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Practical Considerations In The Development Of Ceramic-Based Filters With Additive Manufacturing

Content

Dielectric materials can be found in RF/microwave filters for a wide range of industrial applications. Compared with other technologies, dielectric resonator (DR) filters offer a perfect balance between performance and miniaturization. These structures are capable of handling high-power levels while providing a quality factor (Q) comparable to that of pure waveguide implementations. In addition, the overall volume of the component is significantly reduced thanks to the use of dielectric materials. For that reason, these filters are emerging as the baseline design for many RF filters used in wireless and satellite applications. Due to the difficulty in machining ceramic blocks, the shapes of the dielectric objects included in RF/microwave filters are usually simple: rods, pucks, rectangular blocks, etc. However, the successful development of additive manufacturing (AM) processes for ceramic materials has opened up new geometrical configurations for filter designers to explore. Consequently, we can expect significant advances in key fields for the space industry due to the additional geometrical flexibility provided by AM.
Additive manufacturing of ceramic materials differs significantly from processes for metals and plastics. Having a clear understanding of the chemical and mechanical processes that are involved in the creation of a given structure is key to successfully develop ceramic filters for RF/microwave applications. The proposed presentation in these Industry Days will focus on the different steps of the lithography process for monoblock filters like the one shown in Fig. 1 (see attached files). These filters are completely built out of ceramic materials. After manufacturing, a layer of metallic coating is applied on the exterior faces of the filter to create the metallic enclosure. Coaxial flanges are finally glued to the structure in order to provide input and output couplings.
The lithography-based ceramic manufacturing (LCM) process developed by Lithoz and applied to these filters involves three steps. First, a green body is manufactured by layer-wise curing of a photoreactive ceramic suspension, building up a 3D object directly from the CAD model. Then, this green body is cleaned in order to eliminate the excess of material that has not been hardened. Finally, the green body is thermally treated to remove the organic binder (up to 600 $^\circ$C) and sintered at a materials specific sintering temperature to give the dense ceramics filter (> 1000 $^\circ$C). The successful application of these three steps requires the filtering structure to fulfill certain geometrical specifications. Therefore, filter designers should take into account new geometrical constraints during their design process, not typically present when employing more traditional ways of manufacturing filters. The main constraints of each step that will be discussed in the presentation are:
• In the manufacture of the green body: the LCM process requires all the layers parallel to the building platform to be properly supported. This means that hollow monoblock ceramic filters like the one shown in Fig. 1 cannot be built with its bottom wall attached to the base plate, since that would required the top wall (where the connector openings are placed) to be supported from the inside of the filter (which is not readily accessible after manufacturing). Instead, the structure is tilted as shown in Fig. 1 and supports are only placed in the exterior or the filter, where they can be removed once the 3D block is created. At the same time, the use of these supports degrades the surface roughness of the walls where they are attached. This impacts the performance of the final filter, slightly increasing the insertion losses. Consequently, it is important to minimize their usage, and structures that completely avoid these supports are preferred (when available).
• Slurry removal: this procedure applies a cleaning solvent to remove the excess of slurry material attached to the ceramic parts. The proper removal of the slurry is key to ensure that the manufacture is done with high geometrical accuracy. In order to do this, all the surfaces of the geometry have to be easily accessible for the solvent to reach them, but also for the suction probe to extract the

remaining solvent. As a consequence, the input/output coupling apertures have to be strategically placed to allow this probe to reach the inner part of the filter.
• Debinding and sintering: in order for the photopolymeric binder to be completely removed from the ceramic material, the filter cannot have excessively thick walls. Otherwise, traces of the binder may be locked in the ceramic material leading to potential cracks after sintering.
This contribution will give a review on design rules for manufacturing ceramic filters using the LCM approach and the corresponding constraints on filter designs. As a result, RF/microwave designers will gain knowledge on how to adapt their designs to improve their performance and increase the chances of a successful manufacture using ceramic-based lithography.

JUSTIFICATION FOR THE CONSIDERATION

This proposed presentation will provide a review on design rules for manufacturing ceramic filters using the lithography-based ceramic manufacturing approach, and the corresponding constraints on filter designs. As a result, RF/microwave designers will gain knowledge on how to adapt their designs to improve their performance and increase the chances of a successful manufacture using ceramic-based lithography.

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