**Opening Satellite Capacity to Consumers with Metamaterial Antennas**

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**Abstract**— A metamaterial antenna is being developed for satellite communication that is thin, light-weight, and lower cost than existing technologies. These antennas are built upon reconfigurable metamaterials and the principles of holography, and they produce a directed, steerable, high-gain beam without mechanically moving parts and with considerably lower power-consumption than the competing technologies. This paper briefly introduces this antenna, only made possible by the intentional engineering of metamaterials, that is poised to bring satellite data capacities to the mass market.

1. **INTRODUCTION**

The most well-known non-natural characteristic achieved by the engineering of metamaterials is simultaneous negative magnetic permeability and electric permittivity [1], and metamaterials were responsible for the successful experimental demonstration of the celebrated application of electromagnetic cloaking in 2006 [2]. Yet, there are many other applications in which engineering the electromagnetic response of a material is useful, and, indeed, many other applications that are easier to achieve than the Harry Potter-esque invisibility cloak.

One area that has seen intensive development with the advent of metamaterials is antenna design. Metamaterials are enabling smaller, highly-directive antennas [3, 4] and novel architectures. The engineering of the reconfigurable holographic metamaterial antenna (RHMA) that is the subject of this paper (and is the demonstrated technology that has garnered much commercial attention and impressive financial backing in the form of the internationally recognized Bill Gates-funded company Kymeta) is poised to re-energize the satellite communications sector, particularly mobile applications (moving antenna platforms, moving satellites, or both).

2. **A RECONFIGURABLE HOLOGRAPHIC METAMATERIAL ANTENNA (RHMA)**

![Image: Top-view of a holographic metamaterial antenna, which is composed of a planar array of metamaterial unit cells (seen in the inset) fed by parallel rectangular waveguides beneath the unit cells.](image)

![Image: The parallel rectangular waveguide feed structure of the holographic metamaterial antenna.](image)

The type of metamaterial antenna being developed commercially by Kymeta Corporation is called a *Reconfigurable Holographic Metamaterial Antenna* (RHMA). It is helpful when discussing this technology to describe the RHMA from its constituent parts, starting with the term “antenna.”
Everyone is familiar with what an antenna does whether or not they are familiar with how an antenna works. An antenna is the device by which a guided wave (typically containing encoded information) is transferred to free space where it propagates, without active interference, and is sensed/received at some other location.

Onto “antenna” is layered “metamaterial.” The metamaterial of this device consists of a planar array of densely-packed resonant unit cells. See the left pane of figure 1 for a picture of the planar metamaterial and the inset of figure 1 for a picture of several unit cells. It is this plane of metamaterial that is the interface between the guided wave of the antenna and free space. It is this interface that permits the RHMA to specify in which directions the radiation of the antenna occurs. On the guided-wave side of the metamaterial interface is an array of parallel rectangular waveguides such that each row of unit cells is above each waveguide channel. This array of waveguides confines and propagates the radio frequency wave containing encoded data, and as it propagates past the metamaterial unit cells, the metamaterial allows carefully controlled radiation of this wave to free space.

The next term is “holographic.” The principle of holography is how one selects where the energy of the waveguides is radiated by the metamaterial. Briefly, holography is a means of recording and then “playing back” a three-dimensional image. In the case of the metamaterial antenna, the desired image is the one pin-prick in space that one wants all the energy of the antenna to radiate toward (the satellite). The metamaterial antenna is the surface upon which the image is recorded, and it is “played back” by the guided waves underneath.

Finally, we arrive at “reconfigurable.” The idea of reconfigurability of the metamaterial antenna is that it is possible, in real-time, to change the recorded holographic image, and so, change the radiation direction of the antenna’s energy. The metamaterial unit cells are the means by which the holographic image is recorded, so reconfigurability of the holographic metamaterial antenna ultimately means changing the radiation characteristics of the individual metamaterial unit cells to change the holographic image. For the antenna developed by Kymeta, the resonant frequency of each unit cell is changed by the application of a voltage to each. This tuning shifts the resonance of the cell nearer to or further from the operating frequency of the antenna. When tuned to a resonance far from the operating frequency, the cell scatters little energy into free-space. On the other hand, when tuned such that the resonance is close to the operating frequency, the cell scatters a maximal amount of energy. Then, as mentioned before, holography indicates how on or off each cell should be to record the desired image, pointing the beam in the desired direction.

Taken all together, the reconfigurable holographic metamaterial antenna is described with its means of controlling the radiation of the antenna and its means of real-time reconfigurability.

3. CONCLUSION

In parallel with the success of cell phones, laptops, and tablets, satellite communications consumers are also looking to be able to access data wherever they are, even while fully mobile. This means that the satellite industry is seeking satellite terminal solutions that can deliver connections continuously to aircraft, trains, buses, boats, automobiles, and individuals. The fixed parabolic reflector antenna is the mature technology that is ubiquitously used for geo-stationary satellite communication. Yet, the mobile applications require a different antenna. The reconfigurable holographic metamaterial antenna is a rapidly emerging technology to effectively solve this mounting mobile communications problem.

REFERENCES