Metamaterials for Electronically Steered Beams

Minas Tanielian
Boeing Phantom Works
Seattle, WA 98124
USA

One novel aspect of metamaterials is the possibility of having values of the index of refraction that are $n < 1$. This leads to new possibilities in the optics of electromagnetic beams. We have fabricated a number of negative index lenses using metamaterials and used them for steering electromagnetic beams as a simple alternative to more expensive phased array antennas. There are several advantages in using negative index lenses vs positive index materials. In general, negative index lenses tend to have lower aberrations than positive index lenses, they are much lighter, and they can be made in a graded index, which offers the advantage of trading physical curvature with a change in the index the refraction to bend the beam. Furthermore, in a metamaterial lens one has the capability of independently adjusting the permittivity and permeability of each unit cell. This allows for making flat lenses, which are advantageous for certain applications and generally have lower losses, since there are less metamaterial unit cells in the direction of propagation. Having the capability of adjusting the metamaterial ε and μ one can also match the impedance of the negative index cells to that of free space, thus allowing for almost no reflection from the metamaterial surface. Finally, negative index lenses have shorter focal points than a corresponding positive index lens with the same absolute value of the index of refraction, which makes the lens system more compact.

We have transitioned some of these interesting properties to improve some of the shortcomings of more traditional communication antennas such as phased arrays. Phased arrays electronically steer a beam by adjusting the phase difference between adjoining waveguide elements of an array. The directionality and beam sharpness is generally a function of the number of elements in the array. However, due to impedance mismatches, most phased array antennas are limited in their scan angle to about 60 degrees from the vertical direction. In an effort to overcome this shortcoming, we have designed a metamaterial cover/dome for a phased array that allows scanning to angles which are almost 85 degrees from the vertical. We will discuss some of the tradeoffs one has to make to achieve these benefits and the limitations of such a system, when considering the traditional ring and wire-type metamaterials.