

Chapter 1

Additive Manufacturing of Steerable Antenna Systems for 5G and Adaptive Cruise Control Applications

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ABSTRACT

This chapter gives an insight view of the evolving additive manufacturing technology and its application for designing steerable front-end (FE) array antenna architecture dedicated to mmWave for the 5G network and the adaptive cruise control (ACC) applications. The manufacturing of RF system is a challenging work because it comes with complex designs, a long realization time, and high cost as well as weight. Technically, all these challenges could be addressed up with the use of additive manufacturing technology. It allows an increased flexibility in the manufacturing of complex designs such as steerable beamforming and other advanced RF products. Traditional machining technologies used to manufacture RF products are limited in their ability to produce complex shape. The AM technology allows to realize the entire designs in one single time-phase which positively impacts mass, cost, realization time, assembly quality and RF performance.

INTRODUCTION

In general, 5G new radio (NR) network based on the mmWave spectrum are bound to offer a much-enhanced wireless network connectivity and performance compared to the already existing 4G networks. The prospects of IoT (Internet of Thing), 5G (Peterson & Schnauffer, 2018), and radar applications (Kumar, Cousin & Huyart, 2014) such as the development of Autonomous Cruise Control (ACC discussed by Lacher, 2009 and Ramasubramanian & Ginsburg, 2009 in their works) system are pushing the real-world

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interface close to the digital world by exploring some completely new possibilities at millimeter wave spectrum due to the availability of large contiguous bandwidth. The Front-End (FE) antenna design and its production are going to be a key factor in the success of mmWave services. Moreover, the digitally steerable beamform front-end design is going to replicate the same theme as of a DAC/ADC (that is available in the electronics designs for digital-to-analog and vice-versa), in between the real world and the dedicated machines such as human interface with the 5G network in wireless communication and with the autonomous vehicle in ACC systems. Nevertheless, such developments are going to bring a better experience of the human-machine establishment by enabling an enhanced wireless connectivity for the deployment of various applications through the secure and the reliable data available for the end user, irrespective of their situation, position, and time in space.

However, the manufacturing of RF system, especially a steerable front-end antenna design at millimeter spectrum, is a challenging research-work because it comes with some complex designs, along realization time, and high cost as well as weight. Technically, all these challenges could be addressed up with the use of Additive Manufacturing (AM) which is also known as 3D Printing technology, as discussed by the authors Johan et al. (2016), Fezai et al. (2015), Li et al; (2013) and Kumar, Louzir and Naour (2017). It allows an increased flexibility in the manufacturing of complex product designs such as steerable beamforming and other qualified advanced RF products (waveguides, filters, antenna feed chains, feed for parabolic reflector), array antennas and integrated components. Traditional machining technologies used to manufacture RF products are limited in their ability to produce products with complex shapes. To circumvent this limitation, complex products are often assembled out of many simpler subcomponents. The AM technology will not have such constraints, allowing it to realize the entire designs in one single time-phase which positively impacts mass, cost, realization time, assembly quality and RF performance.

The steerable beam with large spectrum bandwidth provides a dedicated wireless connectivity which is an important enabling factor for the high data capacity of the Non-Standalone 5G NR specifications realized by the 3GPP in Lisbon, December 2017. The one-dimensional beam steering is achieved by feeding a number of linearly equidistance antenna elements (linear array) with constant amplitude as well as constant relative phase differences. Similarly, the two-dimensional steering is achieved by introducing the constant relative phase shift in relative two-dimensional linearly placed antenna elements. Such one-or-two-dimensional array helps in achieving a highly-directive FE antenna array designs. The directivity directly influenced by the number of antenna elements in the array. The improved directivity enhances the coverage range of the signal and simultaneously it also avoids the unintentional interference through better beamwidth resolution. Moreover, it also helps in compensating the higher path loss associated with the millimeter spectrum. To compensate for these losses, the beamforming concept has been introduced to achieve a high antenna gain for a very high effective isotropic radiated power (EIRP). This approach helps in achieving longer radial coverage area for 5G network. Especially, in ACC the emitted power is much higher compared to the 5G and hence it causes more dissipation of heat in FE design. Therefore, the understanding of the heat dissipation requires some level of attention and to use a suitable semiconductor technology like Silicon Germanium (SiGe), Gallium Nitride (GaN) from the implementation perspectives. An overview of different cutting-edge semiconductor technologies is presented in this chapter related to ACC and 5G applications.

Also, the highly-directive beams allow spectral reuse through the spatial diversity. The well-known different architecture for the beam steering concept is explained here. The same concept of steering is also used in the ACC applications. Therefore, an example of the array antenna designs and its feeding

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