Wavelet Based Deconvolution Algorithm for Time-Domain Near-Field ISAR Imaging

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***Abstract*—Based on correlation receiver in communication theory, the measured backscattering waveform of a calibration conducting sphere is adopted as the system impulse response. This antenna-target system response is then approximated by the derivatives of a Gaussian function (DGF) as well as the Coiflets to restore the impulse response of the target and to reconstruct the ISAR images. Both the DGF and Coiflets are applied to the deconvolution and their results are compared. The Gaussian and Coiflet function parameters are derived by a best-fit to the measured time-domain system response. Employing the parametric fits, a lowpass filter has been automatically embedded which performs regularization of the conjugate gradient (CG) optimization and speeds up the CG convergence. Numerical results show that the image quality from the Coiflet system is similar to or better than from the DGF system. Owing to the continuity, smoothness, orthogonality and compact support of the Coiflets, the size of the system matrix has been reduced from 1024 × 1024 for DGF to 261 × 261, and the deconvolution process is accelerated more than 22 fold without sacrificing image characters.**

***Index Terms*—Coifman wavelet, deconvolution, Galerkin's procedure, integral equation, time-domain ISAR imaging.**

I. Introduction

MICROWAVE imaging of airborne targets has been studied for several decades. Most of its early publications were based on frequency domain measurements [1]–[3]. Recently time-domain imaging algorithm has appeared on the scene [4], [5]. However, most measurements were taken from the frequency domain and then converted into the time domain by the fast Fourier transform (FFT). The resulting ISAR images have artifacts caused by the scattering phenomena of resonance, aliasing and dispersive mechanisms. These problems can be alleviated when data are directly collected from the time domain. Moreover, the computation speed of ISAR imaging algorithm in time domain is faster than in frequency domain. With advances in high-speed sampling scope techniques, time-domain radar imaging has recently received more attention [6]–[8]. The major differences between the true time-domain data and the FFT converted data are noise and aliasing. The scattered signals from detailed features of the target are usually weak and are likely contaminated by the system noise and background signals, including thermal noise, echoes from the target supporting structures, and coupling signal inside the measurement electronic system, as shown in Fig. 1. These coupling signals are also time-varying because of the change of the environment factors, such as temperature, moisture and voltage drifting. In order to obtain a clear image, the raw data must be preprocessed to reduce the system background signals before performing the deconvolution.

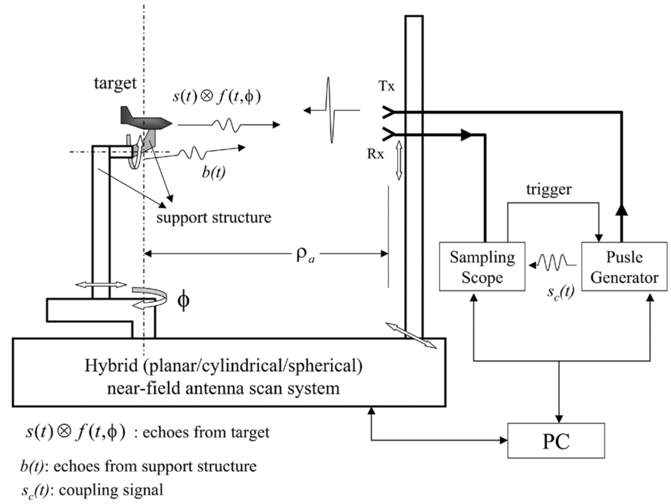

Fig. 1. Measurement scheme for ISAR imaging.

In this paper, we implement the time-domain deconvolution of system response, taking into account the incident impulse waveform, to restore reflectivity features and to enhance the image quality. In principle, this algorithm is similar to the correlation receiver in communication [9] and correlation processor in radar [10]. From its associated time-domain near-field data, the ISAR image of an aircraft is produced to demonstrate the proposed approach. This system response deconvolution can be very useful to improve the radar images suffered from the ringing incident waveform shown in [5]. Our deconvolution algorithm is based on the least-squares solution to the convolutional integral equation, where the system function is the backscattering waveform from a large conducting sphere. This is different from the previous work [6], [7], where the system function was chosen as the target-absent response and the singular value decomposition (SVD) was used. In [8], a similar concept of the system response deconvolution was presented, but it was in the frequency-domain without detailed application to ISAR imaging.

In this article, we employ the Coiflet, which is translation orthogonal, compactly supported, continuous, and smooth, with high precision one-point quadrature [11], [12]. The novelties of the work with respect to the previous publications are the use of

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