Multipath Ghosts in Through-the-Wall Radar Imaging: Challenges and Solutions

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In through-the-wall radar imaging (TWRI), the presence of front and side walls causes multipath propagation, which creates fake targets called multipath ghosts. They populate the scene and reduce the probability of correct target detection, classification, and localization. In modern TWRI, specular multipath exploitation has received considerable attention for reducing the effects of multipath ghosts. However, this exploitation is challenged by the requirements of the reflecting geometry, which is not always available. Currently, the demand for a high radar image resolution dictates the use of a large aperture and wide bandwidth. This results in a large amount of data. To tackle this problem, compressive sensing (CS) is applied to TWRI. With CS, only a fraction of the data are used to produce a high-quality image, provided that the scene is sparse. However, owing to multipath ghosts, the scene sparsity is highly deteriorated; hence, the performance of the CS algorithms is compromised. This paper presents and discusses the adverse effects of multipath ghosts in TWRI. It describes the physical formation of ghosts, their challenges, and existing suppression techniques.

Keywords: Aspect dependence, Compressive sensing, Multipath ghost, Subaperture, Through-the-wall radar imaging.

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I. Introduction

Through-the-wall radar imaging (TWRI) is an emerging technology that facilitates the detection, classification, and localization of targets from behind obstacles or walls using electromagnetic (EM) waves. Radar mainly relies on the time delay to localize a given target. The time delay is defined as the time elapsed when an EM wave travels from the transmitter side and back to the receiver after hitting a distant target. Owing to the presence of reflecting walls in TWRI applications, the multipath spread of EM waves introduces false time delays. Consequently, the receiver declares the presence of targets that do not physically exist in the actual scene. These hypothetical targets are called ghosts [1]–[3]. The number of ghosts expected in a reconstructed image is dictated by the number of registered multipath returns. Since the number of multipath returns in TWRI is higher than the number of direct returns, the formed ghosts outnumber the genuine targets; therefore, target detection and recognition will be highly vulnerable. Without an effective and efficient ghost suppression mechanism, TWRI technology may incorrectly interpret the scene, which can lead to improper resource allocation.

The current trend in TWRI applications is to obtain highly resolved images, as in [1]–[3]. The image resolution along the crossrange and downrange requires a large aperture and wide bandwidth, respectively. Consequently, a large amount of data needs be collected and processed. This explains why, in modern TWRI, the application of compressive sensing (CS) found considerable attention. CS techniques enable us to acquire and reconstruct a sparse signal using a small fraction of linear projections of the original signal without compromising the signal quality [4]. The vector is reconstructed by sparse reconstruction techniques such as minimization of the ℓ_1-norm using a number of algorithms