Agile Prototyping of E-band Devices

Grant D. Heileman*[1,2], Firas Ayoub [1], Derek Doyle[3], and Christos G. Christodoulou[1]
(1) ECE Department, The University of New Mexico, Albuquerque, NM 87131, USA
(2) Applied Technology Associates, Albuquerque, NM 87123, USA
(3) Air Force Research Lab, Space Vehicles Directorate, Kirtland, Albuquerque, NM 87117, USA

Agile Manufacturing (AM) methodologies are inherently limited by their associated prototyping methods. Furthermore, since small manufacturing imperfections can have large effects on the measured performance of millimeter-wave frequency designs; strict tolerances are required. Together, this makes the implementation of AM for microwave design relatively challenging; as optimizing time, cost, and reliability becomes more difficult. The proposed design methodology focuses on cost efficiency, fabrication consistency, design reliability, and overall manufacturability of millimeter-wave devices.

Prototype development can be executed through various manufacturing platforms and postprocessing methods. Depending on design requirements, a list of applicable Agile Prototyping (AP) methods are compiled. Additive manufacturing technologies are specifically considered, and each platform's existing limitations are discussed. Moreover, by combining functionalities the practical limits of various 3D printing platforms are extended. Microwave and antenna engineers have already demonstrated the benefits of 3D printing, and a literature review provides a multitude of examples. While planar devices have relatively simple fabrication processes and have been designed for a large range of frequencies, producing millimeter-wave complex resonant cavities is a difficult task. By engineering designs which conform to the limitations of our AP workflow, E-band waveguide devices can be fabricated.

When reviewing the applicable AP methods, for E-band device prototyping, various 3D printing technologies are shown to reach the tolerances needed. While methods like Selective Metal Sintering (SMS) can fabricate conductive structures, the more popular 3D printing technologies utilize dielectric materials that require postprocessing. While Fused Deposition Model (FDM) and Stereolithography (STL) printers are widely available, these desktop systems tend to have resolutions around 250 μm and 25 μm, respectively. Since this resolution is insufficient for E-band design a polyjet printer with a minimum layer height of 16 μm, resolution of 750 DPI, and accuracy of ± 0.001 inch per inch is utilized.

Electroless plating and electro-deposition techniques are both incredibly precise chemical postprocessing methods; however, developing these types of solutions requires an immense knowledge of chemistry. Contrarily, relatively crude aerosol spray-paint methods have proven useful in X-band design; whereas, precision-aerosol has proven useful in the design of planar E-band electronics. Precision-aerosol coating achieves accuracy comparable to electroless processing, while simplifying the chemistry behind the postprocessing method.

In this work, the design of both a circularly and linearly polarized slotted Leaky Wave Antenna (LWA) operating at 85 GHz is fabricated using a polyjet 3D printer and a precision-aerosol nozzle. Modifications to the original design are considered as a means for AP workflow compatibility. The effect of aerosol coating on the efficiency, radiation properties and polarization is identified by comparing the aerosol prototypes to copper plated ones. Overall, the workflow aims to ease prototype manufacturability while retaining device efficacy.