The analysis of artifacts generated in Microwave near-field breast cancer detection

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Abstract. Firstly, this paper analyzes the relationship between the detection data and the target tissue interface, and inverse the target image by microwave near-field detection data according to this relationship. According to the characteristics of microwave detection, this paper puts forward a practical inversion method, which is comparison with CT imaging method. Finally, it studies the artifacts in inversion imaging.

Introduction

For a long time, microwave engineers have dreamed using nonionizing electromagnetic waves to image the human body in order to detect cancers [1-4]. Over the past several years, significant progress has been made towards making this dream a reality for breast cancer detection. Breast tumors have electrical properties at microwave frequencies that are significantly different than those of healthy breast tissues [5]. The liquid content of tumor tissue is much higher than that of the surrounding normal tissues. The conductivity and dielectric constant is different from the surrounding normal tissues. In the process of propagation, electromagnetic waves would occur reflection and refraction on the surface of the medium boundary, such as, and the transmission path of electromagnetic wave would be changed. Based on this feature, we detect and locate breast tumor by measured the transmission distance and the energy of microwave reflection signal in different medium. We use slot step frequency modulation method to obtain signals in actual breast tumor target information acquisition system [6]. The bandwidth of slop step frequency modulation emission signal is 200 MHz, intermediate frequency is 1.575 GHz, and scanning period is 1ms. The transmitting signal reaches the receiving antenna and mixer after being reflected by breast tumor, while the other part directly gets to the mixer through transmitting antenna coupling networks. The course difference of two parts, which can be deduced from zero-IF, the output of the mixer, is used to determine the distance between the antenna and the tumor.

A comparative approach CT imaging and microwave near-field imaging

The actual breast tissues are very complex. Different interface have reflection (back wave) and refraction. These signals, which processed by difference frequency between the original signal and the back wave, have many frequency components. We assume that the distribution of dielectric constants of internal breast is $\mu(x, y)$, and (x, y) is the coordinate relative the center point. Obviously, $\mu(x, y)$ is bounded, and the back wave (reflection) occurs in the position which dielectric constant distribution is discontinuous. As shown in Figure 1, O is origin coordinate, P_i is detection point and Q_x is the interface between different tissues, which also is position with discontinuous dielectric constants. Reflection data obtained by test point P_i is that the center of the circle, accumulate all possible back waves on the circular arc with the center Pi and the radius P_iQ_x. It is proportional to the integral of $\mu(x, y)$ along the L_i.

$$T_{pi} = a_i \mu(r_x^i) \tag{1}$$

$$\mu(r_x^i) = \int_{Li} \mu(x, y) dl \tag{2}$$

Where a_i is coefficient and r_x^i is $\overrightarrow{P_i Q_x}$. L_i is a circular arc with center Pi and radius $\left\| r_x^i \right\|$. Because the back wave outside the model can be ignored, the integral can be simplified as

$$\mu(r_x^i) = \int_0^{2\pi} \mu(x, y) \times r_x^i d\theta \tag{3}$$

Where θ is polar angle which $P_i O$ is polar axis and P_i is the pole of polar coordinate.

$\mu(r_x^i)$ Can be calculated by the back wave which is detected through the detection point P_i. So the distribution calculation of target permittivity becomes to compute spatial distribution by line integrals in known space.
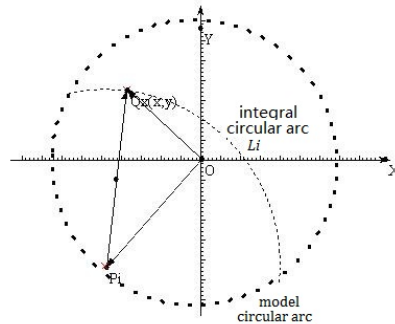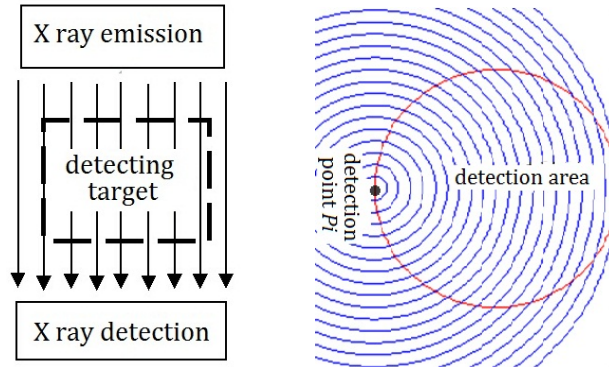

Fig. 1 the relationship between detection point and reflecting interface

The detection of this single test point P_i is accumulated along the concentric circular arc direction, and it can be viewed as the projection along the circular arc, which is different from the CT along a linear projection detection. Fig.2 shows schematic diagram of CT detection and microwave detection.

