Challenges 3D Printing Microwave Components

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***Abstract*— This is an overview of challenges we have encountered when designing, manufacturing and measuring 3D printed antennas, waveguides, and lenses for microwave applications. We also suggest solutions to some of the problems.**

Keywords*— *3 D printing; challenges; plastic; metallization

I. Introduction

Even though some 3D printing, or additive manufacturing (ADM), issues are technology dependent, many challenges are common for all ADM processes. Fig.1 shows a summary of the different ADM processes available. The highlighted sections are the different technologies we have tried. We have used several different FDM printers (black), such as Fortus 400mc, Ultimaker 2, and Makerbot. PolyJet (yellow dotted), and SLA (yellow) parts were printed using the Connex 500 and Form 1 respectively. SLS (blue) parts were printed using Formiga P 110.

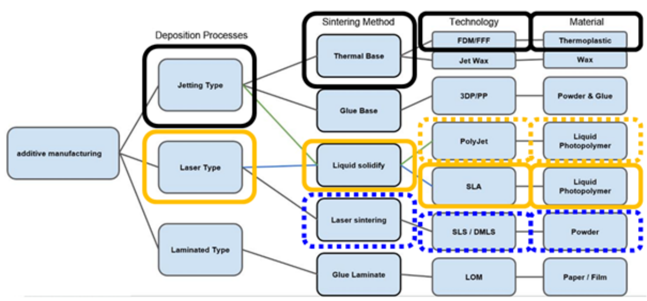

Fig. 1: Summary of different ADM processes [1]

Some of the more common issues are warping of the parts, stair steps for objects with angles, making circular holes, gaps between structures, removing support structures or powder.

II. 3D Printed Radomes

The first 3D-printed microwave component we made was a radome. We use a large number of different horn antennas, and the idea was to produce a series of clip-on radomes which could be resized to fit the different aperture sizes (see Fig. 2 for an example).

Fig. 2: Horn antenna with (right) and without 3D-printed radome (left)

We had two main problems with the radomes.

1. Structural stability of large thin structures – they tend to warp during cooling – Fig. 3 shows warped edges highlighted by the yellow ellipses

Fig. 3: Radome with unintentionally curved edges

2. The radomes were not waterproof – the deposited plastic "threads" had small air gaps between them.

To solve 1, we had to add a so called "brim" around the radome that could be removed after cooling. The original design is shown on the left side of Fig. 4, the design with the brim that fixed the problem is shown on the right.

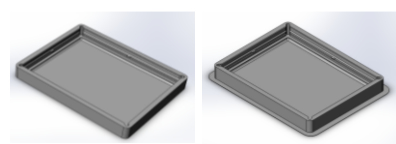

Fig. 4: Radome design with (right) and without brim (left)

To solve 2, we carefully applied acetone to the radome. This made the different threads fuse together.

III. Metallization of Plastic Surfaces

A. Types of plastic and types of metallization

Some plastics, especially the ones used in PolyJet technology, are very brittle. They do not handle temperature and humidity variations; thus, many metallization processes can destroy the parts. These types of plastic are not very practical for robust applications. FDM Technology with layer thickness equal to or higher than 0.254mm requires post processing after printing. Objects should be sanded before metallization is applied. SLS with PA2200 resulted in one of the strongest parts we have 3D printed.

We have also tested different metallization processes. Conductive spray paint is the cheapest and simplest solution to achieve metallization of objects. However, it has the highest conductive loss, hence it is not appropriate for high power applications. Vacuum metallization is difficult for several plastic types and thin structures due to the relatively high temperature. Also it is impossible to achieve a good conductive layer in cavities. Electroplating provides more durable structures, and handles cavities much better. It does however always result in the whole object being covered in metal. This may not always be acceptable.

B. *Complex objects and cavities*

One of our projects was to produce microwave horn antennas with a Fortus 400mc printer using ABS plastic. The inside needed to be metallized. First we produced the antennas as one single unit, but it proved difficult to achieve a uniform metal layer on the inside of the horn. Fig. 5 shows dark areas inside the horns. This was regardless of the metallization process; we tried conductive spray paint, and electroplating – both with similar results. For vacuum metallization the antenna would only be metallized on the outside.

