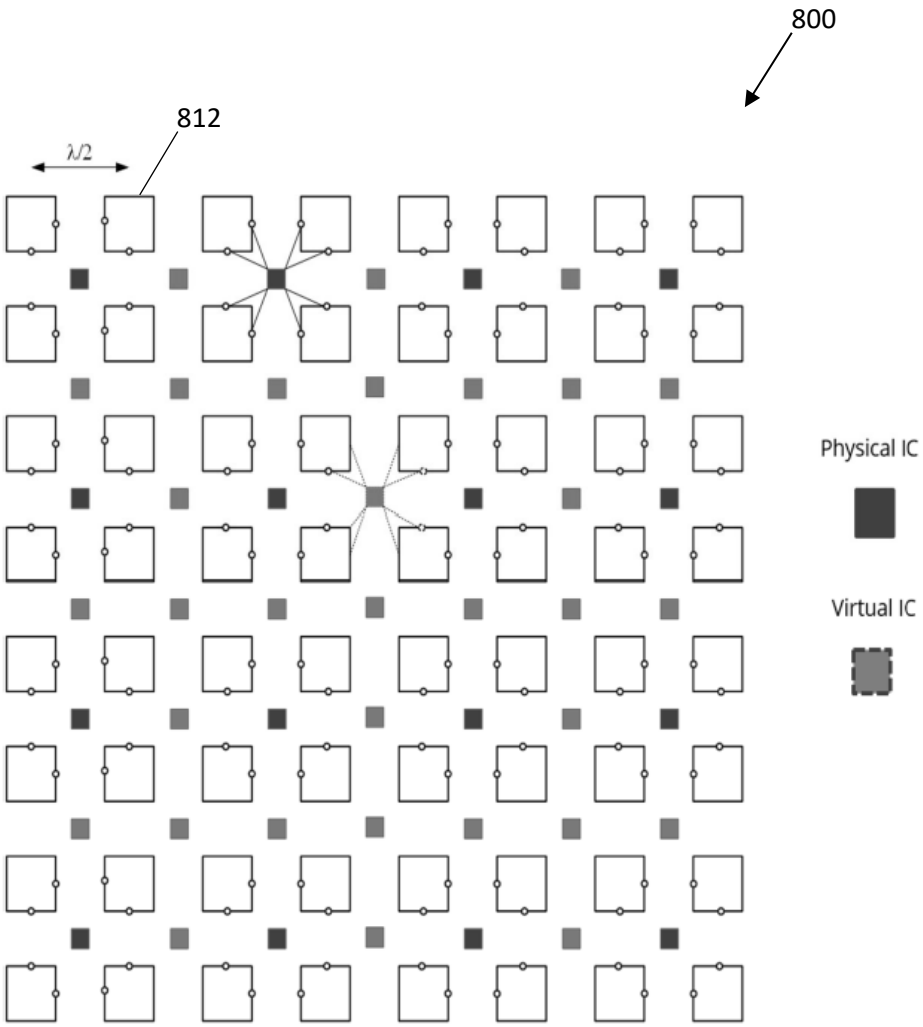

800
812
λ/2
Physical IC
Virtual IC

FIG.8A

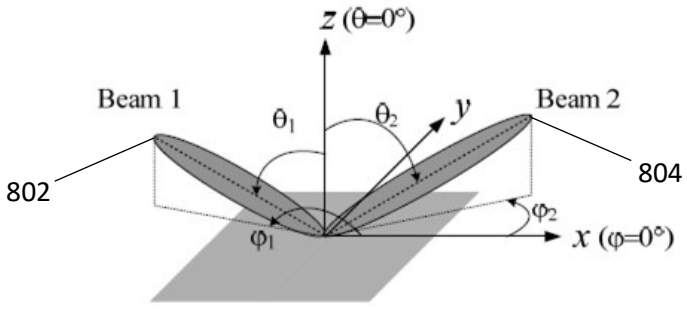
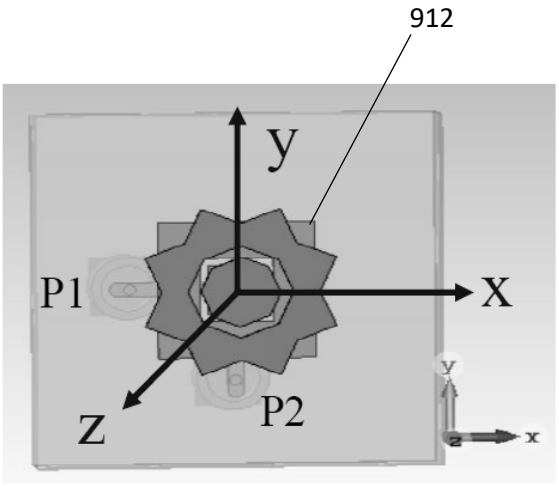

