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Broadband beamforming using Laguerre filters

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ABSTRACT

Space–time processing is a well-substantiated method for designing broadband beamformers. In the conventional Frost space–time beamformer, tapped delay line (TDL) filters are used in each branch of the array to create a wideband response for interference suppression. In this article a new space–time beamforming method is introduced in which Laguerre filters replace the traditional TDL filters in the Frost beamformer. The Laguerre filters are fundamentally IIR filters but with only one pole in their structure. Unlike other IIR-based space–time beamforming methods, the proposed method does not need an adaptive procedure for the pole adjustment and is inherently stable. Simulation results show superior performance of the proposed method compared to the Frost beamformer and comparable results against other IIR-based beamformers with much less computational complexity and guaranteed stability.

1. Introduction

Broadband beamforming has gained considerable interest in recent years due to its wide applications in radio communications, sonar, radar, seismology, acoustics, and many other areas [1,2]. Broadband signals are those who have a fractional bandwidth (FB) of more than 2% up to 50% [3]. Broadband beamforming methods can be classified into three major groups: space–time methods, space–frequency methods, and fully spatial methods [1].

In space–time methods, the broadband property of the array is achieved by processing the received signal of each antenna by appropriate time-domain filters as shown in Fig. 1(a). Frost beamformer [4] and generalized sidelobe canceler (GSC) [5] are two popular types of space–time beamformers. Frost beamformer uses TDL filters in each branch of the array as shown in Fig. 1(b). By increasing the signal bandwidth the number of weights $w_{m,j}$ must be increased in order to achieve a certain level of signal to interference and noise ratio (SINR) [6]. To resolve this, other methods such as beamspace processing [7,8] and replacing TDL filters with IIR filters have been proposed [9–11]. Using IIR filters has the risk of instability due to the update procedure of the poles.

In space–frequency methods, the received broadband signal of each antenna is decomposed into its narrowband components by a DFT operation [12,13]. Next, a narrowband beamforming method is applied to each frequency component. Finally, outputs of narrowband beamformers are added together and an IDFT operator is applied to construct the broadband signal. Space–frequency methods are computationally demanding due to the DFT operation in their structures.

In fully spatial methods another physical dimension is added to the original dimension of the array to create broadband properties. Instead of processing the broadband signal in time domain or in frequency domain, spatial processing and time delays in the added dimension are used to create a broadband beamformer [14,15]. Clearly, adding an extra dimension to the array imposes an extra layer of complexity to the array.

In this paper a new space–time broadband beamformer is introduced, which uses Laguerre filters in its design.

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