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Additive Manufacturing of Rectangular Waveguide Devices for Teaching Microwave Laboratory

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Abstract

In this paper the outline of using of low-cost additive manufacturing FDM/FFF technology to build waveguide devices is presented. The focus is set in a full design from specifications to final measurements in a microwave teaching laboratory. Final results obtained asses that this experience is an extraordinary opportunity for students to get involved in waveguide technology. In addition, the use of 3D design software enriches the curricula of electronic engineering students.

1. Introduction

Waveguide technology is still nowadays a very important technology in microwave and millimetre-wave applications. The main advantages of metallic waveguides over other transmission media are, among others, its low-loss and power-handling capabilities. The fabrication of conventional metallic waveguide devices has been traditionally based in expensive and long time-consuming mechanical procedures using different aluminum alloys. The emergence of additive manufacturing processes is changing some paradigms in waveguide fabrication for certain applications [1]. In this paper, focus is set in educational aspects of these new technologies.

For plastics and resins, additive manufacturing term encloses several technologies, from the most affordable fused filament fabrication -hundred dollars nowadays- to polyjet systems - hundred thousand dollars. Additionally, additive manufacturing of metallic mechanical parts is also available, for instance using selective laser sintering (SLM), but in this work has not been considered as it is not an affordable technology for academic porpoises. In general, additive manufacturing technologies grow parts from scratch adding layers of material one on top of the other. In this work, fused filament fabrication (FFF) or, as it is also known filament deposition modeling (FDM), is considered. Lately, this technology has been spread enormously and a huge community of developers provide software and repositories of parts ready to be fabricated. Some students even have a 3D printer available at home.

Waveguide fabrication has traditionally carried out in external facilities where the device emerges from a cube of aluminum. FDM technology is appropriate for plastic polymers whereas waveguide fabrication requires high conductivity materials. So, a final metal coating is necessary to fabricate waveguides. In this paper, the experience of introducing waveguide 3D printed waveguide devices in a teaching environment is presented.

2. Rectangular Waveguide devices

In order to design real prototypes with dimensions that can be big enough but small enough, the WR62 waveguide, for its dimensions, has been chosen. This waveguide is usable in our teaching laboratories as the frequency range of the ENA Vector Network Analyser available for students is 18 GHz, so the nominal bandwidth (12-18GHz) is completely cover by measurement equipment.

Waveguide parts and devices can be complex and 3D modeling software is important. Open source software OpenSCAD has been used. This is a programming language for creating 3D mechanical parts that is available for different operating system. It has no interactive modeler but in case a more complex structures are needed FreeCAD is fully compatible with OpenSCAD code so both of them can be used for this laboratory. Fig. 1 shows the code and rendering of a TRL calibration kit and a half-wavelength section of rectangular waveguide.

When a 3D part is going to be printed using FDM, special care has to be taken with overhanging surfaces, mainly to avoid support material. In case there are surfaces or cavities support material is necessary unless you keep this fact throughout the design process. In spite of everything, some devices have no solution for this problem unless they are divided into several parts. Waveguide parts library will be available for downloading in parametric format so different waveguide sizes can be fabricated using the same code.

For mechanical reasons and availability, ABS polymer filament is used for FDM [2-3]. Special care has to be taken when coating with metallic layer and it is carried out by instructors, not by students (Fig. 2(a)). TRL calibration is introduced to students and a 3D model of a short and a line is designed as shown in Fig. 2(b). Student are encouraged to develop their own code. As can be seen in Fig. 2(c) different irises shapes can be easily developed and printed [4]. Using these simple elements, a more complex iris-based h-plane filter can be design, simulated, build stacking waveguide sections and measured.