(a)Schematic diagram of CT detection   (b) Schematic diagram of microwave detection

Fig. 2 the comparison between CT detection and microwave detection

In order to calculate the distribution function of the target space, CT uses rotating target method, which is to change the angle of projection [1]. Microwave near-field detection uses rotating transceiver antenna method, as shown in figure 3.

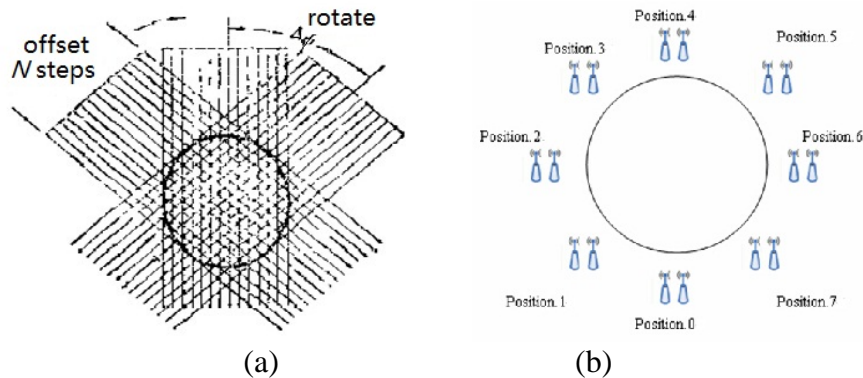(a)   (b)

Fig. 3 the different detection mode of CT and microwave detection. (a) CT scans with panning and rotating mode. Microwave near field detection places the transceiver antenna as shown in (b).

The target segmentation of two detection methods are entirely different, though they all use rotational detection. In order to facilitate comparison, we consider a detection line through point Q in target area, which is shown in figure 4.
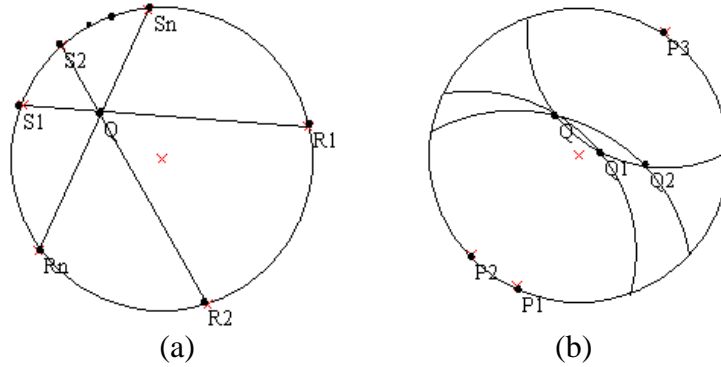

(a)   (b)

Fig. 4 The detection difference of CT and microwave near-field detection. (a) In CT, there has only one point of intersection Q in arbitrary two detecting path. (b) In microwave near-field detection, there also have second point of intersection (Q_1 and Q_2) except Q in arbitrary two detecting path.

For a certain point in the target region, CT can be determined uniquely by two integral paths through the point, which can invert spatial distribution by established linear equations fitted with division of the regional.

For the image reconstruction of CT [7], we suppose that tomography have 3*3 unit and the attenuation coefficient respectively to each unit are μ_1 to μ_9. Nine rays, which are completely disjoint, across the tomography. The equation of their line integrals of attenuation coefficient is shown in equation 1. Where, P_1 to P_9 are respectively line integrals of the attenuation coefficient in different rays. P_1 to P_9, as a known number, can be confirmed by detector, thus we can get the values of μ_1 to μ_9. Then we use image representation μ_1 to μ_9 and generate tomography. That is the reconstruction of CT image.

