On Wideband MIMO Radar: Extended Signal Model and Spectral Beampattern Design

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***Abstract*—MIMO radar systems can increase the radar resolution, the number of targets that can be identified, and the flexibility in beampattern design in comparison with standard phased array radars. To date, most of the work on MIMO radar has been performed assuming the signals are narrowband. However, wideband signals can improve radar resolution, among other benefits, and are sometimes unavoidable when stringent range resolution specifications must be met. In this paper, we present a method for extending the MIMO narrowband model to a wideband model. Next, from the exact expression of the spatial power distribution involving the CSDM (Cross-Spectral power Density Matrix), we propose a suboptimal transmit beampattern synthesis technique, which can be used in the context of wideband signals.**

***Index Terms*—MIMO radar, parameter identification, probing signal design, transmit beampattern, wideband beamforming.**

I. Introduction

Multiple Input Multiple Output (MIMO) radar is a new architecture for radar systems that has been developed, borrowing ideas from MIMO communications systems [1]. The MIMO radar architecture which is of interest in this paper uses identically located transmit and receive antennas [1]–[5]. This form of MIMO has a variety of performance enhancing benefits over phased array systems including higher resolution, improved parameter identifiability for more targets, and greater flexibility in beampattern design [2].

The majority of the work published on MIMO radar systems has assumed narrowband signals and used narrowband models. However, wideband signals improve the target range resolution and parameter estimation, and are less susceptible to detection and interference [6]. In the narrowband case, the time delays due to different antenna to target path lengths are modelled as phase shifts, the error due to this assumption being small. However, as the bandwidth of the signal increases, this assumption no longer holds [7]. Therefore new signal processing methods for the wideband case are required. Methods of performing wideband beamforming at the receiver, using the autocorrelation and spectral density functions of the signals instead of the covariance matrix, are presented in [8] and [9]. Also, a method for synthesising wideband MIMO beampatterns is presented in [10].

In this paper, the wideband beamformer includes a filter on each channel, which reduces the wideband signal to narrowband on reception [11]. Firstly, we derive a new model for this approach which allows the adaptation of well-known techniques used in the narrowband case for the target parameter identification. Next, we propose a suboptimal method for synthesising wideband MIMO beampatterns, based on a spectral approach described in [10]. Finally, some simulation results are presented.

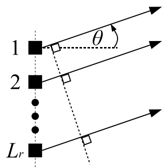

Fig. 1. Target parameter θ.

II. Wideband MIMO Radar

A. Wideband MIMO Radar Signal Model

Consider a MIMO system configuration where the L_t transmitting and L_r receiving antennas are colocated and where the target is in the farfield as shown in Figure 1.

For a target at location θ the bandpass signal received at the target is

$$\tilde{x}(t) = \sum_{i=1}^{L_t} \tilde{c}_i\left(t - \tau_i(\theta)\right) \tag{1}$$

where $\tilde{c}_i(t) = \Re\left(e^{j2\pi f_c t} c_i(t)\right)$ is the i^{th} transmitted bandpass signal with carrier frequency f_c, and $\tau_i(\theta)$ is the time taken for the signal to travel from the i^{th} transmitter element to the target. The corresponding baseband signal is then

$$x(t) = \sum_{i=1}^{L_t} e^{-j2\pi f_c \tau_i(\theta)} c_i\left(t - \tau_i(\theta)\right). \tag{2}$$

At the receiver end the k^{th} received bandpass signal is given by

$$\tilde{x}_k(t) = \beta \tilde{x}\left(t - \tau_k(\theta)\right), \tag{3}$$

and its complex envelope can be written as

$$x_k(t) = \beta e^{-j2\pi f_c \tau_k(\theta)} x\left(t - \tau_k(\theta)\right), \tag{4}$$

where β is a coefficient proportional to the Radar Cross Section of the target. Sampling this signal at frequency $f_s = 1/T_s$ gives

$$x_k(nT_s) = \beta e^{-j2\pi f_c \tau_k} \sum_{i=1}^{L_t} e^{-j2\pi f_c \tau_i} c_i\left(nTs - \tau_i - \tau_k\right) \tag{5}$$

where the dependences of τ_i and τ_k on θ have been omitted for notational simplicity.