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Additive Manufacturing for Microwave Components: Present and Future

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Summary

In this work, Additive Manufacturing for the production of microwave components is analysed. An overview is given of the use of additive manufacturing for microwave components, both for metal-only and plastic components. The various additive manufacturing techniques and the benefits and disadvantages of each are discussed. Finally, it concludes with an overall assessment of additive manufacturing for microwave components today and a vision for the future of the technology.

Additive Manufacturing (AM) is a method of manufacturing parts that has emerged as an alternative to conventional subtractive manufacturing methods, such as milling. This manufacturing method emerged in the field of mechanical manufacturing, allowing the topological optimisation of parts, i.e. weight reduction and improvement of mechanical properties. This method has also advantages over traditional manufacturing methods such as speed, precision, cost-effectiveness and, above all, it allows the creation of arbitrary shapes that were previously unmanufacturable. These advantages have led to this manufacturing method being extended to other fields of engineering, not only for the manufacture of mechanical parts. One of the new fields and sectors where it has gained special interest is that of Radio Frequency (RF) components. AM has been recently used for manufacturing RF components, from traditional components such as waveguides [1,2] or reflectors [3] to horn arrays [4,5] and even complex designs such as Luneburg lenses [6, 7]. Moreover, recently it has been shown that shaped parallel plate half-geodesic lenses in a monolithic piece can be achieved [8], showing the capabilities of the technology. In that work, the metallic part of the lens was optimized to have a more compact and lightweight prototype while keeping its mechanical properties. Thus, the weight was reduced up to 80% and more importantly, it solved the error in previous prototypes where misalignment of parts caused performance to degrade with increasing Side Lobe Levels (SLL) by as much as -10dB. On the other hand, contributions regarding Luneburg lenses based on glide symmetry using Acrylonitrile Butadiene Styrene (ABS) filament and Fuse Deposition Melting (FDM) have been made [9, 10].

The main technologies used for the manufacture of metal-only components are Laser Powder Bed Fusion (LPBF) also known as Selective Laser Melting (SLM), Electron Beam Melting (EBM) or Binder Jetting (BJ). The first of the techniques, which is the most commonly used, consists of the deposition of powdered metallic material on the build-plate by the recoater, creating a thin layer of around 20-60 microns. An energy source, a laser in the case of SLM and an electron beam in the case of EBM, then selectively melts the material to create a metallic bond. Again, metal powder deposition occurs and melting continues until the complete part is created. The main metallic materials used in this technology are aluminium alloy AlSi10Mg and AlSi12Mg, stainless steel 316L and 17-4PH, titanium Ti64 and inconel. Added to the manufacturing process is the post-processing of the parts. As a general rule, post-processing tasks require the removal of supports and their subsequent cleaning, and sandblasting with micro-glass spheres to reduce surface roughness. On the other hand, if necessary, the threading or polishing of the flanges must be added for the correct measurement of the component.

For the manufacture of dielectric components, FDM or Stereolithography (SLA) technologies are used. The former is based on the deposition of plastic material in successive layers, creating the part as layers of filament. To do this, a head with a nozzle heats and guides the material, using movement in the X and Y axes, through the build-plate which in turn, by varying the height, allows the creation of the part on the Z axis. This technology has allowed the creation of dielectric components [9, 10], and if this is followed by a post-processing stage where the part is provided with a metallic coating, typically copper or nickel, a low-cost component is achieved [3]. Of particular interest is the use of this technology for the design and manufacture of dielectric radomes. The use of FDM technology allows the design of geometries that not only serve to cover and protect the antenna array, but also have effects on its frequency response, such as increasing the scanning angle.

The future of additive manufacturing technology for microwave components is based on the combination of multiple technologies, both metallic and dielectric, in order to obtain in each case the best performance of the complete system. Finally, it should be noted that one of the most important points in the use of additive manufacturing technology is the knowledge and control of the printing parameters by the engineer who designs the part, not only limited to sending the part for the manufacture itself. The knowledge and control enables direct interaction between the engineer in the design process and the technician in charge of manufacturing, thus maximising the capabilities of the technology and even increasing the performance of the manufacturing process.

Figure 1. Example of a system based on additive manufacturing by combining metal only horns arrays and dieletric radome.

References

[1] M. González-Calvo, J. R. Montejo-Garai, J. A. Ruiz-Cruz, and J. M. Rebollar, “Additive Manufacturing of a High-Performance Q-band Circular TE01 Mode Flared-Type Transducer,” *IEEE Microwave and Wireless Components Letters*, vol. 29, no. 9, pp. 577–579, 2019.

[2] R. Salazar, F. Pizarro, D. Vasquez, and E. Rajo-Iglesias, “Assessment of 3D-printed Waveguides Using Conductive Filaments and a Chloroform-based Smoothing Process,” *Additive Manufacturing*, vol. 51, p. 102593, 2022.

[3] A. Rebollo, A. F. Vaquero, M. Arrebola, and M. R. Pino, “3D-Printed Dual-Reflector Antenna With Self-Supported Dielectric Subreflector,” *IEEE Access*, vol. 8, pp. 209091–209100, 2020.

[4] A. I. Dimitriadis, M. Favre, M. Billod, J.-P. Ansermet, and E. de Rijk, “Design and Fabrication of a Lightweight Additive-Manufactured Ka-Band Horn Antenna Array,” in *2016 10th European Conference on Antennas and Propagation (EuCAP)*, pp. 1–4, 2016.

[5] L. Alonso-González, J. Rico-Fernández, A. F. Vaquero, and M. Arrebola, “Millimeter-Wave Lightweight 3D-Printed 4×1 Aluminum Array Antenna,” in *2022 16th European Conference on Antennas and Propagation (EuCAP)*, pp. 1–5, 2022.

[6] A. B. Numan, J.-F. Frigon, and J.-J. Laurin, “Printed W-Band Multibeam Antenna With Luneburg Lens-Based Beamforming Network,” *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 10, pp. 5614–5619, 2018.

[7] C. Pfeiffer and A. Grbic, “A Printed, Broadband Luneburg Lens Antenna,” *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 9, pp. 3055–3059, 2010.

[8] J. Rico-Fernandez, F. V. Vidarsson, M. Arrebola, N. Fonseca, and O. Quevedo-Teruel, “Compact and Lightweight Additive Manufactured Parallel-Plate Waveguide Half-Luneburg Geodesic Lens Multiple-Beam Antenna in the K_a-Band,” *IEEE Antennas and Wireless Propagation Letters*, 2022.

[9] J.-M. Poyanco, O. Zetterstrom, P. Castillo-Tapia, N. J. G. Fonseca, F. Pizarro, and O. Quevedo-Teruel, “Two-Dimensional Glide-Symmetric Dielectric Structures for Planar Graded-Index Lens Antennas,” *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 11, pp. 2171–2175, 2021.

[10] O. Zetterstrom, N. J. G. Fonseca, and O. Quevedo-Teruel, “Compact Half-Luneburg Lens Antenna Based on a Glide-Symmetric Dielectric Structure,” *IEEE Antennas and Wireless Propagation Letters*, vol. 21, no. 11, pp. 2283–2287, 2022.