

Chapter 3

Prospect of Dynamic Metasurface Array Antenna System With Machine Learning

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ABSTRACT

This chapter presents the machine learning (ML) concept for standard RF component design in microwave frequency. It will explain the use of the deep machine learning concept for antenna and other RF components, such as RF filter, and all relevant analysis will be based on the CST simulations. The comparative study of the ML approach and the antenna design tool (such as CST) will be presented in the form of their performance. This chapter will explain the perspectives of ML in RF system design and analysis. This chapter will present the design of the antenna and filter as examples. The simulated results will be obtained by the CST MW Studio and the ML will be implemented in MATLAB.

INTRODUCTION

Traditionally the standard RF components (such as divider, filter, coupler, etc.) have been designed using different available 3D EM (Electro-Magnetic) Wave Simulator tools such as ADS, CST, HFSS, etc. For example, antenna simulation has been satisfactorily performed in CST or HFSS whereas the standard RF components, filter coupler, mixer, amplifier, etc., in ADS. These tools have gained reputation and trust from researchers and other Radio Frequency (RF) fraternities, and over the years, it has performed very well from an individual component design to a

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more complex integrated system design and analysis through different simulation modalities. At the same time, the complexity scale has also grown exponentially with the advancement of wireless technologies for different applications such as wireless sensing and for establishing wireless communication. In this context, the array aperture antenna based on dynamic metasurface design has many applications related to remote sensing as well as wireless communication under 5G and 6G schemes (Araghi, 2022; Bianco, 2020; Chaudhuri & Pal, 2022; Hamdi & Aguilu, 2021). Nevertheless, this new concept has brought new challenges for system design, especially concerning simulation tools because of their more complex structure compared to generally known antenna or RF component designs.

It becomes more challenging, in terms of computational cost as well as time, for a larger array size. This is evident in the case of Dynamic Metasurface Array antenna design because of the scarce increase in the number of radiating antenna elements which are known as meta-elements. Further, the optimization of such design becomes impossible with traditional computing resources because of the increased number of iteration steps involved in such approaches irrespective of known algorithms.

However, the recent development of Machine Learning (ML) (Alsharari, 2023; Huang et al., 2023; Koziel & Pietrenko-Dabrowska, 2023; Sendrea et al., 2023; Yang et al., 2023) has opened a new door across the domains such as statistics, decision-making, signal processing, optimization, prediction, identification, etc., while targeting different applications such as autonomous-driving, industrial autonomous, speech recognition, agriculture, and computer vision, where it is a challenge for researchers, scientists, and engineers to develop conventional algorithms to perform the needed tasks. Now, we need to understand machine learning before we go further. In simple terms, Machine Learning can be defined as a branch of Computer Science and Artificial Intelligence that focuses on the development of human-like learning as well as self-correction tendencies for attaining higher accuracy through data mining and algorithm developments. It is important to emphasize the two very special features of ML, that is, data mining can be related to establishing unknown mathematical relationships among data and doing meaningful data processing in the form of algorithms so that deviation from the expected values should remain minimal or within acceptable limits as an error. One keynote can be outlined here as these two special features always remain associated with repetitive or iterative tasks. Likewise, the available 3D Microwave Simulator tools are also solving Maxwell's equations at the mesh level in iterative patterns to compute the performance of an antenna or an RF component. Therefore, it is possible to use the ML concepts to achieve the expected results which are computed through different available EM Wave tools.

In this chapter, we will learn more about the dual-band antenna and RF filters as the standard RF component designs under a supervised learning approach, and

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