**Novel Additive Manufactured Synthetic Dielectric Substrates**

Shiyu Zhang, Chinwe Njoku, William Whittow, J.(Yiannis) Vardaxoglou
School of Electronic, Electrical and Systems Engineering,
Loughborough University, Loughborough, UK.

Dielectric substrates are widely used in antenna applications. Since the specifications of a dielectric substrate such as thickness and relative permittivity are determined by manufacturers, antenna engineers' designs are restricted. Using additive manufacturing (AM) technology in dielectric materials fabrication allows customizing the dimensions of the materials and this is useful in conformal antenna applications. Furthermore, AM technology constructs successive layers of materials to create a three-dimensional (3D) structures. It can fabricate dielectric substrates with customized internal structures in one process. This enables AM to produce synthetic dielectric materials without mechanical machining. The dielectric index of materials such as permittivity and loss factor can be tailored to the value as demanded with different internal structures of the material. Therefore the additive manufactured dielectric materials that are cost efficient and can be rapid manufactured will become increasingly attractive in antenna fabrication. The advances in digital AM equipment and new materials enable 3D printing to produce a wide range of products and have been applied in electronics manufacturing and antenna applications (E. Canelon *et al*. EuCAP, 2014).

This paper demonstrates fabricating dielectric substrates with non-toxic thermoplastic polylactic acid (PLA) using a fused deposition modelling (FDM) 3D printing machine. The thermoplastic material is heated and fused by the printer nozzle, and then it creates the objects from the bottom upwards in a series of layers. The geometry of the internal structure is designed using computer-aided design (CAD) tools. This reduces the manufacturing process which diminishes the physical machining error and therefore minimizes the EM variation of the final products.

The relative permittivity and loss factor of the PLA material has been measured as 2.72 and 0.008 respectively at 2 GHz and 10 GHz. By introducing air voids inclusions in the PLA substrate, the relative permittivity and loss tangent of the non-solid substrate can be reduced. Lower relative permittivity and loss tangent values are obtained by higher volume fractions of the air voids. The relative permittivity can be reduced to 1.24 and the loss tangent can be reduced to 0.002 by having 82% air in the substrate. By contrast, adding metallic cuboids inclusions into the PLA substrate can increase the dielectric index. The effective permittivity and loss tangent of the mixture is increased with a higher volume fraction of the metallic cuboids. Representative results show that the relative permittivity of the mixture is increased to 4.52 and the loss tangent is increased to 0.017 by using 16% metallic volume fraction. Experimental results with the additive manufactured dielectric substrates will be presented.