z (θ=0°)
Beam 1
θ1
θ2
y
Beam 2
802
804
φ2
φ1
x (φ=0°)

FIG. 8B



5.0 × 5. 0×1.1 mm

FIG. 9A

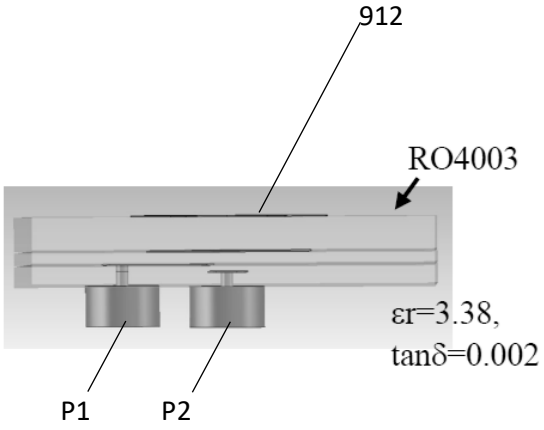


FIG. 9B

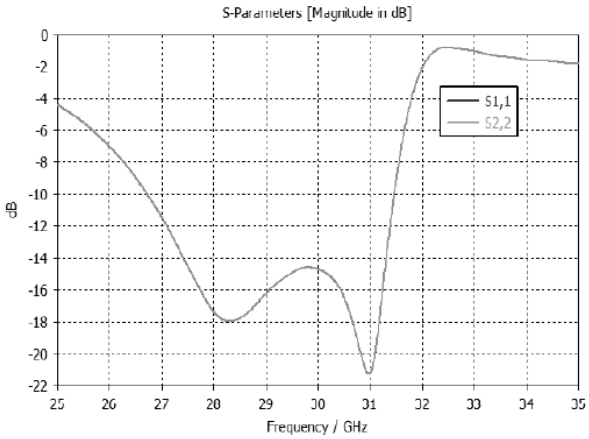


FIG. 9C

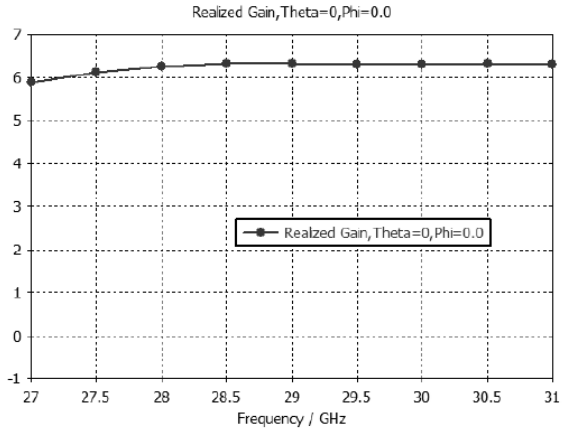


FIG. 9D

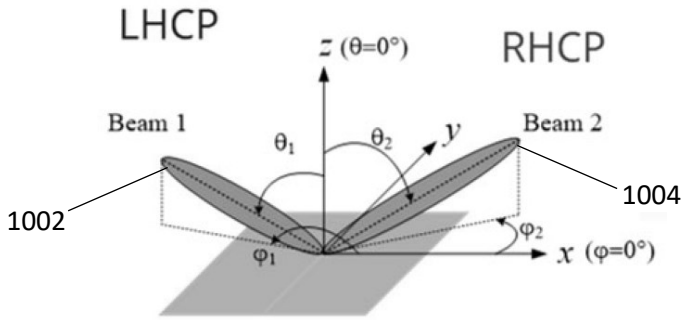


FIG. 10A

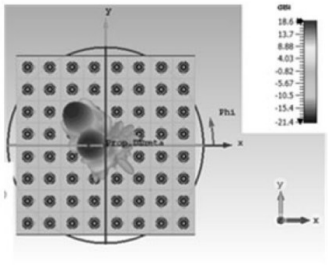


FIG. 10B

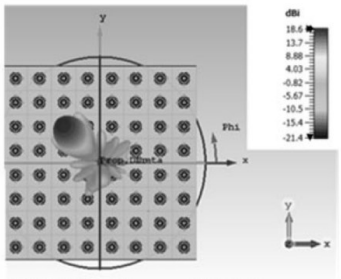


