Development of tomographic methods in MM wave range

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Abstract

The experimental results on reconstruction of the cross-section images of the weakly scattered dielectric objects by the first-order diffraction tomography method in frequency band 99 \div 145 GHz are submitted. Descriptions of two experimental setups with different ways to obtain scattered field data are presented. The used theoretical model is considered. It is shown that MM wave tomography setups allow obtaining the images of the objects with a quality, which is sufficient for practical applications. It is offered a way, which gives possibility to extend, considered method on a case when the first-order diffraction tomography approach can not be used.

1. Introduction

Possibilities of the first-order diffraction tomography in the case of using the millimeter (MM) electromagnetic waves for object sounding were studied in [1]. Experimental images obtained by using tomography setup with operating frequency $f \approx 136.5$ GHz were represented in that work. The setup allowed measuring phase and amplitude of electromagnetic field scattered by object under investigation. It was shown that the cross-sections images weakly scattering objects made from materials with dielectric permittivities $\varepsilon \leq 1.1$ and having characteristic dimensions $A \approx 7\lambda + 15\lambda (\lambda = 2.2\text{mm})$ could be obtained by first-order diffraction tomography method. In present work, two new tomography setups are described.

2. Experimental setups and reconstruction

The setup schemes developed are shown in Fig.1, 2.

![Fig.1. Functional scheme of 99 GHz unit](image1)

(1 - oscillator 49GHz; 2 - ferrite isolator; 3 - frequency doubler; 4 - 3dB splitters; 5 - power amplifiers; 6 - phase shifter; 7 - balanced mixers; 8 - p-i-n attenuator; 9 - p-i-n modulator).

![Fig.2. Functional scheme of 2 mm tomograph setup](image2)

(1 - waveguide to quasi-optical beam wave guide transformer; 2 - matched load; 3 - beam splitter; 4 - attenuator; 5 - quasi-optical beam waveguides; 6 - frequency shifter; 7 - dielectric antennas; 8 - 90\degree degree turn; 9 - microwave detector).
One of them works at the frequency \( f \approx 99 \text{ GHz} \) and it is assembled on base of waveguide components (Fig.1). Another one has operating frequency band \( \Delta f \approx 125 \div 145 \text{ GHz} \) and was made out with using quasi-optical technique (Fig.2). The setups work on analogous principle, which has been described in [1]. Fig.3a, b, c and Fig.4a, b, c, d show images \((\varepsilon(x,y) - 1)\) of the object cross-sections under experimental investigation by using quasi-optical setup \((f \approx 136.5 \text{ GHz})\). Similar pictures are obtained with setup operating on the frequency \( f \approx 99 \text{ GHz} \). Objects were made from plastic foam and had characteristic dimensions \( A \approx 20 \lambda \). The reconstruction algorithm is based on the first-order diffraction tomography formulae. Fig.3a, b illustrate difference in image when angle of rotation between two linear scans is changed. In Fig.3c original object cross-section is represented.

In Fig.4a, c one can see images of more complex forms obtained at \( \Delta \phi = 10^\circ \). Fig.4b, d illustrate original object cross-sections. The quality of images obtained is sufficient for practice. It is offered to immerse target in medium with close electrodynamical parameters if scattered field by target can not be described in the framework of Born or Rytov approximation.

References