Dual-sided Phase Conjugating Surface Techniques for Imaging

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***Abstract*— We describe the principle of operation and study the imaging capabilities of a dual sided phase conjugating lens operating as an imaging sensor in free space or in an environment where significant multipath or scattering may be present. The image formation is based on the wavefront reversal properties of the phase conjugating array. By the means of numerical simulation we show that the characteristic resolution of a single dielectric target in free space is about one wavelength, λ, across the range and 3-4λ along the range for CW illumination and about one centre-wavelength λ_0 when the target is illuminated with a Gaussian packet. For multiple targets in free space resolution across and along the range is ~2λ_0 when illuminated by a Gaussian packet. It is shown that a weakly scattering object can only be detected behind a lossy dielectric wall using CW or UWB phase conjugation techniques when the backscattered field from the wall is eliminated. A procedure for achieving this is proposed. Numerical simulations for through-the-wall imaging using the phase conjugating lens technique with wall backscatter elimination demonstrates the possibility for small target high-resolution imaging.**

I. Introduction

Single or multiple target acquisition and tracking can be efficiently achieved with a novel class of radars based on retrodirective antenna techniques [1], [2]. Retrodirective radars based on phase conjugation offer major advantages over conventional modulated frequency radars, particularly the possibility of automatic beam steering, cancellation of signal distortions due to multipath effects and promise of all analogue realization. In this paper we study the imaging properties of a dual sided phase conjugating lens (PCL) [3], [4] operated as an imaging sensor i.e. phase conjugating radar in free space or in an environment where significant multipath or scattering may be present. Particularly we examine if phase conjugating technique can be used for the detection of weakly scattering targets located behind an electrically large lossy object, e.g. a wall. We show that in this case straightforward localization of the object using a PCL is not possible due to large masking effect from the wall. However the backscattered field from the wall can be extracted from the total scattered field by either PCL hardware calibration or by using signal processing algorithms [5], [6]. The target can then be located with good resolution ~λ_0 when illuminated by a Gaussian packet (λ_0 = centre-wavelength of the packet). We also provide the numerical simulations demonstrating the ability of a PCL to image multiple weakly scattering dielectric targets in free space with characteristic resolution ~2λ_0 when illuminated by a Gaussian wave packet.

II. Principle of Operation

The prototype concept presented here offers advantages with respect to time reversal techniques, [7], as no digital signal processing is required. The imaging array whose geometry is shown in Fig.1 operates such that it can image inhomogeneities in an arbitrary medium which may contain multipath or other scattering properties. In this paper we consider imaging through free space and in simple layered geometry in order to elaborate the concept.

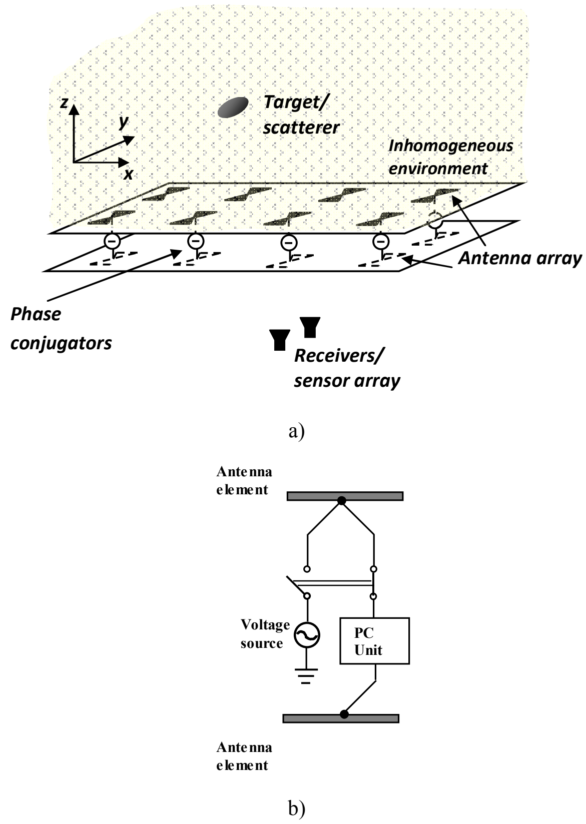

Fig. 1 a) Imaging geometry; b) Array element interconnection arrangement.

Each element in the array is fed by a sequentially switched voltage generator, Fig. 1, interconnected to its respective top layer radiator. A bottom element radiator is connected via phase conjugating circuitry such as that described in [3] and