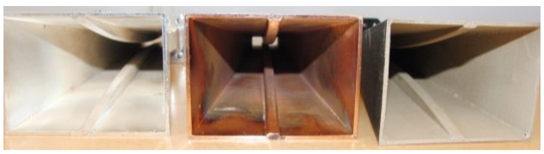

Fig. 5: WRD750 horn antennas 3D printed and metallized as a single unit

The solution was to split the antennas as seen in Fig. 6. This resulted in good metallization for all processes, but required post-production assembly and resulted in less robust antennas.

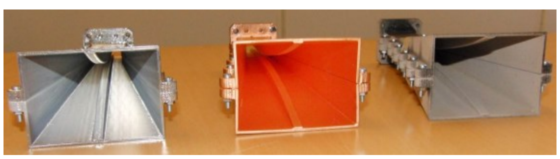

Fig. 6: WRD750 horn antennas 3D printed and metallized split in two

IV. MANUFACTURING OF FINE RESOLUTION COMPLEX OBJECTS

A. *Printing direction and object orientation*

ADM processes provide different precision and accuracy in different directions, and usually the orientation of the object must be taken into account. For example, to produce smooth ridges on FDM printed double ridged horns/waveguides, they should be printed standing up.

B. *ADM processes*

In general our experience tells us that SLA produces the best surface roughness while FDM produces the worst. Cleaning supporting structures in SLA and PolyJet is difficult and requires more time in post-processing. These processes are best for solid objects with very little overhang. SLS is the strongest with very good surface roughness. Also the powder provides support during production, making printing air bridges/overhang possible. But SLS is the most expensive ADM process, and care must be taken for fine structures where the loose powder might be difficult to remove. FDM is the cheapest process, and it provides decent surface roughness. Some post processing may be required. FDM is not at all suitable for objects with thin structures and fine details.

C. *Air bridges and support materials*

FDM, PolyJet and SLA require supporting materials for overhanging objects. It can be hard to remove supporting structures without destroying the integrity of the object itself, especially for very thin structures. Another project we worked on was testing dielectric properties of the material by varying the density of the plastic as can be seen in Fig. 7.

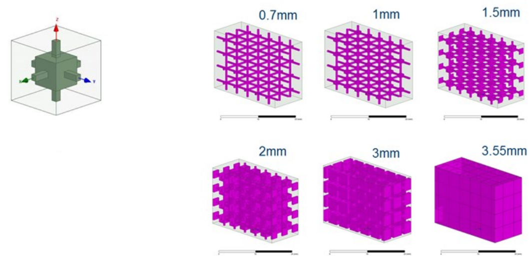

Fig. 7: Left: Unit cell, right: Grid-block structures - cube-sizes from 0.7mm to 3.55mm to vary ε_r

We first printed our dielectric grid-blocks using SLA technology. It was very hard to remove the support material, and some of the thin rods broke off. We opted to use SLS technology to print them instead, see Fig. 8.

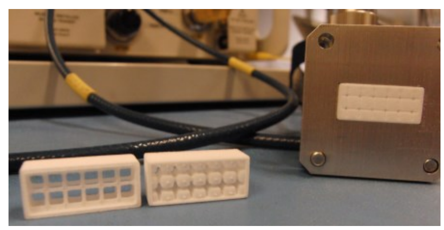

Fig. 8: Three of the SLS grid-blocks tested

SLS was ideal for these types of structures with exception that a thin wall was necessary to hold the layers together. However, in SLS the minimum gap size depends on the wall thickness. When structures are less than 0.3 mm apart, it is hard to remove the loose powder, which melts in the process.

CONCLUSIONS

3D printing has made manufacturing microwave components much easier and faster, but engineers and scientists have to pay close attention to the new design challenges and issues and many times have an innovative way of thinking.

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REFERENCES

[1] http://i.imgur.com/TkUOxBu.