Microstrip Patch Antennas with Controlled Pattern Tilt using Multi-Material Additive Manufacturing for Piecewise Planar Conformal Arrays

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In antenna arrays, in order to achieve a high directivity, the direction of element pattern and array factor need to be aligned. For a linear or planar array this is generally not a problem when the antenna array pattern is in the broadside direction, however for some other applications where a tilted beam is required, this misalignment results in a reduced directivity. Examples of these scenarios include base-station antennas where system capacity and interference immunity can be improved using the down-tilt radiation pattern towards a desired direction. For conformal arrays however, the situation is different. In a piecewise planar configuration, the element pattern for the element or elements in each planar section are normal to the local surface. As a result, for a broadside beam, the element patterns and the array factor will not point in the same direction, consequently reducing the directivity and gain of the conformal antenna array.

To provide maximum directivity in these conformal antenna arrays, we propose a novel type of microstrip patch element that can achieve a controllable beam tilt. This is realized using state-of-the-art multi-material additive manufacturing. For the most part, current microwave devices, antennas, and arrays, are built from monolithic components of individual, typically linear materials. While incremental increases in device performance have been achieved with these materials over the past 3 decades, the fact is that these have been incremental growths. We need a major change. Recent advances in additive manufacturing is now opening a path for a new electromagnetic device that use spatially distributed materials to realize capabilities and functionalities that were once unimaginable.

In this study, we develop a microstrip patch antenna where the dielectric constant of the substrate material is graded, i.e. it increases from a low value at the first radiating edge of the patch to a high value at the second edge. Note that the substrate thickness remains constant, making it a suitable choice for the conformal platform, however the increase in dielectric constant means that the electrical thickness of the substrate increases from the first radiating edge to the second. As a result, the radiation pattern of the patch antenna tilts in the E-plane. The tilt angle of the antenna pattern is controlled by the ratio of maximum to minimum dielectric constant. While large values result in a larger tilt angle, they do increase the surface wave propagation, and thus are kept to a minimum. In the studies conducted the patch antenna was excited with a coaxial feed, however the proposed technique is equally valid for microstrip feed networks and can be utilized to maximize the directivity of piecewise planar conformal arrays.