Synthesis of Adaptive Monopulse Patterns

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***Abstract*— A procedure is developed to simultaneously synthesize sum and difference patterns for space–time adaptive processing (STAP) in such a way that a specified monopulse slope after adaptation is achieved.**

***Index Terms*—Antenna pattern synthesis, monopulse antennas.**

I. Analysis

SPACE–TIME adaptive processing (STAP) is an effective method used by airborne radars for adaptively canceling clutter and jammers while simultaneously detecting targets. However, while it is straightforward to form adapted sum (Σ) and difference (Δ) beams, the adapted monopulse pattern Δ/Σ may have a highly distorted slope, rendering it ineffective for angular location [1]. In this letter, we present an approach to obtain controlled monopulse patterns for an adaptive radar. The classical STAP architecture is shown in Fig. 1 [2], [3]. Our procedure is to first form the adapted sum beam using the classic weight vector [4]

$$w = \frac{\Phi^{-1}s^*}{s^T\Phi^{-1}s^*} \tag{1}$$

where for K antennas and M time taps $w^T = [w_{11}\cdots w_{1M}\cdots w_{N1}\cdots w_{NM}], \Phi$ is the $NM \times NM$ interference covariance matrix and s is the steering vector for the signal defined as $s^T = [s_{11}\cdots s_{1M}\cdots s_{NM}]$. For a linear array and a target at azimuth θ_o and Doppler frequency f_o, the components of s are $s_{nm} = \exp[ikx_n \sin\theta_o - i2\pi m f_o T]$, where x_n is the location of antenna n and k is the wavenumber.

The difference beam $\Delta(\theta, f_o)$ is now formed such that the received interference is minimized subject to the constraints that $\Delta(\theta_o, f_o) = 0$ and the ratio Δ/Σ maintains a constant slope at Doppler frequency f as specified by

$$\frac{\Delta(\theta_o \pm \Delta\theta, f_o)}{\Sigma(\theta_o \pm \Delta\theta, f_o)} = \pm k_s \Delta\theta \tag{2}$$

where k_s is a slope constant. If we define a difference-beam weight vector w_Δ and recognize that the adapted difference pattern in the azimuth-Doppler domain (θ, f) is $w_\Delta^T g = g^T w_\Delta$, where $g(\theta, f)$ is an $NM \times 1$ vector with components $g_{nm} = \exp(ikx_n \sin\theta - i2\pi m f T)$, we see that the above three constraints can be written in matrix notation as

$$H^T w_\Delta = \rho \tag{3}$$

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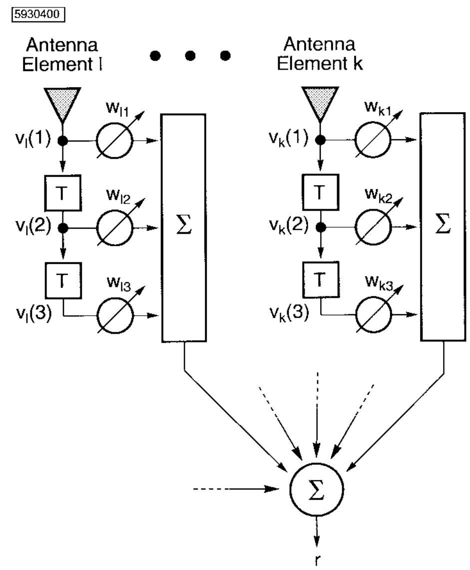

Fig. 1. Space–time adaptive processor.

where[1]

$$H^T = \begin{bmatrix} g^T(\theta_o + \Delta\theta, f_o) \\ g^T(\theta_o, f_o) \\ g^T(\theta_o - \Delta\theta, f_o) \end{bmatrix} \tag{4}$$

$$\rho = k_s \begin{bmatrix} w^T g(\theta_o + \Delta\theta, f_o) \\ 0 \\ -w^T g(\theta_o - \Delta\theta, f_o) \end{bmatrix} \Delta\theta. \tag{5}$$

The weight vector w_Δ that minimizes the difference beam interference

$$w_\Delta^H \Phi w_\Delta$$

subject to the constraint in (3) is [5]

$$w_\Delta = \Phi^{-1}H^*(H^T\Phi^{-1}H^*)^{-1}\rho. \tag{6}$$

In order to illustrate the results, we consider a 13-element linear array with 14 temporal taps per element, designed to detect low-speed targets in heavy ground clutter (clutter-to-noise ratio = 65 dB per element). In this case, the weight vector in (1) produces a sum beam that has an interference-plus-noise power after adaptation that is close to the noise floor for all target speeds V such that $0.05 < V/V_b < 0.95$, where V_b is the radar blind speed. The weight vector given in (6) produces a difference beam with an adapted, interference-plus-noise power close to the noise floor for all target speeds. The adapted monopulse pattern Δ/Σ is shown in Fig. 2 for

[1] In order to ensure that no anomalies occur we actually used $|w^T g|$ in (5).

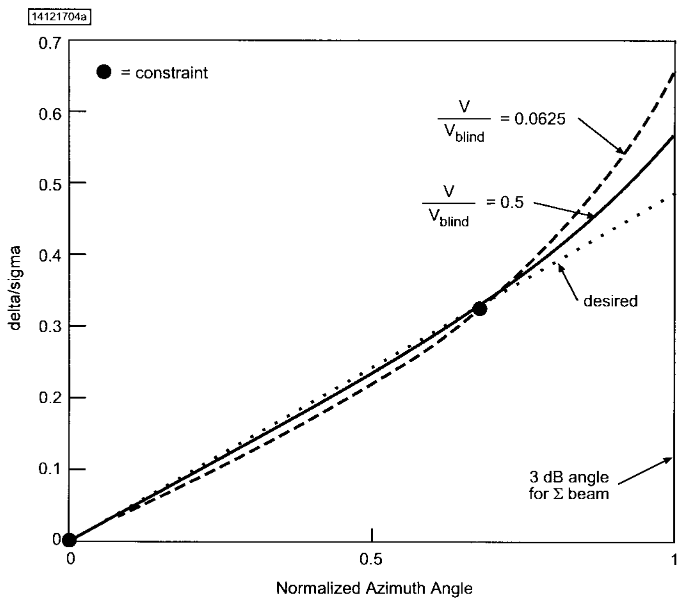

Fig. 2. Positive angle portion of adapted monopulse pattern for three constraints.

two different target[2] speeds. Note that the monopulse slope is nearly linear over the entire 3-dB width of the sum beam, as required. If the constraint in (3) is not applied, the adapted monopulse pattern is highly distorted!

[2]The processor produces a different weight vector for each target speed (target Doppler) to which it is tuned.

II. SUMMARY

We have developed a procedure to synthesize sum and difference patterns for space–time adaptive arrays in such a way that a specified monopulse response can be achieved. The approach is quite general and has been applied to more scenarios than presented here, including the case of an adaptive array with spatial degrees of freedom only (i.e., $M = 1$). Additional details are available from the author.

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Ronald L. Fante, photograph and biography not available at the time of publication.