Beamforming and Reconfiguration of a Structurally Embedded Vascular Antenna Array (SEVA^2) in a Complex Curved Composite

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Recently, reconfigurable structurally embedded vascular antenna (SEVA) has been demonstrated in flat epoxy/quartz fiber composite panels based on the internal transport of liquid metal within embedded microchannels. The liquid metal is a non-toxic eutectic gallium-indium alloy which remains liquid down to -20 C, has low viscosity, and has high electrical conductivity. Patterned microchannels are created using fused deposition printing of sacrificial catalyzed polylactic acid (cPLA) followed by transfer, composite lamination, composite cure, and then thermal removal of the sacrificial cPLA during post-cure. When the resulting embedded channel are progressively filled with liquid metal and electromagnetically connected, they can be tuned over a large frequency range which is dependent on the resulting shape of the liquid metal. The large frequency response, the small footprint, the low volume of the metal (<2%), and the retention of an aerodynamically efficient composite shape makes SEVA attractive for agile aircraft antenna. Mechanical modeling, mechanical testing, and multi-physics optimization of the microvascular panels has shown modest decreases in tensile strength due to the microchannels, depending on the design and thermal/RF environment. This paper will highlight the composite fabrication of a multi-element SEVA, or Structurally Embedded Antenna Array (SEVA^2), within a complex curved article that resembles an aircraft leading-edge. It will also provide a detailed discussion on the design and operation of the structure as a phased array of physically-reconfigurable antennas. These frequency-agile antennas can also be interconnected to form larger contiguous reconfigurable antenna structures that extend the range of electromagnetic tunability and/or provide other operational modalities. This will be discussed as well using simulations and measurements for a three-element SEVA^2.