Politecnico di Torino

MATERIALS SCIENCE AND TECHNOLOGY

ASI - 3D Printing of RF sub-systems and components at millimeter wavelength operating at 40-50 GHz for space applications

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Context of the research activity	3D-printing is leading to a major transformation in many industrial sectors. Recently, thanks to improvements in precision and surface roughness, 3D-printing technologies have steadily been investigated for the development of radio frequency (RF) components in the space field, including next generation software-defined communication satellites. In fact they enable a drastic simplification of mechanical designs by reducing the number of interfaces and assembling screws of large RF front-ends, thus leading to significant mass savings and higher integration.

	Additive Manufacturing (AM), also known as 3D-printing, encompasses several technologies, in which objects are built by adding material layer-by-layer according to digital 3D models. The various AM technologies currently available mainly differ in the process used to solidify materials (e.g., laser melting, or photo-polymerization) as well as the materials themselves (e.g., metallic alloys, polymers or ceramics). These technologies offer the potentiality of building parts quickly, optimized and customized for individual or series production. In the space sector, 3D-printing was initially investigated for developing lightweight and robust structural parts, such as antenna brackets. In more recent years, AM technologies have steadily been investigated also for the development of Radio Frequency (RF) components and payloads. Some simple 3D-printed RF front-ends are even already in orbit. The number of 3D-printed RF front-ends in space is expected to grow exponentially in coming years as satellite manufacturers and microwave payload sub-system providers are turning to the technology to address the needs of future space systems. The complexity of RF payloads for communication satellites have steadily increased throughout the past decades with the introduction of new services and the use of higher frequencies for commercial, military, and civil applications, among which are Fixed Satellite Services (FSS), Direct Broadcast Satellite (DBS) services, Personal Communications Services (PCS), Mobile Satellite Services (MSS), and Inter-Satellite Services (ISS). These services require the availability of communication links between the satellite and ground stations, user

Objectives	terminals, other satellites, and/or moving platforms such as aircrafts and ships. For example, In the area of Geostationary Earth Orbit (GEO) satellite communication, High Throughput Satellites (HTS) and Very High Throughput Satellites (VHTS) with aggregate capacity of hundreds of Gbps and up to Tbps are required to meet the increasing data traffic demands. Indeed, in GEO applications, dense and complex focal planes of hundreds of feed chains are required to implement Tbps VHTS systems. In Medium Earth Orbit (MEO) and Low Earth Orbit (LEO) satellite communication constellations of several tenths, hundreds, or even thousands of low-cost small satellites have to be deployed, as in the case of Starlink, OneWeb and Kuiper mega constellations. It can be understood that the satellite communication market is evolving from small to medium volume production of antennas and associated front-ends. In this framework AM technologies provide several advantages with respect to conventional machining, among which are: free-form capability, fit-for-purpose design, where parts may be optimized for the required functionalities, screwless near-net shapes, where components do not need to be split in several mechanical parts that are individually machined and then assembled. This property allows for the manufacturing of sub-assemblies implementing several RF functionalities in a single mechanical part, sometimes referred to as a “monolithic” design. Therefore, the number of flanges can be minimized, which is beneficial for high power applications, where passive intermodulation products can arise at interfaces. Moreover, integration of RF functionalities in a single mechanical part simplifies the assembling and testing procedures. Finally, the use of screws or alignment pins to mount the several mechanical parts composing the components is reduced to the interface between parts. AM technologies have already proved to be novel and efficient solutions for the development of either complex RF front-ends for dense focal planes or very simple cube-sat payloads. As current AM processes are improved and new ones are placed on the market, the impact of these technologies in the space sector is envisaged to grow. Consequently, research and training activities on all the aspects of the supply chain, from design to manufacturing and testing, are required to make 3D-printing a real breakthrough in the development of space-borne RF payloads. To summarize, the main activities foreseen in the development of this PhD research projects are the following: literature study to define a state of the art related to the topic; production by 3D printing of components for RF applications in the 40-50 GHz range (using mainly aluminium alloys); microstructural and mechanical characterization of samples and RF components; evaluation of the equivalent surface electrical conductivity of RF components; development and implementation of surface finishing processes (post processing) to reduce the surface roughness and improve the dimensional accuracy of components 3D printed from metal powders; development and implementation of surface metallization (coating) processes to improve the surface electrical conductivity of RF components made of structural polymer materials compatible with the typical requirements of space applications (like Ultem, or PEEK).

Skills and competencies for the development of the activity	Candidates should have a solid engineering background and strong motivation to learn through advanced research. Expertise in materials science, advanced processes and technologies from manufacturing to surface finishing one, mechanical, thermal and microstructural characterization of metallic and polymeric materials, is a plus. Curiosity-driven problem solving ability and practical attitude for the design of additive manufacturing/3D printing parts and components is also appreciated and evaluated.