FIG. 10C

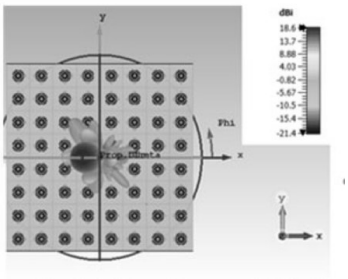


FIG. 10D

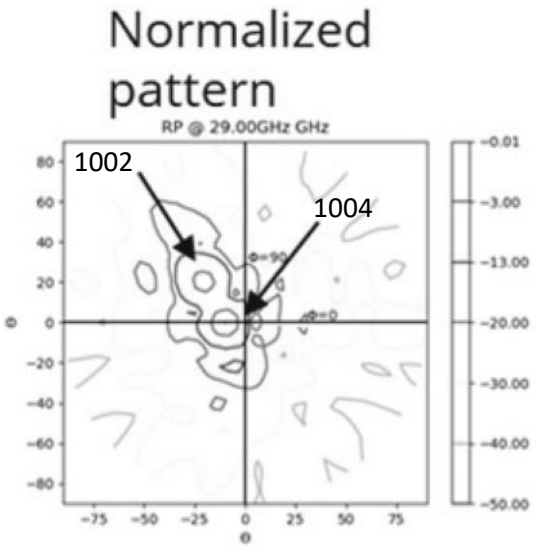


FIG. 10E

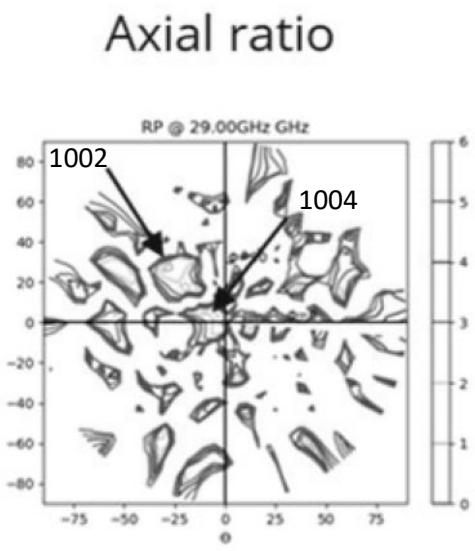


FIG. 10F

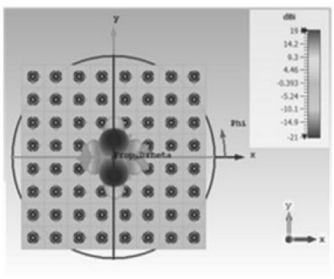


FIG. 10G

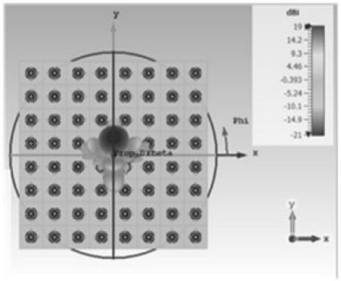


FIG. 10H

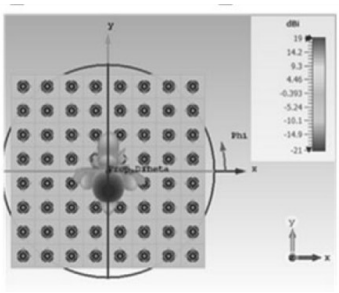


FIG. 10I

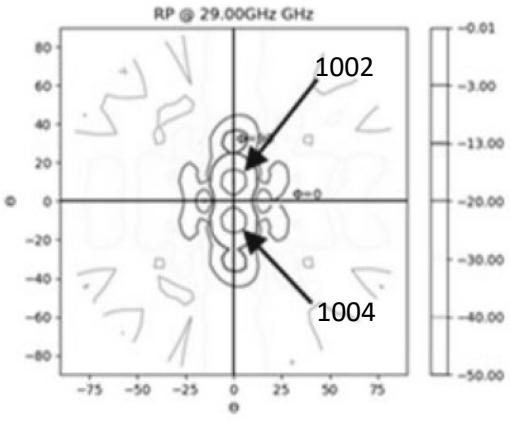


