Side-Lobe Suppression Techniques for a Uniform Circular Array

Francesco Belfiori #1, Stefania Monni *2, Wim Van Rossum *3, Peter Hoogeboom #*4

#*IRCTR Department, Delft University of Technology*
Mekelweg 4, 2628CD Delft, The Netherlands
1 f.belfiori@tudelft.nl

**TNO - Defence, Security and Safety*
P.O. Box 96864, 2509JG The Hague, The Netherlands
2 stefania.monni@tno.nl
3 wim.vanrossum@tno.nl
4 peter.hoogeboom@tno.nl

Abstract— **This paper provides a comparison between two different techniques for the array pattern side-lobe reduction in a passive radar system based on a circular array. The first method retrieves the phase modes pattern for the reference array and then applies a conventional tapering for the side lobe suppression of the obtained virtual uniform linear array. The second approach foresees instead an optimization algorithm in order to obtain the desired level of the side lobes. Both techniques have been adapted for being used with an 8 elements FM-based circular array for passive radar applications developed at TNO - Defence, Security and Safety in The Hague. The effect of the directional elements has been also considered for the array pattern synthesis. The different advantages of the algorithms are described and a distinction about the possible fields of application is retrieved.**

I. Introduction

The main advantage of using circular arrays, instead of the linear ones, is the ability of these symmetrical systems to steer the beam electronically through 360° ([1]). The pattern behavior is also characterised by very small dependance of the azimuth resolution and of the side-lobe level on the steering angle. The array configuration, as is well known, allows the application of digital beam forming (DBF) algorithms for the formation of multiple beams, for the insertion of angular nulls inside the antenna pattern (AP) in order to minimize jamming, interferences and, for the passive radar applications, the direct path signal of the reference transmitter. On the other hand, the utilization of a system of multiple antenna elements introduces the mutual coupling (MC) effect that has to be compensated. Several techniques for the MC parameter estimation have been presented in literature for the different classes of antenna configurations ([3],[4]) and also for the compensation of the aforementioned system ([2]). As this paper it is not focused on that topic, in the rest of the article the MC compensation will be assumed already performed. Under this assumption and referring to a N elements circular array, the AP can be expressed as:

$$AP(\theta,\phi) = \sum_{n=1}^{N} a_n f_n(\theta, \phi-\phi_n) e^{jkr\sin(\theta)\cos(\phi-\phi_n)} \quad (1)$$

being r the array radius, θ and ϕ the elevation and the azimuth angle respectively, $\phi_n = \frac{2\pi}{N}n$ is the angular position of element number n around the circle, a_n is the complex coefficient which performs the beam shaping and pointing and f_n is the radiation pattern of the $n-th$ element of the array. For a specific pointing direction (θ_0, ϕ_0), the selection of a phase-only coefficient a_n as:

$$a_n(\theta_0,\phi_0) = e^{-jkr\sin(\theta_0)\cos(\phi_0-\phi_n)} \quad (2)$$

provides the simplest synthesis of the AP for an uniform circular array (UCA). In several applications the requirement on the side-lobe level can be a very stringent constraint and the pattern obtained with (2) could not be able to satisfy it. In order to get a better behavior of the side-lobes a different selection of the excitation coefficients is needed. This paper analyzes two different approaches for the side-lobe reduction; the first one is based on the phase modes decomposition of the circular array pattern while the second algorithm is based on an optimization procedure. In Sec. II the phase mode technique is shown and the final form of the coefficient a_n is estimated both for the omnidirectional and for the directional element pattern case. In Sec. III the latter approach is depicted while results and conclusions are reported in Sec. IV and V.

II. Phase Mode Technique

The array pattern of a circular array is a periodic function in the interval $[0, 2\pi]$ and this characteristic allows its representation in terms of a complex Fourier series. Referring to (1) and first considering the case of omnidirectional radiating elements ($f_n(\theta, \phi-\phi_n) = 1$), we can write:

$$AP(\theta,\phi) = \sum_{p=-\infty}^{\infty} C_p(\theta) e^{jp\phi} \quad (3)$$

being:

$$C_p(\theta) = \frac{1}{2\pi}\int_{-\pi}^{\pi} AP(\theta,\phi) e^{-jp\phi} d\phi \quad (4)$$

Each term of the sum in (3) is normally referred as phase mode of the radiation pattern ([1]) and it has a $2p\pi$ phase

978-2-87487-019-4