Signal Processing Approach to Realizing Enhanced Resolution from Imaging Systems Such as Lenses

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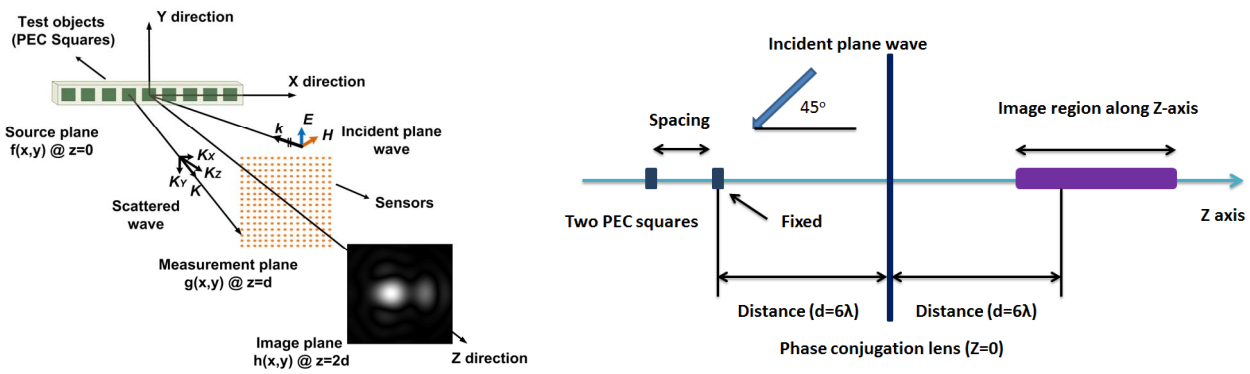
Abstract

In this paper, we discuss some strategies for improving the performance of imaging lenses by achieving enhanced resolution from the lenses that may have been designed by using Transformation Optics (TO), Field Transformation (FT) or Ray Optics (RO). Our focus is on using Signal Processing techniques to realize improved performance, rather than employing active materials, restoring evanescent wave contribution, or using other similar techniques that have been proposed in the past [1-8].

Some of the existing approaches in the antenna area are based on the use of phase-conjugating lenses consisting of a double-sided 2D assembly of straight wire elements; metallic strip gratings which perform evanescent-to-propagating wave conversion; sub-wavelength array of planar monopoles and split-ring resonators loaded with varactor diodes, etc. Here we propose to examine some alternative approaches that are currently being used by the radar community for performance enhancement of radar imaging systems, and to see if they can be utilized for the problem at hand, namely improving the resolution of microwave lenses.

The paper will begin with a review of the existing technique, and then propose a novel and general purpose signal processing approach for enhancing the image resolution. The details of this approach, whose first step is to construct a matrix to be used for processing the measured field distribution, say in the focal plane of the lens, to achieve improved resolution by being able to resolve two test objects located in the vicinity of each other.

Illustrative examples showing improved image resolution both in the transverse and longitudinal directions will be included in the paper. The schematic of the proposed scheme is illustrated in Fig. 1. The objects may be located either in a transverse plane or along the longitudinal axis.



(a) (b)

Fig. 1. Schematic of systems for sub-wavelength imaging using PC lens with the objects located along (a) transverse axis (along x-axis) and (b) longitudinal axis (along z-axis).

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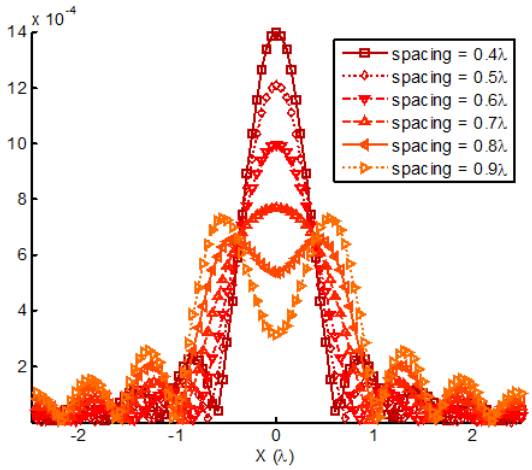


Fig. 2. Raw image (field distribution) results obtained by using the PC lens when two objects are located in the transverse plane along the x-axis, and their spacing is varied from 0.4λ to 0.9λ, with a 0.1λ step.

