Linear and Non-Linear Synthesis of Unequally Spaced Time-Modulated Linear Arrays Using Evolutionary Algorithms

Somnath PATRA [1,2], Sujit Kumar MANDAL [2], Gautam Kumar MAHANTI [2], Narendra Nath PATHAK [3]

[1] Dept. of Electronics and Communication Engineering, SMIT (TIG), Guptipara, Hooghly, WB, India
[2] Dept. of Electronics and Communication Engineering, NIT Durgapur, WB, India
[3] Dept. of Electronics and Communication Engineering, Dr. B. C. Roy Engineering College, Durgapur, WB, India

somnath.tech@gmail.com, skmandal2006@gmail.com, gkm@ece.nitdgp.ac.in, narendra.pathak@bcrec.ac.in

Submitted February 7, 2021 / Accepted May 15, 2021

Abstract. *A novel method of designing unequally spaced time-modulated arrays (UESTMAs) by handling fewer optimization parameters with reduced problem dimension is presented in this paper. For synthesizing UESTMA, two design parameters, specifically, the non-linear parameter – element position, and the linear parameter – on-time durations are optimized in two steps. Different possible cases of linear and non-linear synthesis methods such as, position-only (PO), on-time only (OTO), position then on-time (PTOT), on-time then position (OTTP), and simultaneous position on-time (SPOT) are considered. To examine the performance of the synthesis methods, three global search stochastic algorithms based on differential evolution (DE), teaching-learning-based optimization (TLBO) and quantum particle swarm optimization (QPSO) have been employed to achieve the array pattern with significantly suppressed side lobe levels and sideband levels. Through comparative study, it is observed that the two step non-liner to linear synthesis method by fewer optimization parameters is efficient to provide better pattern with less computation time.*

Keywords

Time-modulation, position-only, on-time only, position on-time, side lobe level, sideband level

1. Introduction

Suppression of side lobe level (SLL) plays a vital role for designing antenna arrays and it has been extensively studied over several years. Theoretically, SLL of the array pattern can be suppressed to a desired value by providing proper excitation amplitude distribution in the array elements. There are various numerical and analytical techniques such as Dolph-Chebyshev and Taylor series methods [1] which are used to synthesize low side lobe antenna array patterns over the past years. These numerical methods are applicable for equally spaced antenna arrays and are employed to realize non-uniform excitation amplitude distribution of the desired pattern. However, high dynamic range ratio (DRR) of non-uniform amplitude excitation as required to reduce SLL in equally spaced antenna arrays increases the complexity and cost of the feed network [2], [3]. In contrast to equally spaced antenna arrays, in the recent past years, unequally spaced antenna array has been found to be effective to provide low side lobe patterns with uniform amplitude excitation [4]. The additional advantage of using unequally spaced antenna array is that the low side lobe pattern can be obtained with a smaller number of antenna elements for a given aperture size [5].

However, in 1959, H. E. Shanks [6] first proposed time-modulation to synthesize power pattern in antenna arrays by periodically controlling ON-OFF switching sequence of the radiating elements by using high-speed RF switches. The periodical switching of the antenna elements with some predetermined timing sequence leads to introduce 'time' as a 'fourth dimension' for synthesizing antenna array patterns with low and ultra-low values of SLL [7], [8]. The simple ON-OFF switching mechanism with optimized time pulse enables to suppress the SLL of the power pattern even with uniform excitation amplitude [9] and is effective in synthesizing different power patterns such as, sum and difference pattern [10], and flat-top shaped beam pattern [11]. It is to be noted that, in traditional amplitude tapering method, due to the various systematic errors, the array elements are not possible to feed with the exact value of the excitation amplitude of the required pattern. As a result, practically, it is exceedingly difficult to realize low/ultra-low sidelobe pattern with high DRR of static excitation amplitude in conventional antenna arrays (CAAs). On the other hand, power pattern in time-modulated arrays (TMAs) is controlled by using a set of switch-on time sequence of the array elements. Accordingly, the exact value of the on-time sequence for the low sidelobe patterns in TMA can be accurately maintained with the help of software. However, the sideband radiation due to the periodical commutation of the antenna elements