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Selective Laser Melting Manufacturing of Integrated Microwave Waveguide Components

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Introduction

This work reports on the integration of different RF functionalities in a microwave waveguide component through the selective laser melting (SLM) process. SLM is an additive manufacturing (AM) process that allows the manufacturing of all-metal parts. A relevant application domain is the development of Multi Beam Antenna (MBA) systems for the next generation of High-Throughput Satellite (HTS) [1]. Such application consists of hundreds of antenna-feed chains. Typically, each antenna-feed chain consists of several waveguide components, such as a feed horn, a polarizer, an orthomode transducer (OMT), filters, bends and twists. SLM technology is expected to be a valuable solution for the development of these payloads, since the free-form capability of AM technologies allows for a high design flexibility and, as a consequence, better RF performance. Moreover, complex geometries can be manufactured in one part, with reduction of connection flanges, screws and dowel pins. This aspect results in an alleviation of passive intermodulation products (PIM) problems and in a reduction of mass and volume. Furthermore, different RF and mechanical functionalities can be implemented in a single part [2], thus leading to miniaturization of RF sub-systems. Finally, AM technologies can lead to important reduction of costs and lead time, if AM-oriented designs are applied.

Three study-cases of integrated RF components have been analyzed, namely, a Ku/K-band low-pass filter with integrated twist and H-plane bend, a Ka-band orthomode transducer with integrated twist, a Ka-band smooth-wall feed-horn with integrated septum polarizer.

Low-pass filter with integrated twist and H-plane bend

The first study-case consists of a ninth-order composite step/stub filter mapped in a 90 deg twist and a 90-deg H-plane bend structure. The integrated component is housed on a WR51 waveguide. Figure 1 shows the internal geometry and the mechanical implementation of the component. Three prototypes with different bend radius have been designed and manufactured. The measured RF performances are reported in Table 1.

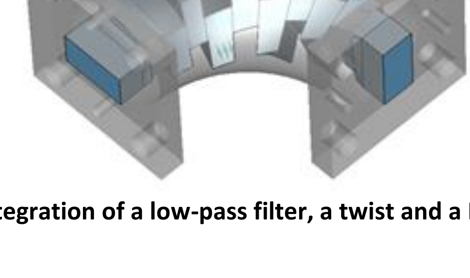

Figure 1: Integration of a low-pass filter, a twist and a H-plane bend

Table 1: Measured RF performances of the low-pass filter with integrated twist and H-plane bend

Pass-band (GHz)	Stop-band (GHz)	Radius (mm)	Return loss (dB)	Insertion loss (dB)	Rejection (dB)
12.5 - 15	17.5 – 21.2	30	≥ 21	≤ 0.16	≥ 60
12.5 - 15	17.5 – 21.2	40	≥ 25	≤ 0.15	≥ 60
12.5 - 15	17.5 – 21.2	50	≥ 20	≤ 0.20	≥ 60

Orthomode transducer and twist

In the second study-case a dual-linear polarized component has been analyzed. A Ka-band OMT has been integrated with a twist, in order to align the orientation of the two WR28 rectangular ports. The internal geometry and the mechanical implementation are shown in Figure 2. The component has been designed with the propagation axis of the main square-waveguide aligned with the building direction. This results in a good cross-section symmetry and, hence, in good RF performances in terms of cross-coupling and isolation between the two rectangular ports. Measured RF performances are summarized in Table 2.

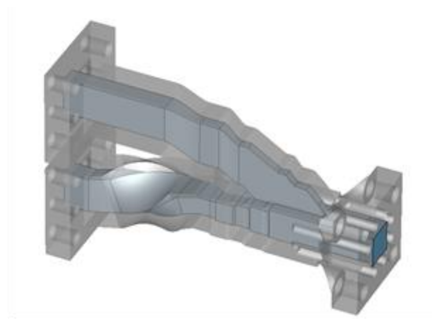

Figure 2: Integration of an OMT with a twist

Table 2: Measured RF performances of the OMT with integrated twist

Operative band (GHz)	28.5 - 31.2
Return loss (dB)	> 25
Insertion loss (dB)	< 0.2
Isolation between rectangular ports (dB)	> 50
Cross-coupling (dB)	<- 35

Feed horn and septum polarizer

The latter study-case is the combination of a Ka-band feed horn with a septum polarizer. Generally, a corrugated feed horn is usually chosen. Regarding the SLM technology, this solution prevents the alignment of the main waveguide axis with the building direction. The corrugated feed horn can be tilted on the building platform. However, in this case, longitudinal and transversal tolerances mix together [3]. This results to worse RF performances, since each building layer is not symmetric. To overcome this problem, a smooth-wall feed-horn has been considered. This layout allows the alignment of the feed-horn main axis with the building direction and, hence, a good azimuthal symmetry. The integrated septum polarizer includes the bends necessary for the accommodation of the flanges at the WR28 rectangular ports. The internal geometry and the mechanical implementation are shown in Figure 3, while RF performances are reported in Table 3

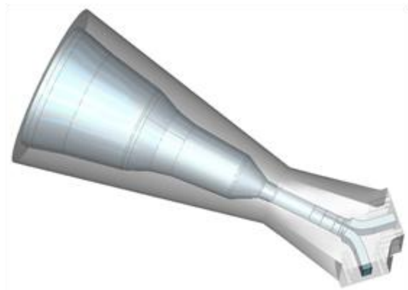

Figure 3: Integration of a feed horn with a septum polarizer

Table 3: Measured RF performances of the feed-horn with integrated septum polarizer

Operative band (GHz)	28.5 - 31.2
Return loss (dB)	> 25
Insertion loss (dB)	< 0.2
Isolation between rectangular ports (dB)	> 50
Illumination angle	22°
Maximum radiated cross-polarization within the illumination angle of 22 deg (dB)	<- 28
Field taper at the illumination angle of 22 deg (dB)	16 - 20

Conclusion

This work proves that the free-form fabrication capability of SLM can be effectively used to integrate RF functionalities into single-part waveguide components. However, in order to achieve high RF performance while increasing component integration rate, the electromagnetic and mechanical layouts have to be designed jointly.

References

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