FIG. 10J

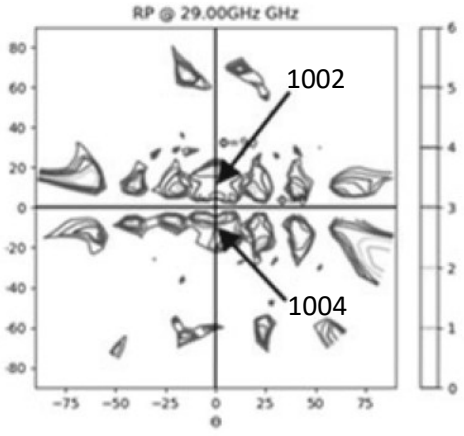


FIG. 10K

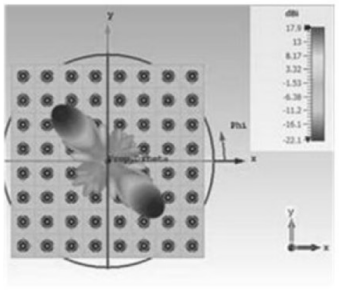


FIG. 10L

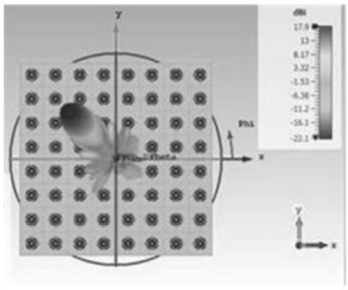


FIG. 10M

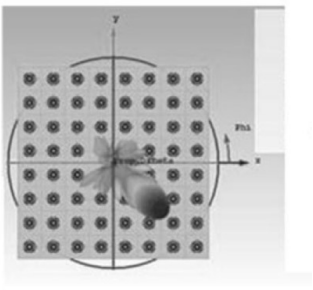


FIG. 10N

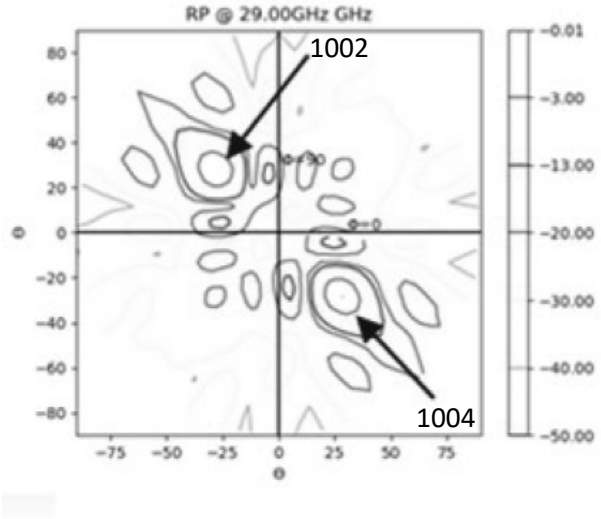


FIG. 10O

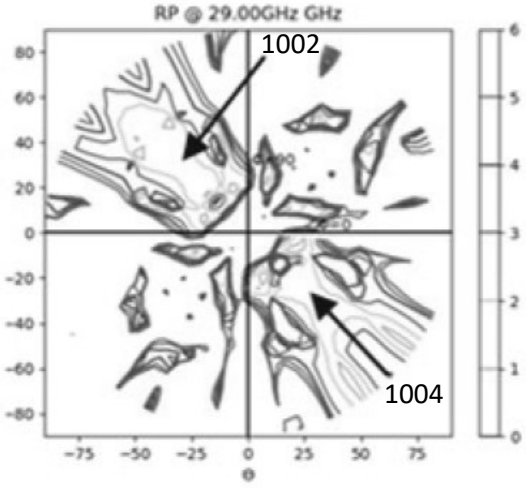


FIG. 10P

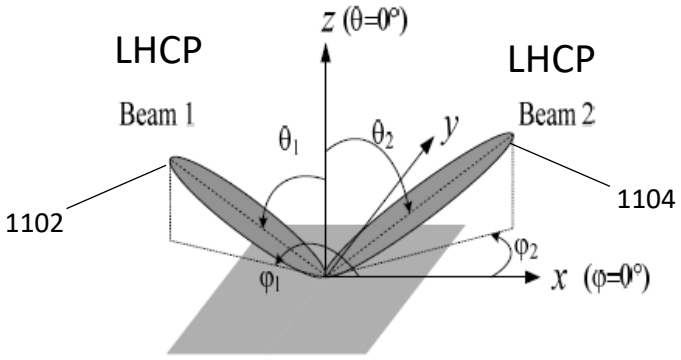


