Assessment of multimaterial 3D printed microstrip circuits

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Multimaterial 3D printing poses both a challenge and opportunity for microwave engineering. As an additive manufacturing (AM) process there are many challenges to true multimaterial 3D printing such as optimization of materials, extrusion processing parameters, post deposition processing, resolution, co-deposition of materials, chemical and mechanical compatibility etc. Overcoming these challenges can allow for the fabrication of novel microwave electronics structures and circuits that exploit the advantages of AM over conventional manufacturing techniques.

Examples of single material AM techniques in microwave circuitry include the creation of tailored permittivity microwave substrates (Zhang et al., IET Microwave & Opt. Tech. Letters, Vol. 57, pp2344-2346, 2015) using the extrusion of plastic filaments in a process called Fused Filament Fabrication (FFF), or the manufacture of low cost, lightweight waveguides by the company Swissto12 using stereolithography apparatus (SLA). Direct digital manufacture demonstrated by Ketterl (Ketterl *et al.*, IEEE MTT Vol. 63, No. 12, pp. 4382-4394, 2015) is a hybrid approach deploying two different AM processes within a single build to fabricate a 2.45GHz phased array unit cell. Here the substrate was created using FFF to produce significant vertical dimensions while thick film silver paste was micro-dispensed to create the conductive tracks and through hole vias.

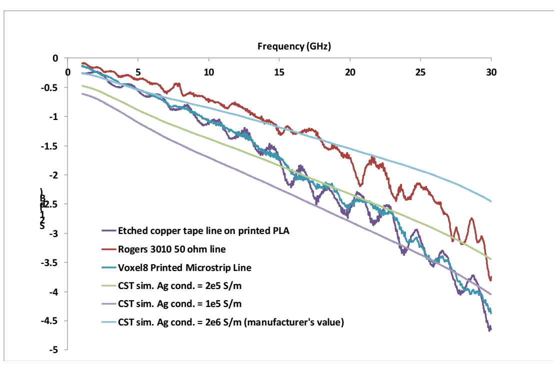

Figure 1: measured and simulated Microstrip S21 for Voxel8 printed, Rogers substrate and copper tape on PLA

Here we have used Voxel8's Developer Kit, a 3D printer with 2 heads allowing the deposition of dielectrics through a FFF print head and a second extrusion print head that creates conductive elements with their proprietary silver microparticle ink which according to the datasheet has $\sigma = 2 \times 10^6$ S/m once fully cured. Voxel8 silver ink based microstrip lines were printed on FFF substrates of Polylactic Acid (PLA) filament ($\varepsilon_r = 2.65$ to 2.75 dependent upon the quality of the material and also the print quality). Measurements were made over the frequency range 1 – 30 GHz and the results were compared with those of a microstrip line on Rogers 3010, a 50 Ω copper line on printed PLA substrate, and CST simulations of the Voxel8 printed structure with different values of silver conductivity.

The S21 results shown in Figure 1 indicate that the Voxel8 printed microstrip performs modestly well compared to what could be considered as the benchmark, the Rogers microstrip line. Simulations results indicate that at lower frequencies (< 10 GHz) then the Ag conductivity could be assumed to be as per the datasheet, while at > 25GHz its closer to 2×10^5 S/m.

The assessment and characterization of these materials and 3D printing process is allowing us to assess the ability to not only create microstrip circuits but also 3D metamaterial based designs for microwave and millimeter wave applications.