Path-loss Compensation in Through-the-wall Radar Imaging

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***Abstract*— In through-the-wall radar imaging (TWRI), path-loss can result in misleading targets. The fact that distant targets experience more path-loss than near targets is an essential feature of propagating signals. This paper proposes a path-loss compensator, which reverts the unavoidable loss in power by using different path-loss models. This will be effectively done by developing and incorporating the path-loss compensator matrix. The signal model is generalized so that it includes the front wall reflections. Many research papers in the field do not account for the differences in the propagation losses of the paths due to its complexity and mutable behavior, which can bring great difficulties to establish distance path-loss model. Simulation and experimental results are presented to show how the proposed approach can efficiently compensate for far targets and thus enhancing the signal-to-clutter ratio and reducing the normalized mean square error.**

Keywords*— *path-loss; signal propagation; signal-to-clutter ratio; through-the-wall radar imaging.

I. INTRODUCTION

For many years, the feature of seeing through walls was something extraordinary and thus it was always tied with ghouls and invisible souls. However, nowadays, through-the-wall radar imaging (TWRI) enabled us to view objects and effectively acquire information about scenes behind the walls and other opaque structures by exploiting the characteristics of electromagnetic waves propagation [1]. Thus, opening various promising prospects for future applications. The applications can range from military to civilian uses [2]. Although, TWRI technology drew a remarkable attention to many researchers in the past years, it however, still suffers many challenges in constructing the scene such as the effect of path-loss, multipath propagation, front wall reverberation, through wall propagation and noise [3]. In this work, we focus on the effect of path-loss due to its significant consequences on the scene reconstruction and interpretation. Many research papers in the field do not account for the differences in the propagation losses of the paths due to its complexity and mutable behavior. Far targets experience more path-loss than near targets which will eventually result in weak received signal and thus these targets can be unintentionally neglected. This research considers the design of a path-loss compensator which reverts the unavoidable loss in power by using free space path-loss model. The path-loss changes with both target-to-transceiver distance and the transmitted frequency given by [4]:

$$P_r = P_t\left(\frac{(antenna\ gain) * c^2}{(4\pi df)^2}\right) \qquad (1)$$

where c is the speed of light, d is the distance between the transceiver and the target, f is frequency transmitted, P_t and P_r are the transmitted and received signal power, respectively. To the best of our knowledge, most if not all the presented research do not employ path-loss, which adversely affects the scene interpretation particularly for heterogeneous scene imaging.

In [5], the authors proposed group sparse reconstruction approaches, however, the effect of path-loss was ignored during image reconstruction. Moreover, the authors in [6] conducted various experiments using frequency-modulated continuous wave radar under multiple scenarios but none of the scenarios dealt with free space path-loss which is normally severe and results in a significant loss. In [7], the authors recovered the signal by considering the correlations among measurements and then used a back-projection method to form the radar image, however, the received signal will be attenuated if the free-space path-loss was injected and thus the signal will have different amplitudes at different receivers. In [8], beam-forming method was used to reconstruct the image with the addition of wall attenuation effects and incorrect estimation of wall parameters but the multipath effect was not considered. In extension to this work, [9, 10] included multipath in their work and used two different techniques to exploit multipath. To correct the effect of multipath, authors of [9] mapped ghosts to their original targets but this technique has some drawbacks. It can map some targets to other targets if it was located within ghost position. On the other hand, [10] used compressive sensing (CS) to account for multipath. Unfortunately, the effect of path-loss was left out. In [11], the authors assessed CS and compared it with time domain back projection without considering path-loss. Furthermore, Capon beam-forming was used in [12] instead of delay-and-sum beamforming (DSBF) and took into consideration the effect of wall on the received signal. It showed a good resolution and side lobes reduction, yet they didn't take into account the significant effects of multipath and path-loss. In [13], the authors proposed new technique of reducing the number of samples and recovering all frequency samples from small subsets using CS and then generate the image using DSBF. In [14], Jungang et al. proposed a method that can estimate the observation position error as part of the imaging process. The CS imaging technique was used to acquire the results, however, the effect of path-loss was not taken into account, which could have increased the practicality of the outcomes.

Free space path-loss is crucial in many cases no matter what approaches of imaging researchers consider. path-loss

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