Sampling Interval Parameter Design Based on Active Millimeter Wave Imaging

He Zhang, Hua Zong and Jinhui Qiu

Abstract
Millimeter wave has good penetration and security, which can be better applied in security check system. The security system needs to consider the imaging time and resolution, so it has great significance to rapidly reconstruct the imaging and improve the resolution for active millimeter-wave imaging. In this paper, the design of millimeter wave reconstruction imaging sampling interval is studied. Through analysis and experiment, the sampling interval is optimized, and the imaging results of traditional millimeter wave reconstruction algorithm and accurate millimeter wave algorithm are verified, which provides a theoretical basis for the design of active millimeter wave imaging system.

Introduction
In the actual imaging process, the data must be discretized before reconstruction, and the discretization of the collected data requires an appropriate sampling interval. The size of the sampling interval affects the resolution, the amount of computing time and the quality of the final reconstructed image, and the sampling interval is related to several parameters of the system [1].

The image information needs to be accurately restored. Nyquist sampling theorem should be satisfied when sampling the received data [2]. Received data information is mainly reflected on the phase information, and amplitude information change more slowly. To avoid spectral aliasing, the sampling interval of scattered echo data in the spatial domain cannot exceed half of the wavelength corresponding to the highest frequency, that is, the phase interval of adjacent sampling point. The frequency domain is less than 0 - 3 - 5. The spatial frequency of the phase information is expressed as follows:

\[ f = \frac{1}{2\pi} \sqrt{\left( x-x_0 \right)^2 + \left( y-y_0 \right)^2} \]

The maximum value of \( f \) can be calculated:

\[ f_{max} = \frac{1}{2\pi} \sqrt{\frac{L_x}{L_y + 2\pi}} \]

\( L_x \) is the transverse distance of the scanning area, and \( Z_0 \) is the distance between the front surface of the target and the scanning surface. According to the sampling theorem [6], the transverse sampling interval \( L_x \) is:

\[ L_x = \frac{\pi f_{max}}{\sin[\frac{\pi}{2}] + \sin[\frac{\pi}{4}]} \]

It can be seen that the size of the sampling interval and the wavelength of millimeter wave, target, and the size of the scanning range and imaging distance are related [7-8]. Sampling interval had a great influence on reconstruction image quality, so it is very important for the selection of sampling interval, different system parameters should select the appropriate sampling interval to ensure better reconstruction image.

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Fig.1 the two-dimensional holographic target object

Fig.2 the two-dimensional reconstruction image (a) holographic amplitude image (b) Reconstruction of the image (c) Reconstruction of the image amplitude image (d) Reconstruction of the image amplitude image (e) Reconstruction of the image amplitude image (f) Reconstruction of the image amplitude image (g) Reconstruction of the image amplitude image (h) Reconstruction of the image amplitude image (i) Reconstruction of the image amplitude image (j) Reconstruction of the image amplitude image

Fig.3 Reconstruction image when sampling interval does not meet the conditions (a) Holographic amplitude image (b) Reconstruction of the image (c) Reconstruction of the image amplitude image (d) Reconstruction of the image amplitude image (e) Reconstruction of the image amplitude image (f) Reconstruction of the image amplitude image (g) Reconstruction of the image amplitude image (h) Reconstruction of the image amplitude image (i) Reconstruction of the image amplitude image (j) Reconstruction of the image amplitude image

Fig.4 Reconstruction image when the scanning aperture smaller (a) Holographic amplitude image (b) Reconstruction of the image (c) Reconstruction of the image amplitude image (d) Reconstruction of the image amplitude image (e) Reconstruction of the image amplitude image (f) Reconstruction of the image amplitude image (g) Reconstruction of the image amplitude image (h) Reconstruction of the image amplitude image (i) Reconstruction of the image amplitude image (j) Reconstruction of the image amplitude image

Fig.5 Comparison of reconstructed images under different sampling conditions

(a) 7.5mm (b) 12.5mm (c) 25mm

Fig.6 Imaging results of different reconstruction methods (a) Imaging results by traditional methods (b) Accurate millimeter wave imaging results

Fig.7 Reconstruction of the image center section value

(a) Accurate reconstruction results to the original image (b) Traditional reconstruction

Conclusion
In this paper, the influence of sampling conditions on imaging results is analyzed. In the case that sampling conditions are satisfied and the scanning aperture is sufficient, the target reflectivity information can be recovered well. However, the sampling interval is not satisfied or the scanning aperture is insufficient, the reconstructed image will be blurred. Therefore, in the actual imaging process, appropriate sampling interval and scanning aperture should be selected to provide good data for subsequent reconstruction of images. At the same time, the millimeter-wave holographic accurate reconstruction algorithm can not only recover the original target image from the value and phase, but also recover the original distribution of the image well, which can better ensure the details of the image to a certain extent, which provides a theoretical basis for the design of millimeter-wave imaging system.

References