Leveraging Data Science to Characterize Additively Manufactured Electromagnetic Components

Deanna M. Sessions* (1), Andrew S. Gillman (2, 3), Alexander B. Cook(4), Kazuko Fuchi(2, 5), Gregory H. Huff(1), and Philip R. Buskohl(2)
(1) Pennsylvania State University, State College, PA, 16802
(2) Air Force Research Laboratory, Wright Patterson AFB, OH, 45433
(3) UES Inc., Dayton, OH, 45432
(4) NextFlex, San Jose, CA, 95131
(5) University of Dayton Research Institute, Dayton, OH, 45469

Additive manufacturing (AM) has significantly reduced the technical barriers and costs to fabricate complex geometries for electromagnetic (EM) applications. However, inherent variabilities in the AM process generate distinct classes of morphological defects, which are specific to AM and possess unknown consequences for EM performance. To address this challenge, a data analysis and computational modeling framework is developed to connect print geometry to RF performance, using a spiral-based frequency selective surface (FSS) as a representative test case. Each spiral is examined for its geometric deviance and simulated for its frequency response. These responses, in combination with a data science clustering algorithm, advise on the overall expected response of the system and provide feedback for the additive manufacturing process.

The spirals are printed of silver thermoplastic polyurethane (Ag-TPU) ink on a Kapton substrate using a pressure driven gantry printer. The spiral elements are configured in a densely packed triangular lattice of repeated sub-wavelength unit cells to create a FSS, with a targeted spatial band-stop filter at 14 GHz. The spirals provide a complex geometry for the print system with multiple parameters that influence the frequency response: arm width, arm length, spiral curvature, center radius, etc. After a set of ~4000 spirals are printed, each spiral is individually imaged and converted into a binary image. This binary image is converted into nodal coordinates of the exterior contour. Each geometric parameter is analyzed through image processing of the exterior contour and the spirals are grouped into ‘clusters’ of spirals containing similar physical characteristics. Each spiral is then simulated in an infinite lattice to determine frequency response and this information is then linked back to the clusters. The similarities among the spirals in each cluster and the aggregate frequency response advise on how specific geometric variances influence the overall response of the FSS. The aggregated simulated responses are compared to measured results.

The presented data analysis and computational modeling framework provides a process to directly link print defects and variances to the impact on frequency response. This direct link can be used to adjust the manufacturing process and tailor future print jobs to user needs.