Additive Manufacturing Technology for High Performances Feed Horn

(Article begins on next page)

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***Abstract*—In this work the design and manufacturing through selective laser melting technology of single-band dual circular feed-system operating in Ka-band is reported. In the feed design an *AM oriented* architecture has been employed. The measured performances confirms the good manufacturing of the system that satisfies very stringent requirements in terms of polarization purity.**

I. Introduction

Additive Manufacturing (AM) technologies are receiving an increasing interest from antenna and microwave communities thanks to their intrinsic feature in manufacturing complex parts that would be too expensive or, even, not feasible by classical manufacturing process [1]-[5]. One of the most interesting field of application of AM process is the realization of feed chains for SatCom. Indeed, high demanding requirement in terms of electromagnetic performances and integration level are of particular interest for high-throughput satellite payloads operating from Ka to V bands. Unfortunately, the actual AM technology readiness level is not sufficient mature and further investigations are mandatory. Among the different AM techniques, Selective Laser Melting (SLM) is particularly suitable for waveguide components since the parts are realized directly in metal. As a consequence, metal plating, which is cumbersome in other AM technologies, is not mandatory. In SLM, the part is realized from metal powders spread on the building platform by a recoater and, layer by layer, selectively melted by a high-power laser. The powders most exploited are the AlSi10Mg and Ti6Al4V alloys. The former presents good characteristics in terms of conductivity, while the latter provides potential better accuracy. As reported in [7]-[8], the tuning of the machine and post-processing parameters according to an AM oriented layout are keypoints to enhance the AM manufacture quality in terms of accuracy and surface finishing. These ideas have been successfully applied to the design of high-performances stop-band filters [9] and of an integrated filter, bend and twist device [10]. In this work, the design and SLM manufacturing of an integrated single-band feed (composed by a septum polarizer and a feed-horn) is reported. The architecture has been conceived to be *AM oriented* and this approach leads to a very good accordance between measured and predicted performances.

II. Integrated Feed-System Design

In [11], the design of feed horns via SLM technology has been addressed. In particular, Ku- and K-band prototypes have been realized and measured. The successful results in terms of low cross-polarization level and radiation-pattern characteristics have encouraged the authors to consider the Ka band that is currently quite challenging because of to the achievable SLM accuracy levels. At the same time, dual-polarization systems have not been fully considered in literature although the large number of applications. Taking into account these considerations, the design of a dual-circular polarization feed-system operating in Ka band has been developed. The assembly is composed by a septum polarizer connected to a feed horn. Typical SatCom requirements, reported in Table 1, has been considered in the design. The septum polarizer has been obtained as a cascade of five steps in circular ridge waveguide. To simplify the design, the ridge width and the circular waveguide diameter steps has been fixed equal to 1 mm and 0.2 mm, respectively. The values of ridge widths and cavity lengths have been, instead, defined exploiting an optimization technique. Finally two 45 degree bends have been connected to the two half circular waveguide sections in order to achieve the sufficient margin for the insertion of standard UG-599/U flanges at the output WR28 rectangular waveguide ports. The simulation of the septum polarizer reveals a return loss better than 25 dB, an isolation level between the two rectangular ports higher than 30 dB and a cross-polarization level between the two polarizations of the TE_{11} mode lower than -40 dB. These values are a good compromise between desirable performances and complexity of this sub-part of the feed-system. Better results in terms of matching at the rectangular ports can be obtained by considering a higher number of steps. As far as the feed is concerned, the configuration usually chosen is a corrugated horn. Unfortunately, in SLM technology this architecture leads to overhanging parts in the corrugation upper walls if the horn axis is chosen coincident to the building direction (that is the laser axis). Hence, in this case a tilting of the part in the building machine is mandatory in order to prevent cracks and deformations. Nevertheless, as discussed in [8], this manufacturing solution mix longitudinal and transversal tolerances, thus resulting in lower manufacture accuracy. To overcome these problems, a smooth-wall architecture has been implemented. The antenna has been designed by following the procedure described in [12]. Starting from a linear profile as a guess structure, the generatrix is divided in N equidistant nodes whose coordinates are used as degrees of freedom in the design. Indeed, their radial and longitudinal position is modified, exploiting an optimization algorithm, in order to minimize a cost function defined as weighted sum of the differences between the desired and actual return loss, edge field taper and cross-polarization level. In the case of operative frequency band lower than 15%, as the feed under consideration, this procedure is quite efficient. The analysis has been carried out by considering a stepwise approximation of the horn profile and applying the classical Coupled Integral Equation Technique [13]. The horn and the septum have been connected by a line of 15 mm. This value has been chosen in order to minimize the effect of higher-order modes and to optimize the assembly matching. The overall feed dimensions are 44 mm x 44 mm x 150 mm. As far as the mechanical design is concerned, the feed external profile traces the internal one and the supports have been defined only for the WR28 rectangular-waveguide flanges. The prototype has been manufactured in AlSi10Mg alloy, Fig. 1 shows the component still attached to the building platform. The feed has been measured in anechoic chamber and the comparison between measured and simulated performances, reported in Table 2, confirms the feasibility of SLM manufacturing of high performance single band feed system.

TABLE I
REQUIREMENTS FOR THE KA-BAND FEED

Input rectangular waveguide	standard WR28
Operative Bandwidth	[28.5,31.2] GHz
Return Loss	≥ 25dB
Isolation	≥ 30dB
Cross-Polarization	≤ -35dB
Illumination Angle θ^*	22 deg
Field Taper at θ^*	$[16, 20]$ dB

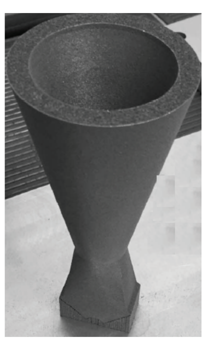

Fig. 1. Prototype of the Ka-band feed in AlSi10Mg alloy still attached at the building platform. In the bottom part it can be observed the presence of supports for the WR28 flanges.

TABLE II
COMPARISON BETWEEN SIMULATED AND MEASURED KA-BAND FEED

	Simulation	AlSi10Mg Prototype
Return Loss (dB)	≥ 25	≥ 23
Isolation (dB)	≥ 28	≥ 27
Cross Polarization (dB)	≤ -35	≤ -30
Field Taper at $\theta^* = 22°$	$[18, 20]$ dB	$[18, 20]$ dB

III. CONCLUSION

This work has reported on the design and the SLM manufacturing of an *AM oriented* feed-horn with integrated septum polarizer operating in Ka-band. Measured performance are in line with those achievable through conventional machining techniques, while higher integration levels are guaranteed by the SLM technology.

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