A single-axis electrically-steered panel is much simpler and less expensive than a full two-dimensional scanning phased array, but has a narrow azimuthal beamwidth, which maintains the high requirements on pointing accuracy and response time on the mechanical actuators.

Phased arrays of electrically-reconfigurable RF lens modules, as in U.S. Patent No. 10,116,051 to Scarborough et al., offer a number of advantages in power consumption and component count over conventional phased arrays for SATCOM, radar, and other purposes.

SUMMARY

The disclosure pertains generally to a radio-frequency lens array that employs tilted elements, tilted sub-arrays, and/or a degree of azimuthal mechanical scan to all or a subset of the lens elements. The addition of mechanical rotation allows for a reduction to the required scanning range, and therefore feed count, of each lens element. The azimuthal scan that the mechanical rotation provides also enables various configurations of tilted elements and tilted arrays. Tilting the individual lens elements and/or tilting the arrays provides improved gain performance at scan compared to a standard planar-phased array, while maintaining a low profile compared to gimbaled antennas.

According to an aspect, there is an antenna system comprising a substantially planar phased array of radio-frequency lens modules, each of said lens modules having an RF lens and one or more feed(s), wherein said array of lens modules scans in elevation and a mechanical actuator, said lens modules mounted to said mechanical actuator, said mechanical actuator mechanically rotating said array of lens modules to scan in azimuth. According to an aspect, there is an antenna system comprising a primary phased array of radio-frequency lens modules, each of said lens modules electronically scan in a first azimuth, and a secondary phased array of radio-frequency lens modules where each lens module is tilted in elevation with respect to the primary phased array toward the first azimuth.

In an embodiment, a planar array of a plurality of lens modules is mechanically rotated. This configuration allows for a significant reduction in the scan range, and therefore feed count, required of each lens element. The elements themselves primarily provide elevation scan with limited range of azimuth scan. The main azimuth scan is provided by the mechanical rotation. Unlike a standard phased array that has been configured for single-

axis scanning, the lens array maintains a degree of two-dimensional scanning capability within the beamwidth of the lens element pattern (typically 5-15 deg). In this way, the antenna can electrically scan (for example) within any +/- 5 deg cone of all points on the line between 0 and 65 deg parallel with the Azimuth=0 deg axis relative to the panel itself.

In order to increase scanned gain performance from the above configuration, the array can be tilted towards the horizon in a specified azimuth angle. The provides a larger projected area of the array facing the scan direction, thereby increasing the scanned gain.

CLAIMS:

1. An antenna system comprising:
    a. a substantially planar phased array of radio-frequency lens modules, each of said lens modules having an RF lens and one or more feed(s), wherein said array of lens modules scans in elevation; and
    b. a mechanical actuator, said lens modules mounted to said mechanical actuator, said mechanical actuator mechanically rotating said array of lens modules to scan in azimuth.
2. The antenna system of Claim 1 where the second azimuth overlaps with or is different than the first azimuth to scan over a combined 360 degrees.
3. The antenna system of Claim 1 or 2 where each lens module is individually tilted in elevation with respect to the actuator towards the first azimuth.
4. The antenna system of any of Claims 1-3 further comprising a rotation platform connected to said actuator where said array is mounted to said rotation platform and said rotation platform is tilted with respect to the actuator toward the first azimuth.
5. The antenna system of Claim 4 where each lens module is individually tilted in elevation with respect to the rotation platform towards the first azimuth.
6. The antenna system of any of Claims 1-5 wherein each of the lens modules electronically scans in the elevation plane.
7. An antenna system comprising:
    a. a primary phased array of radio-frequency lens modules, each of said lens modules electronically scan in a first azimuth, and
    b. a secondary phased array of radio-frequency lens modules where each lens module is tilted in elevation with respect to the primary phased array toward the first azimuth.

8. The antenna system of Claim 7, additionally comprising a mechanical actuator, said lens modules in said primary and secondary arrays mounted to said mechanical actuator, said mechanical actuator mechanically rotating said lens modules from pointing at the first azimuth to instead scan at a second azimuth.
9. The antenna system of any of Claims 7-8, where the elements in the secondary array are mounted on the perimeter of the primary array.
10. The antenna system of Claim 7 additionally comprising a mechanical actuator, said lens modules in only the secondary array mounted to said mechanical actuator, said mechanical actuator mechanically rotating said lens modules from pointing first azimuth to instead scan at a second azimuth.
11. The antenna system of Claim 8 where the second azimuth overlaps with the first azimuth to scan over a combined 360 deg.
12. The antenna system of Claim 8, 11 where each lens module is individually tilted in elevation with respect to the actuator towards the first azimuth.
13. The antenna system of any of Claims 8, 11-12 further comprising a rotation platform connected to said actuator where said array is mounted to said rotation platform and said rotation platform is tilted with respect to the actuator toward the first azimuth
14. The antenna system of any of Claims 8, 11-13 where each lens module is individually tilted in elevation with respect to the rotation platform towards the first azimuth.
15. The antenna system of any of Claims 7-14 where the lens modules electronically scan in the elevation plane.
16. An antenna assembly comprising:
    a. a platform having a primary portion and a secondary portion, said secondary portion angled to be offset with respect to said primary portion;

b. a primary lens array mounted to the primary portion of said platform, said primary lens array having a plurality of primary antenna lens assemblies; and

c. a secondary lens array mounted to the secondary portion of said platform, said secondary lens array having a plurality of secondary antenna lens assemblies, whereby said secondary lens array is angled to be offset with respect to said primary lens array.

17. The antenna system of Claim 16, further comprising an actuator coupled to said platform to rotate said platform to provide azimuthal steering of said primary and secondary lens arrays.

18. The assembly system of any of Claims 16 or 17, said primary portion having a primary plane and said secondary portion having a secondary plane, the secondary plane at an angle of 30-70 degrees to the primary plane, said secondary portion below and to a side of said primary portion.