5D Array Synthesis for Future Radar Array Antenna Design

Xiao Xiao and Yilong Lu
Nanyang Technological University, Singapore 639798

Frequency Diversity Array (FDA) is a relatively new concept in radar array antenna research. Evolved from the widely known phased array, FDA utilizes small, well-designed frequency shift, rather than a phase shift among antenna element in an array. As a result, FDA could deliver a radiation pattern which is a function of direction, range and time. Such characteristic leads to a vast potential for FDA to be utilized in future radio systems such as advanced radar and high-speed communication.

Without loss of generality, the array factor of a uniform linear FDA with n elements and distance d between elements could be described in (1), where $\varphi_i(t)$ is the phase, $f_i(t)$ is the frequency and $A_i(t)$ stands for the amplitude weightage for i^{th} element respectively.

$$AF = \sum_{i=1}^{n} A_i e^{j\left[2\pi f_i(t)\left(t - \frac{r - id\sin\theta}{c}\right) + \varphi_i(t)\right]} \tag{1}$$

In principle, by designing the $f_i(t)$, $\varphi_i(t)$ and $A_i(t)$, the desired pattern could be achieved. Current studies in FDA mainly focused on development of $f_i(t)$ and hence achieve the desired pattern of the array. $A_i(t)$ is assumed to be equal among elements and $\varphi_i(t)$ is seen as one part of the $f_i(t)$ from (2). However, it is noticeable that $A_i(t)$ and $\varphi_i(t)$ serve the important role as well. Equation (2) only describes the changing part in $\varphi_i(t)$ could be seen as part of $f_i(t)$. From this point, (1) could only be simplified into (3) with no loss of generality. The φ_{0i} in (3) describes the constant phase shift of i^{th} element.

$$\frac{d\varphi}{dt} = \hat{f}(t) \tag{2}$$

$$AF = \sum_{i=1}^{n} A_i e^{j\left[2\pi f_i(t)\left(t - \frac{r - id\sin\theta}{c}\right) + \varphi_{i0}\right]} \tag{3}$$

Our research focuses on the effect of all three factors and hence introduces more degree of freedom in pattern synthesis and optimization as compare to conventional studies. Sparse array setup with non-uniform distance between array elements is also considered as a factor for the task. Together with the known factor of time t, a total of five dimensions (5D) are employed in array synthesis and optimization. Significant improvement in performance, such as side-lobe-level, is observed as compare to similar design using only $f_i(t)$ optimization.