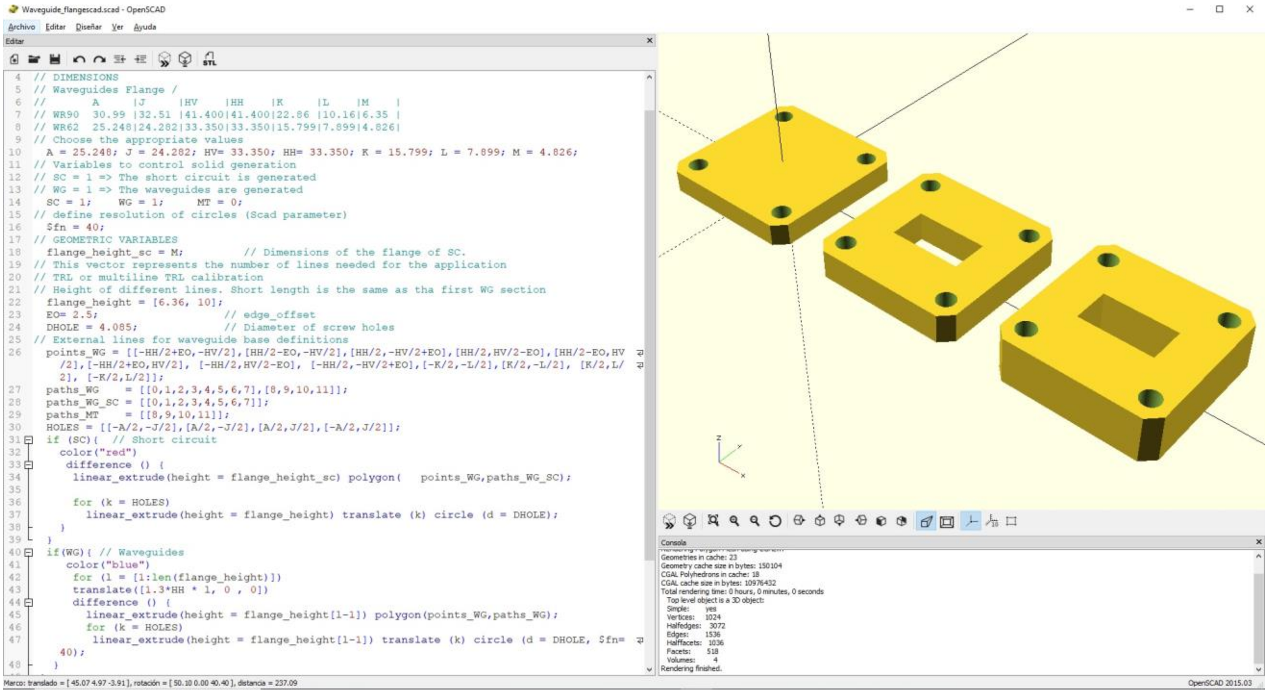
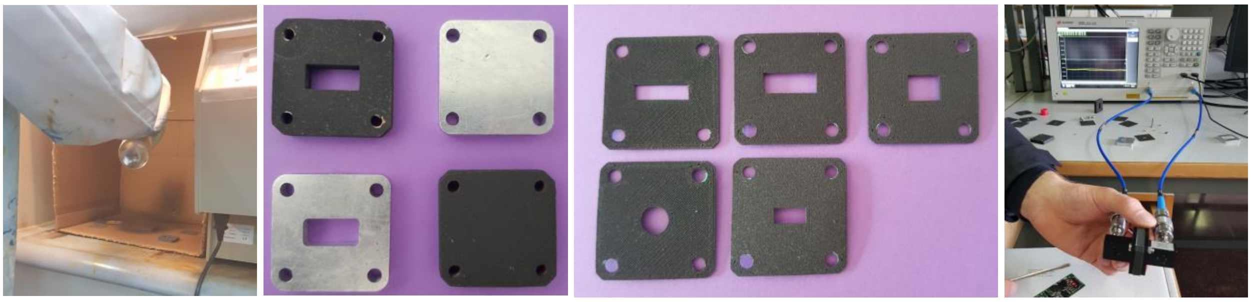


Figure 1: OpenSCAD software environment shown TRL calibration code and rendering of waveguide parts.



(a) (b)

Figure 2: (a) Nickel Spraying process for ABS coating with air extraction. (b) WR62 TRL calibration kit once metallized compared with aluminium one. (c) Different irises fabricated. (c) 1 out of 3 measurement bench available for students.

3. Discussion

Additive manufacturing technology has been introduced in a master level subject entitled Microwave Laboratory. The experience has been introduced in a project-based learning scheme where students actively explore the issues associated with the final fabrication technologies and the necessary loop from specifications to prototype in a CAD environment. The academic outcomes of the project excessed original expectations and students get involved in the process intensively. The analysis of the perception of the activity among students is excellent, mainly because they get a product designed and build by themselves in contrast with the use of expensive prefabricated commercial available waveguide kits.

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