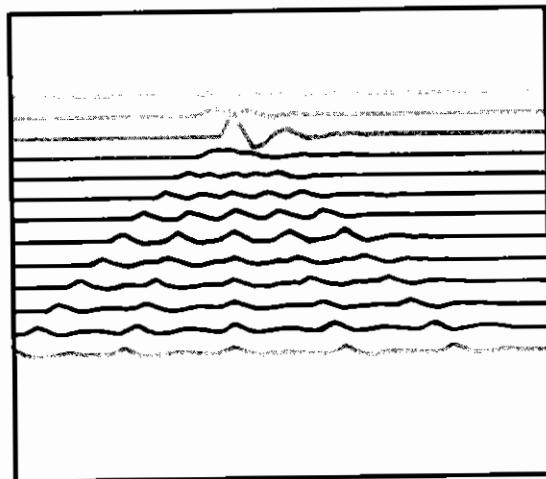
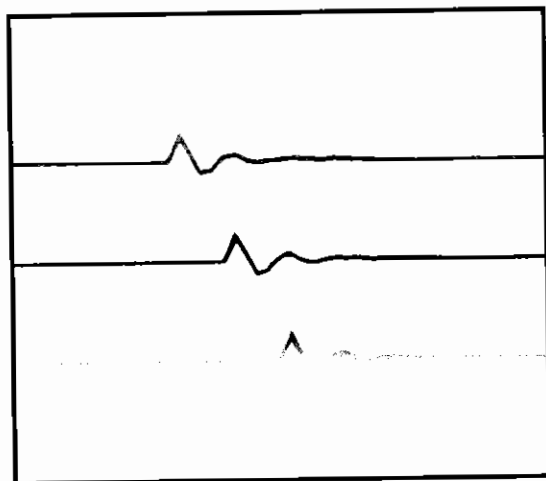


ARRAY SIGNAL PROCESSING

CONCEPTS AND TECHNIQUES



DON H. JOHNSON - DAN E. DUDGEON

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Array Signal Processing: Concepts and Techniques

Don H. Johnson
Rice University

Dan E. Dudgeon
Lincoln Laboratory,
Massachusetts Institute
of Technology



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In the search for cheaper, more flexible alternatives, arrays deserve consideration. As described in the previous chapter, an array processing system spatially samples the propagating field, and, if well-designed, no information is lost in the sampling process. The sensors can be directional, as in the *VLA*, or *omnidirectional*, having equal sensitivity to all directions of propagation. In either case, the array acts, as does the continuous aperture, as a spatial filter, attenuating all signals save those propagating from certain directions. The previous chapter details how an array's directivity pattern is determined by the aperture the sensors circumscribe and by the number of sensors. Sensors can be placed over a much wider area than the face of a parabolic dish without suffering the precision penalty. Consequently, the aperture of the array can be much greater than that of the single antenna, and, as we saw in the last chapter, increased aperture means greater angular resolution.

Augmenting an array with signal processing techniques not only enhances directivity but also allows us to aim the directivity pattern without physical changes. Furthermore, we can aim it in different directions simultaneously using signal processing notions. Thus, in addition to temporal filtering, array processing techniques can enhance an array's spatial filtering properties beyond those of a simple aperture filled with sensors. *Beamforming* is the name given to a wide variety of array processing algorithms that, by some means, focus the array's signal-capturing abilities in a particular direction. Based on the analogy of a flashlight, the mainlobe of an array's directivity pattern is called a *beam*.[†] Just as one might point a telescope or a radar dish, a beamforming algorithm "points" the array's spatial filter toward desired directions but algorithmically rather than physically. Beamforming algorithms generally perform the same operations on the sensors' outputs regardless of the number of sources or the character of the noise present in the wavefield. The signal processing algorithms developed for these *conventional* beamforming algorithms date from the early days of array processing and are well understood. Conventional beamforming algorithms use modern digital signal processing algorithms (such as the *FFT*) to great advantage, resulting in some of the most efficient array processing algorithms known. This chapter describes these algorithms and how they are implemented; later chapters describe more modern, adaptive algorithms. Array processing algorithms in conjunction with the array provide the best known spatiotemporal filters for decomposing the wavefield harmoniously into its components.

4.1 Delay-and-Sum Beamforming

Delay-and-sum beamforming, the oldest and simplest array signal processing algorithm, remains a powerful approach today. The underlying idea is quite simple: If a propagating signal is present in an array's aperture, the sensor outputs, delayed by appropriate amounts and added together, reinforce the signal with respect to noise or waves propagating in different directions. The delays that reinforce the signal are directly related to the length of time it takes for the signal to propagate between sensors (see Prob. 4.2). To be concrete,

[†] This nomenclature has its origins in arrays transmitting rather than receiving energy. Be that as it may, a beam now refers to the mainlobe of the directivity pattern whether the array transmits or receives.