FIG. 11A

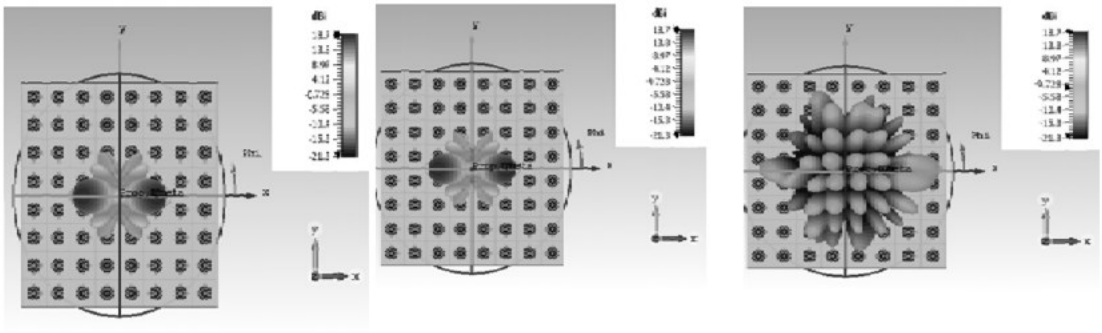


FIG. 11B FIG. 11C FIG. 11D

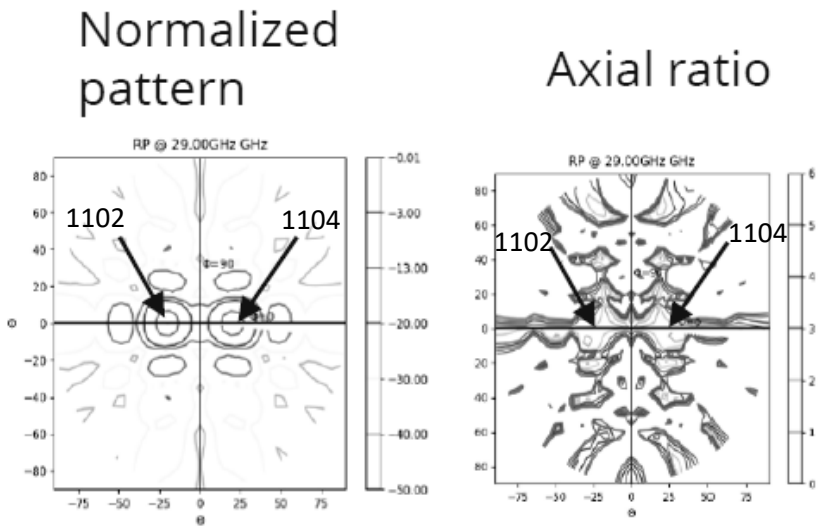


FIG. 11E FIG. 11F

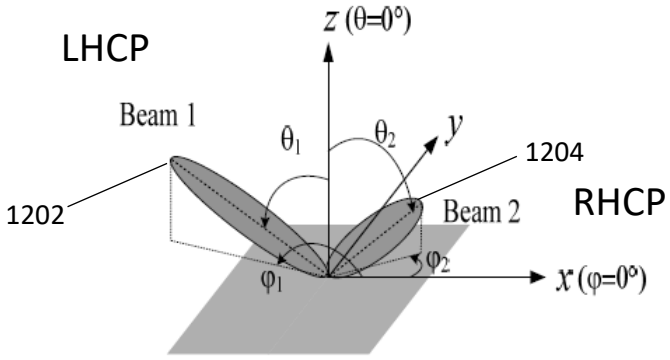


FIG. 12A

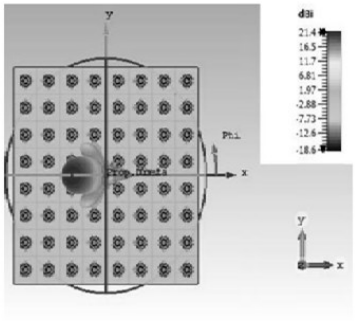


FIG. 12B

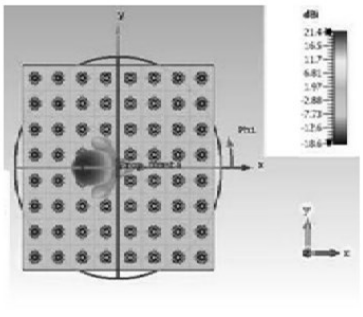


FIG. 12C

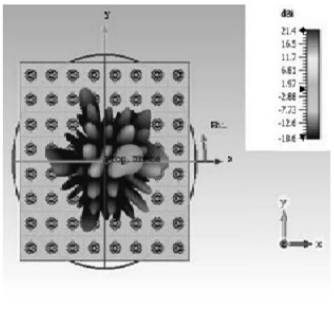


FIG. 12D

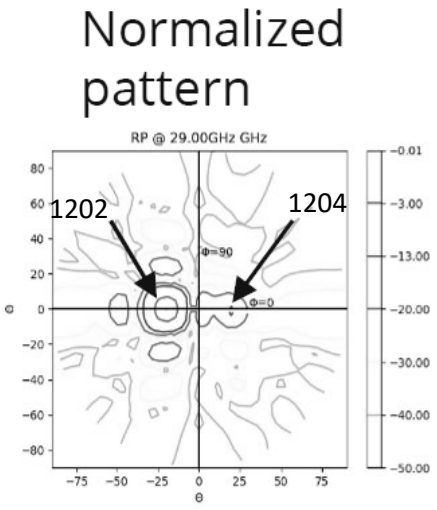