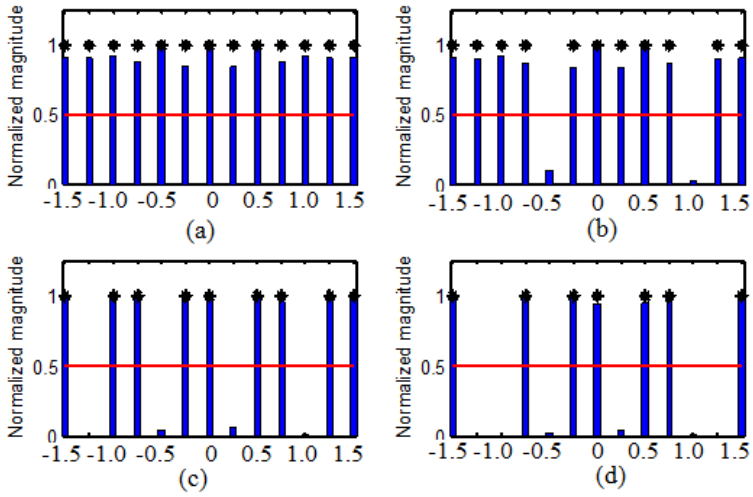


Fig. 3. Processed image results for different number of objects, obtained by using the proposed techniques when the objects are located in a transverse plane, and are spaced along the x-axis: (a) 13 objects locating at (-1.5λ, -1.25λ, -1.0λ, -0.75λ, -0.5λ, -0.25λ, 0.0λ, 0.25λ, 0.5λ, 0.75λ, 1.0λ, 1.25λ, 1.5λ); (b) 11 objects locating at (-1.5λ, -1.25λ, -1.0λ, -0.75λ, -0.25λ, 0.0λ, 0.25λ, 0.5λ, 0.75λ, 1.25λ, 1.5λ); (c) 9 objects locating at (-1.5λ, -1.0λ, -0.75λ, -0.25λ, 0.0λ, 0.5λ, 0.75λ, 1.25λ, 1.5λ); (d) 7 objects locating at (-1.5λ, -0.75λ, -0.25λ, 0.0λ, 0.5λ, 0.75λ, 1.5λ).

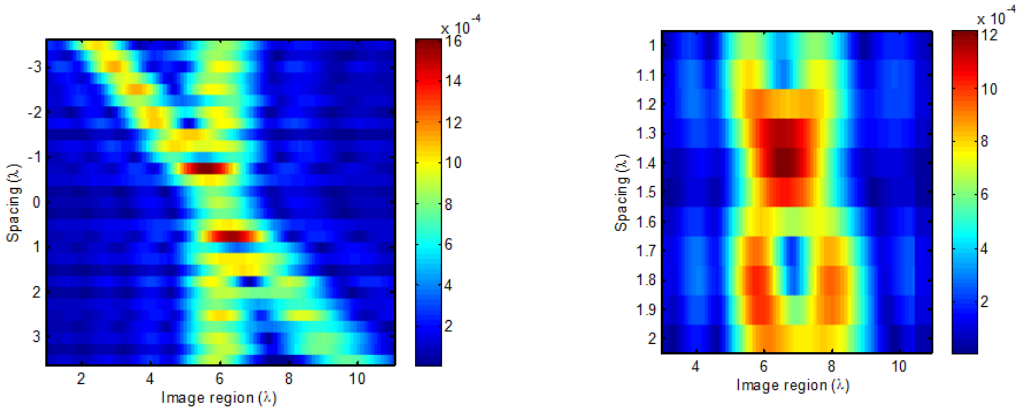
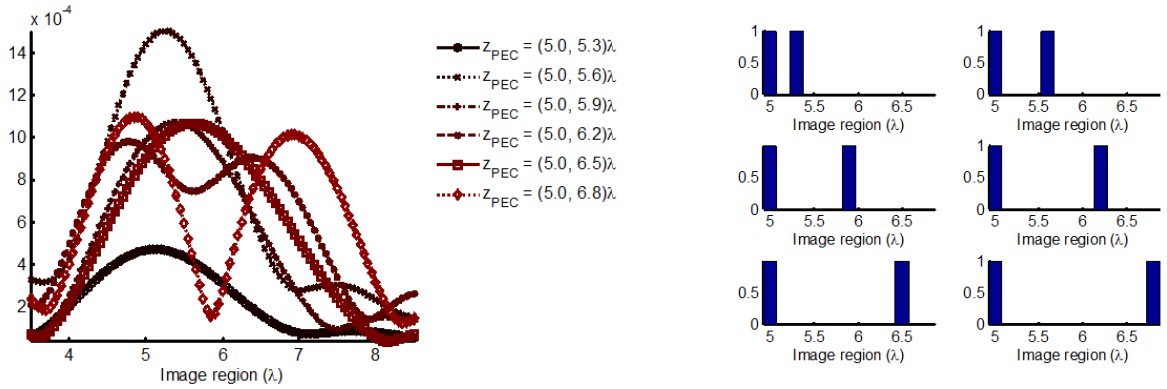


Fig. 4. Raw image (field intensity) results obtained by using the PC lens when two objects are located along the longitudinal axis (z-axis): (a) region from -3.5λ to 3.5λ with a 0.25λ step; and (b) region from 1.0λ to 2.0λ with a 0.1λ step.



(a) (b)

Fig. 5. Image results (field distribution) obtained by using a PC lens when two objects are located along the longitudinal axis (z-axis) and the spacing between them is varied: (a) raw images (field distribution) before processing; (b) results after processing the raw images by using the proposed technique.

It is evident from the results presented above that signal processing can enhance the resolution of the images generated by a PC lens quite considerably.

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