FOCAL PLANE APPROXIMATION FOR NEAR FIELD INTERFEROMETRIC RADIOMETER IMAGING

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Synthetic aperture interferometic radiometer (SAIR) is a promising technique for passive remote sensing which can achieve high resolution without the problem of deploying large scanning antenna for traditional real aperture radiometer. With the development interferometry technology, there has been growing interest in applying SAIR to short range imaging applications [1], such as security detection of concealed weapons or other contrabands, all weather reconnaissance and surveillance, and ground penetrating imaging for landmine detection or archeology. All these applications require a rather high spatial resolution, and the objects are inevitably within the near field of the antenna array. In this case, the traditional Fourier based imaging theories are not available and the near field effect must be taken into account. More explicitly in theory, in far field condition, the curvature of the radiation wave fronts is neglected and performing as plane wave. The cross correlation of the antenna pairs with deferent antenna pair spacing (baselines), called visibility function, exactly correspond to the Fourier transform of the incoming brightness temperature distribution. While in near field condition, for the array baselines, especially the longer ones, the distance is not large enough for neglecting the incident wave front curvature. Therefore, the Fourier relationship between the correlation results and the radiation distribution can not stand any longer; other appropriate techniques for near field imaging should be explored. In addition, exploring near filed imaging technique will also be helpful for SAIR on-ground calibration and characterization inside range limited anechoic chamber or at open air experimental field before launching into space.

Now some solutions have been proposed for SAIR near field imaging problem. It can be classified into two types. One is based on hardware transformation as what described in [2] and [3]. It physically rearranges the antenna elements from planar array to circular or spherical array. The other is based on software modification, as proposed in [4] and [5], and still keeps the traditional planar array but theoretically adding a correction phase term on the measured near-field visibility to get the equivalent far-field visibility, which also called near-field to far-field transformation. Both the two kind approaches can directly use traditional Fourier inversion algorithm, but have obvious disadvantages in practical application. The spherical array has a little FOV and only fit for the targets fixed on the focus point, while the corrected Fourier method only fit for point source. It still remains large errors in off-boresight areas for complex extended source especially large 3D targets.

This paper is devoted to analyze the near filed imaging problems of SAIR and develop a more efficient and accurate near field imaging technique. Firstly we analyzed the system impulse response of Fourier algorithm in near field condition, the distortion features are exactly same as those described in [4], but noted that the main lobe shift is not appeared in the figure, because it is essentially determined by the geometrical arrangement of antenna pairs and can be eliminated by choosing an appropriate "center point" of the whole array as the coordinate origin point. Since it is impossible to analytically inverse the near-field visibility because of the non-planar incidence wave front, i.e. the incidence wave rays from one point source to the interferometer elements are non-parallel, we can adopt a discrete form of the visibility that discretize the visibility integral equation to a vector product equation, and apply a numerical inversion like Moore-penrose Generalized Inverse formula to get the optimal discrete brightness distribution. The distance matrix between targets and each antenna pairs is needed for performing numerical inversion. Because the targets spatial distribution is unknown without special ranger instruments, we can attempt to replace it by a supposed simple surface like plane to calculate the distance matrix approximately. In some essence this method corresponds to focusing the imaging array on a plane where the scene targets are equivalently located, so we call it focal plane approximation. Because of the usual ill-posedness of the inverse equation, the Tikhonov regularization should be used to modify the bad condition of the distance coefficient matrix. Numerical simulations show that this method has a better performance than the corrected Fourier method (see Fig.1). More complicated 3D scenes are also tested to illustrate the feasibility of this focal plane approximation method (see Fig.2).