FIG. 12E

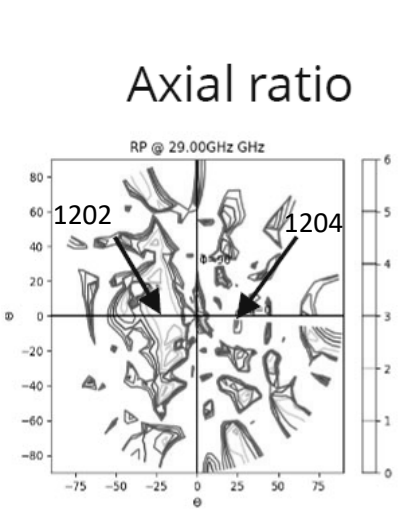


FIG. 12F

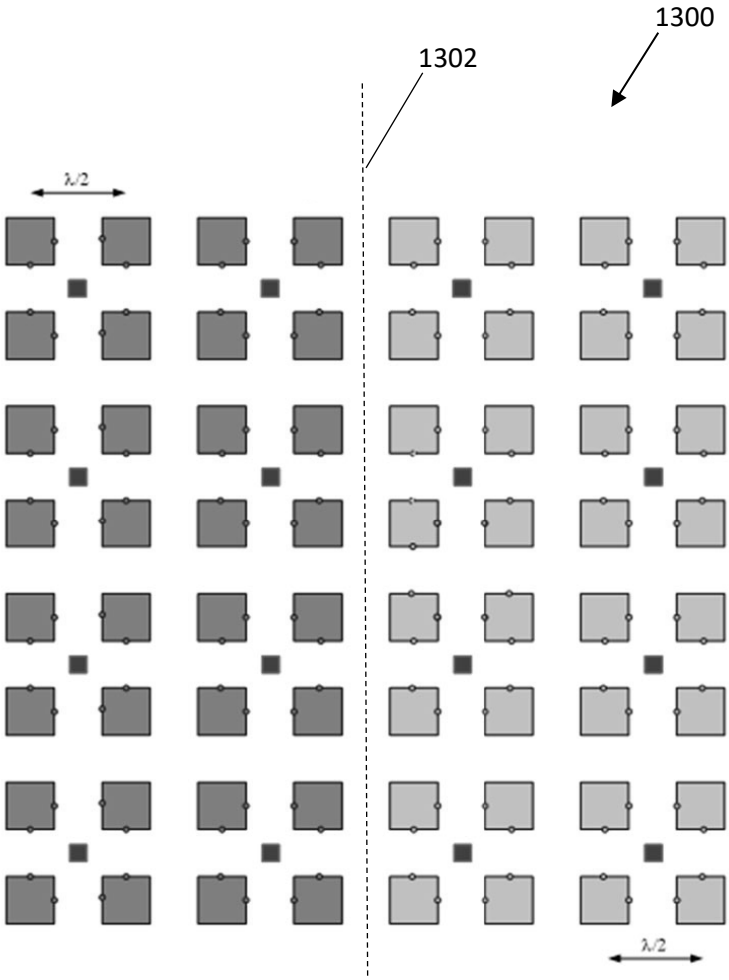


FIG. 13A

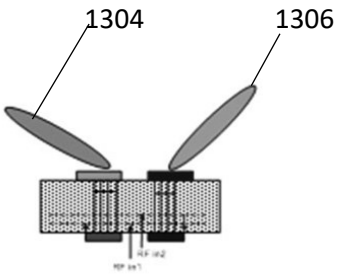


FIG. 13B

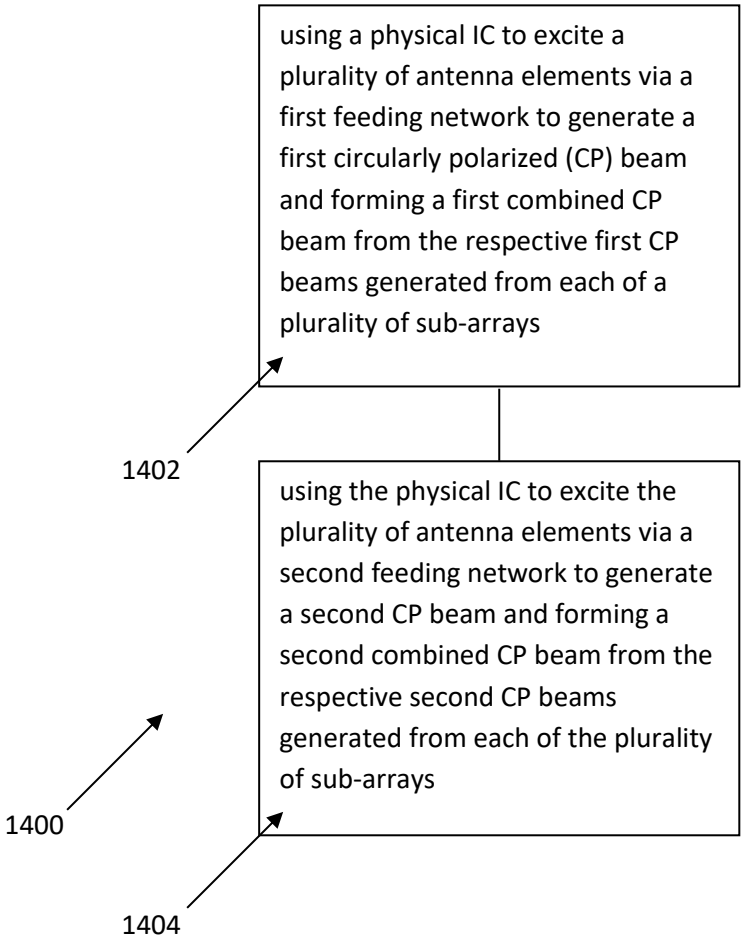

using a physical IC to excite a plurality of antenna elements via a first feeding network to generate a first circularly polarized (CP) beam and forming a first combined CP beam from the respective first CP beams generated from each of a plurality of sub-arrays
1402
using the physical IC to excite the plurality of antenna elements via a second feeding network to generate a second CP beam and forming a second combined CP beam from the respective second CP beams generated from each of the plurality of sub-arrays
1400
1404

FIG. 14