antennas, each having a 33° azimuth HPBW antenna serving a 60° sector. In other proposed solutions, a single, multi-column array may be driven by a feed network to produce two or more beams from a single phased array antenna. For example, if multi-column array antennas are used that each generate two beams, then only three antennas may be required for a six sector configuration. Antennas that generate multiple beams are disclosed, for example, in U.S. Patent Publication No. 2011/0205119, which is incorporated herein by reference.

[0005] Increasing the number of sectors increases system capacity because each antenna can service a smaller area and therefore provide higher antenna gain throughout the sector. However, dividing a coverage area into smaller sectors has drawbacks because antennas covering narrow sectors generally have more radiating elements that are spaced wider apart than are the radiating elements of antennas covering wider sectors. For example, a typical 33° azimuth HPBW antenna is generally twice as wide as a typical 65° azimuth HPBW antenna. Thus, cost, space and tower loading requirements increase as a cell is divided into a greater number of sectors.

SUMMARY

[0006] In a first aspect, the present disclosure provides a multi-beam antenna, comprising: a plurality of radiating elements; and a lens that is positioned to receive electromagnetic radiation from at least one of the radiating elements, the lens comprising a composite dielectric material, wherein the composite dielectric material comprises a foamed base dielectric material having particles of a high dielectric constant material embedded therein, the high dielectric constant material having a dielectric constant that is at least three times a dielectric constant of the foamed base dielectric material.

[0007] In a second aspect, the present disclosure provides a multi-beam antenna, comprising: a plurality of radiating elements; and a lens that is positioned to receive electromagnetic radiation from at least one of the radiating elements, the lens comprising a plurality of blocks that are contained within an outer shell of a composite dielectric material, wherein each block comprises a composite dielectric material that includes a base dielectric material having particles of a high dielectric constant material embedded therein, the high dielectric constant material having a dielectric constant that is at least three times a dielectric constant of the base dielectric material.

[0008] In a third aspect, the present disclosure provides a method of fabricating a multi-beam antenna, the method comprising: mixing particles of a second dielectric material into a first dielectric material that is in liquid form, the second dielectric

That Which is Claimed is:

1. A multi-beam antenna, comprising:

a plurality of radiating elements; and

a lens that is positioned to receive electromagnetic radiation from at least one of the radiating elements, the lens comprising a composite dielectric material,

wherein the composite dielectric material comprises a foamed base dielectric material having particles of a high dielectric constant material embedded therein, the high dielectric constant material having a dielectric constant that is at least three times a dielectric constant of the foamed base dielectric material.

2. The multi-beam antenna of Claim 1, wherein the high dielectric constant material has a dielectric constant of at least 10.

3. The multi-beam antenna of Claim 1 or Claim 2, wherein the high dielectric constant material comprises a ceramic material.

4. A multi-beam antenna, comprising:

a plurality of radiating elements; and

a lens that is positioned to receive electromagnetic radiation from at least one of the radiating elements, the lens comprising a plurality of blocks that are contained within an outer shell of a composite dielectric material,

wherein each block comprises a composite dielectric material that includes a base dielectric material having particles of a high dielectric constant material embedded therein, the high dielectric constant material having a dielectric constant that is at least three times a dielectric constant of the base dielectric material.

5. The multi-beam antenna of Claim 4, wherein the high dielectric constant material has a dielectric constant of at least 10.

6. The multi-beam antenna of Claim 4 or Claim 5, wherein the base dielectric material comprises a foamed dielectric material and the high dielectric constant material comprises a ceramic material or a metal oxide.

7. The multi-beam antenna of Claim 6, wherein the foamed dielectric material has an open-cell structure and a foaming percentage of at least 50%.

8. A method of fabricating a multi-beam antenna, the method comprising:

mixing particles of a second dielectric material into a first dielectric material that is in liquid form, the second dielectric material having a dielectric constant that is at least three times a dielectric constant of the first dielectric material;

adding a nucleating agent to the first dielectric material;

using a blowing agent to foam the first dielectric material having the particles of the second dielectric material mixed therein;

using the foamed first dielectric material for a lens for the multi-beam antenna; and

mounting the lens in front of at least one radiating element.

9. The method of Claim 8, wherein the second dielectric material comprises a ceramic material.

10. The method of Claim 8 or Claim 9, wherein the second dielectric material comprises a metal oxide.