$$\mu_7 + \mu_8 + \mu_9 = P_1$$
$$\mu_4 + \mu_5 + \mu_6 = P_2$$
$$\mu_1 + \mu_2 + \mu_3 = P_3$$
$$\mu_4 + \mu_8 = P_4$$
$$\mu_1 + \mu_5 + \mu_9 = P_5$$
$$\mu_2 + \mu_6 = P_6$$
$$\mu_1 + \mu_4 + \mu_7 = P_7$$
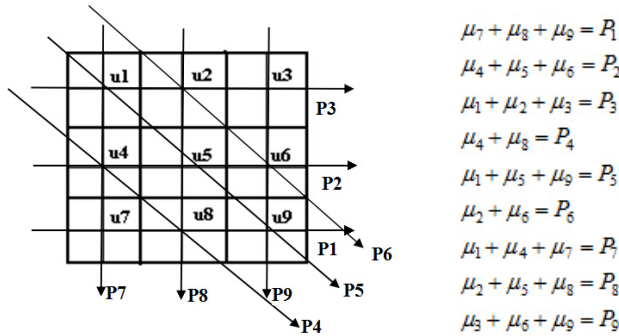$$\mu_2 + \mu_5 + \mu_8 = P_8$$
$$\mu_3 + \mu_6 + \mu_9 = P_9$$

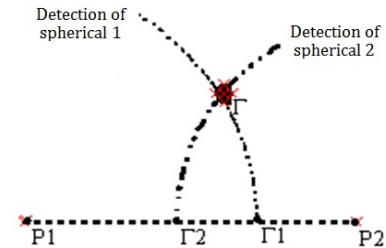Fig. 5 Schematic diagram of reconstruction of CT images [7]

Fig. 6 schematic diagram of artifacts produced

For the microwave near-field imaging, arbitrary two integrals path, which are all through point Q, may have another intersection, so it is difficult to reconstruction the microwave image using the CT reconstruction method.

The principle of generating artifact

The way to reconstruct image may bring artifacts, which mean the dielectric constants of some places becoming abnormal after inversion reconstruction. In the microwave near-field imaging, the artifacts product for the following reasons.

(1) The radius of actual detection circle is different from the radius of model circle, so it must cause some dislocations. This dislocations lead to suspicious point from one to several, forming artifacts.

(2) The detection wave surface is a sphere, but we reconstruct image only in one plane. That certainly appear many artifacts.

As shown in figure 6, there have a suspicious reflection surface unit Γ in detection space. Points P_1 and P_2 are two detection points, and the dotted line P1P2 is the inversion plane. Γ is the actual suspicious unit, Γ_1 is the corresponding point appearing in the inversion plane using detection point P_1, and Γ_2 is the corresponding point appearing in the inversion plane using detection point P_2.

The distance between Γ_1 and Γ_2 is related to the distance between the suspicious unit and inversion plane. In the inversion plane, there form a concentric ring artifacts with the increasing number of points. This is different from the star shaped artifacts produced by CT reconstruction images. Figure 7 is the comparison of artifacts emerged from microwave inversion and CT images.

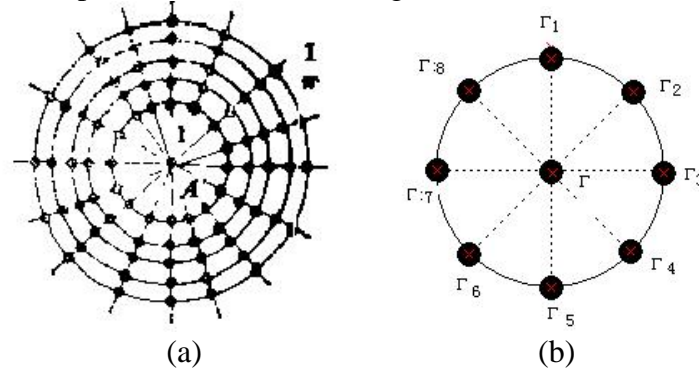(a)   (b)

Fig. 7 The comparison of artifacts emerged from microwave inversion and CT images. (a) The star artifacts of reconstructed by CT. Point A is the real point, and the points distributed with concentric circle are artifacts. (b) The artifacts of reconstructed by microwave near-field reconstruction.

Further work

Microwave near-field imaging detection method applied to breast cancer detection as a new technology developed in recent years. This article puts a new inversion method to reconstruct microwave near-field image, and give a real image inversion. Then this paper also analyze the reason of artifacts appeared in real microwave near-field detection. Our next step is to further study how to eliminate the artifacts in the imaging process.

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