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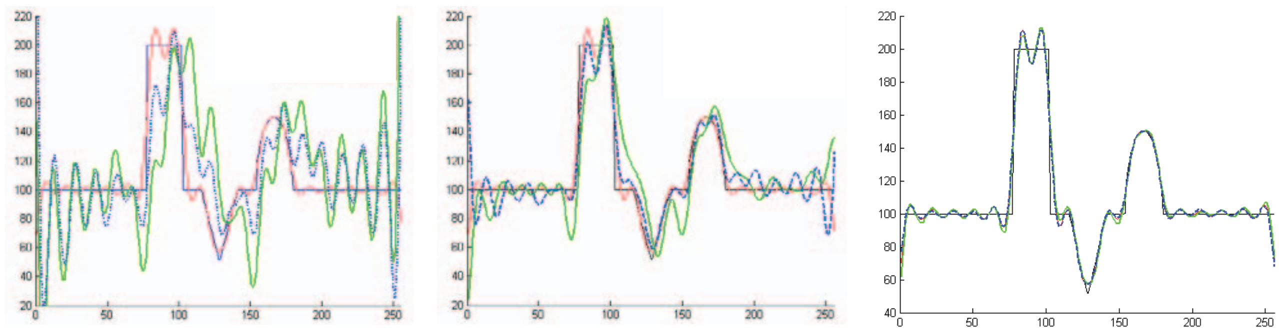
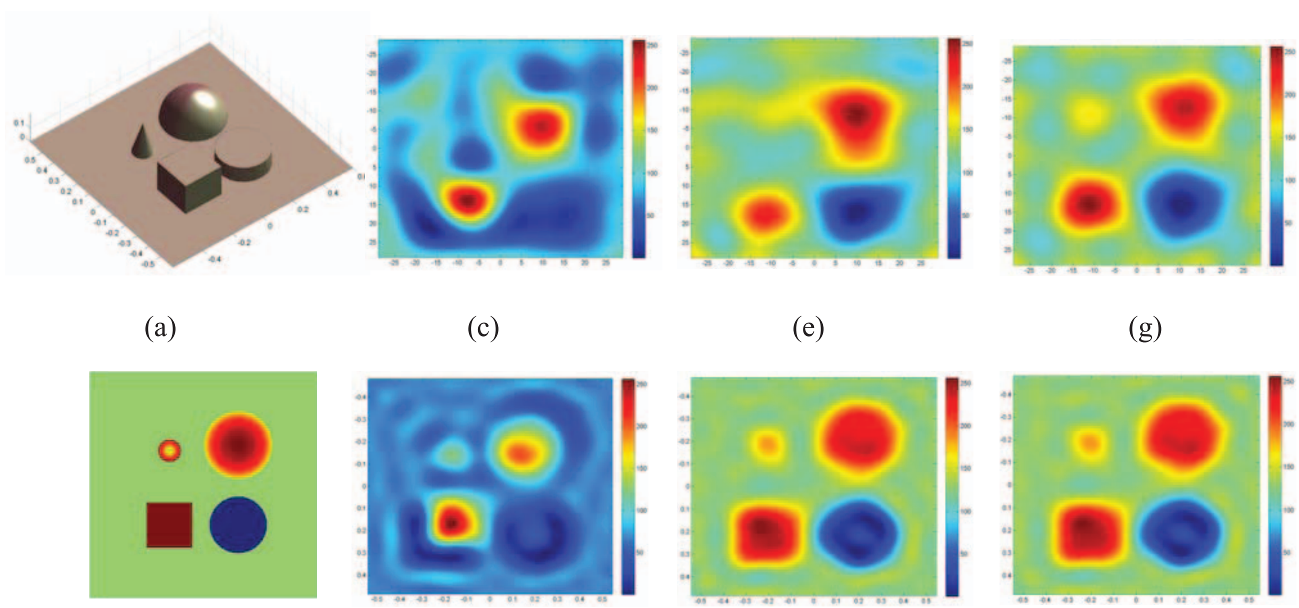


(a) (b) (c)

— Original brightness temperature
— Direct Fourier method
···· Near field modified Fourier method
— Near field focal plane approximation method

Fig. 1 Numerical simulation results of 1D objects in near field condition (a), in almost far field condition (b) and in very far field condition (c) by different imaging methods.



(a) (c) (e) (g)

(b) (d) (f) (h)

Fig. 2 Numerical simulation results: the 3-D objects (a) and its brightness temperature image (b); the reconstruction results by Fourier based near field modification method in a very near field of 1m (c), a moderate near field of 5m (e) and an almost far field 50m (g); the corresponding results reconstructed by focal plane approximation near field method are shown as (d), (f) and (h). The very far filed results by these two imaging methods, not shown out, are identical and almost same as (h).