SINGLE-POINT ARRAY RESPONSE CONTROL WITH MINIMUM PATTERN DEVIATION

Xiaoyu Ai, Lu Gan

School of Information and Communication Engineering, University of Electronic Science and Technology of China, P. R. China

No:1597

Introduction

Beam-pattern synthesis is one of the key techniques in the field of multi-antenna research, and has been applied to radar, sonar, and wireless communications. After determining a set of appropriate weight vectors, the controllable pattern is obtained to improve the system performance.

This paper presents a new beam-pattern synthesis algorithm so that the magnitude response at a given direction can be accurately adjusted. By analyzing the optimal weight vector in adaptive beamforming, it is found that the array response at one single direction is determined by a complex factor, and there are infinite complex factors that can achieve accurate magnitude response control. Moreover, the minimum pattern deviation criterion is established to optimize the complex factor. This results in the so-called single-point array response control with minimum pattern deviation (SPARC-MPD) method.

Background

The main task of beam-pattern synthesis is to design a complex weight vector that satisfies certain specifications, and the pattern of the designed weight is $P_k(\theta) = w^H(\theta) \cdot 0 \leq \theta \leq \omega$

In beam-pattern synthesis, it is desirable to design a pattern that has the minimum pattern error with the reference one in the mainlobe region $\Theta_{main}$ and has a maximum ratio of the mainlobe power to the sideband power on the sideband region $\Theta_{sid}:

$$P_{min} = \min_{\theta} \left| P_k(\theta) - P_{ref}(\theta) \right|$$

The main idea of this paper comes from adaptive array theory. Specifically, in adaptive beamforming, the pattern is adaptively obtained based on the received data, and the array response at the interference direction would decrease with the increase of the interference power to suppress the interference source.

Proposed Approach

It is known that, in adaptive array theory, the optimal weight vector is a linear combination of the signal steering vector multiplied by a complex factor, the signal vector affects the beam axis, and the interference component determines the direction of null. The interference steering vector multiplied by a complex factor, the signal vector affects the beam axis, and the interference component determines the direction of null. Moreover, the complex factor determines the depth of null.

By inspired by adaptive array theory, the designed weights in this paper is constructed as an iterative form, and the controllable pattern is obtained to improve the system performance. Moreover, the complex factor determines the depth of null.

In this example, the maximum magnitude response deviation is introduced to intuitively explain the convergence speed of the tested methods. At the k-th step, the maximum magnitude response deviation is defined as:

$$\Delta_k = \max \left[ w_k^H \cdot (\Omega_1 - \Omega_2) \right]$$

For $\Omega_1$ and $\Omega_2$, if the mainlobe pattern is not satisfactorily synthesized, the angle where the magnitude response deviates most from the reference level is selected as $\Omega_1$. Otherwise, set $\Omega_1 = \Omega_2$.

Conclusion

This paper presents a single-point array response control with minimum pattern deviation (SPARC-MPD) approach to synthesize beampattern. Unlike previous contributions of other adaptive array theory-based methods, the SPARC-MPD approach can adjust the magnitude response at one preassigned direction and minimize the pattern deviations at other directions. Moreover, the SPARC-MPD approach obtains desired weights in a low-complexity manner. Numerical results under the linear and planar arrays are carried out to validate the effectiveness of our approach, and the reasons for the pattern distortion issue in A^2RC and SPARC are analyzed. In future work, we shall consider how to obtain desired patterns with multi-point array response control to improve the efficiency of beampattern synthesis.

Simulation Results

Cosecant pattern with nonuniform sidelobe: Consider an array composed of 30 half-wavelength spaced isotropic elements. The reference pattern is a cosecant beam with

$$P_{ref}(\theta) = \frac{1}{\sin(\theta)} \quad 0.1 \leq c \leq 0.5$$

In this example, the maximum magnitude response deviation is introduced to intuitively explain the convergence speed of the tested methods. At the k-th step, the maximum magnitude response deviation is defined as:

$$\Delta_k = \max \left[ w_k^H \cdot (\Omega_1 - \Omega_2) \right]$$

Conclusion

This paper presents a single-point array response control with minimum pattern deviation (SPARC-MPD) approach to synthesize beampattern. Unlike previous contributions of other adaptive array theory-based methods, the SPARC-MPD approach can adjust the magnitude response at one preassigned direction and minimize the pattern deviations at other directions. Moreover, the SPARC-MPD approach obtains desired weights in a low-complexity manner. Numerical results under the linear and planar arrays are carried out to validate the effectiveness of our approach, and the reasons for the pattern distortion issue in A^2RC and SPARC are analyzed. In future work, we shall consider how to obtain desired patterns with multi-point array response control to improve the efficiency of beampattern synthesis.

Synthesized cosecant pattern with nonuniform sidelobe: (a) Patterns associated with the tested approaches; (b) Minimum deviation versus the iteration number.

Pattern synthesis for two-dimensional arrays pattern with nonuniform sidelobe: A rectangular array structure composed of 16 × 16 isotropic elements with half a wavelength is considered, and the steering vector becomes $\hat{w}(\Omega) = u \cdot \sin(\theta) \cos(\phi)$ and $v \cdot \sin(\theta) \sin(\phi)$, where $u$ and $v$ are the elevation and azimuth angles, respectively. The reference patterns steers at $\{u, v\} = \{-0.3, 0.3\}$, the normalized magnitude array response at the mainlobe region $\Theta_{main} = \{u, v\} = \{-0.5, 0.5\}$ is 0 dB. The notch area is $\Theta_{notch} = \{u, v\} = \{-0.8, -0.5\}$ with the upper level -35 dB, and the sidelobe level is lower than -25 dB in the rest of the area.