Estimate the Location of a Breast Tumor using the Received Signal Angle

Javad Nouri Pour[1], Mohammad Ali Pourmina[2*], Mohammad Naser Moghaddasi[3], Behbod Ghalamkari [4]

1-Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
Email: javad.nooripoor@srbiau.ac.ir

2-Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
Email: Pourmina@srbiau.ac.ir(Corresponding author)

3-Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
Email: mn.moghaddasi@srbiau.ac.ir

4-Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
Email: ghalamkari@srbiau.ac.ir

Received: 3 November 2022 Revised: 10 December 2022 Accepted: 14 January 2023

ABSTRACT:
In this paper, a new method for estimating the tumor's location is presented; the technique is based on the arrangement of sensors and received wave changes. A new method has been developed for locating the return signal from the tumor. The main idea is that the location of the tumor is randomly assumed. And then estimates the location of the tumor. It presents a phase event. Various articles have used a combination of these methods to shape different issues. However, these methods have not been used to estimate tumor location. In this article, two types of wavelengths are used; the transmitter node first sends a signal with a specific frequency, it is assumed that the reflection is almost complete. Therefore, according to the reviews of the tumor signal, we find that the tumor is in the region of intensification, i.e., the dimensions of the tumor are in the order of the transmitted wavelength. Then, by changing the frequency, the signal passes through the tumor. The signal passing through the tumor (according to "Snell's" law) fails; that is, the received signal is received with angular deviation and delay. An estimator is suggested by the maximum likelihood maximum (MLE). The estimators have a nonlinear form. We use the SD reduction slope algorithm to LS linear search algorithm for optimizations.

KEYWORDS: Tumor, AOA, Maximum Probability, Signal Angle Deviation, Breast Tumor.

1. INTRODUCTION

Much work has been done to locate the tumor, most of which focuses on the type of antenna and its design, less on its processing. In the article [1] [2], a microwave imaging method is based on antenna design, and the challenges facing antenna design have been partially solved by the signal processing part. In the discussion of estimating the location of the tumor, no work has been done in this field, or if it has been done, it is in order to remove the fixed and moving artifact. Unlike previous work [3] [4] that focuses on the type of antenna and its design, the innovative aspect of this article is that with only one antenna, how the antenna is arranged, signal processing and estimation, an estimate of the tumor location is extracted.

Diagnosis of breast tumors using radar waves has always been challenging because the reflective signals from the cancer include two types of early and late time signals. Early time signals consist of reflected skin, while late time signals consist of tumor response and clotting. Pre-processing algorithms eliminate the early scattered field time signal [1]. Various methods for tumor detection or clutter removal have been proposed in this paper [1]. A method for estimating the tumor response in scattered signal fields that are received with delay. This method uses a parametric function to model the tumor response. The inductive maximum estimation (MAP) solution is used to evaluate the optimal values for estimating the parameters. Accurate identification of the tumor response allows the clutter to be isolated from the late reply.

This paper presents a method [2] from scattered reflections of a single-pulse tumor estimation method. This method is a suitable method for modeling tumor

Paper type: Research paper
DOI: 10.30486/MJTD.2022.678909
How to cite this paper: J. Nouri Pour, M. A. Pourmina, M. N. Moghaddasi and B. Ghalamkari, "**Estimate the Location of a Breast Tumor using the Received Signal Angle**", *Majlesi Journal of Telecommunication Devices*, Vol. 12, No. 1, pp. 1-6, 2023.

response. The maximum inductive estimation solution is used for evaluation. The pattern classification technique is then used to validate the estimator. In this article [3], we review recent research in this field.

First, we introduce the concept of microwave imaging through space-time beam (MIST) formation and related signal processing algorithms. The purpose of these signal processing techniques is to form a spatial image of scattered microwave energy and also to identify the presence and location of malignant lesions as signs of their scattering. Then, I present numerical studies based on time domain simulations of finite differences to demonstrate the effect of MIST radiation formation on the diagnosis of small malignant breast tumors in both susceptible and passive structures.

Various methods have been proposed for locating an electromagnetic wave emitter. Most of these methods use target angle information (AOA) and arrival time (TOA) or arrival time difference (TDOA) information or using frequency information [5]to locate the target. Presents [6]a new method for locating a transmitter from a phase event. Various articles have used a combination of these methods to form different problems. However, these methods have not been used to estimate the location of the tumor.

Tumor radar detection Adaptive Tissue Sensor Radar is recommended for the early detection of breast cancer. Tumor diagnosis is made using differences in the electromagnetic properties of malignant tumors and surrounding healthy breast tissue (fat). The resulting scattered fields are recorded and processed to amplify the tumor response.

Then different algorithms are used for signal processing. An antenna is applied to the processed signals from different positions, allowing the tumor to be identified and located.

In this paper, the geometry of the problem is first discussed to determine the location of the tumor. In the next sections, the method of resolving the tumor package is examined, this method can be solved based on the phase and amplitude of the tumor. In Section 4; an estimator with a nonlinear form is then proposed. Finally, the simulation and evaluation results are presented.

2. PROBLEM GEOMETRY

The problem is shown in Fig. 1 Geometry. The transmitter node is in a specific position where there is a (tumor) in an unknown situation; its location is unknown. A moving node is rotated around it to find the location of the cancer. The return signal from the tumor has certain changes; the moving node around the breast tissue rotates at a certain angular velocity and receives the return signal from the tumor.

Assuming knowing the angle of the transmitter node. The moving node calculates the amount of signal deviation from the straight line. At any given moment, we extract the input phase according to the number of transmitted waves and the angle of the node. To calculate the range, we calculate the amount of deviation.

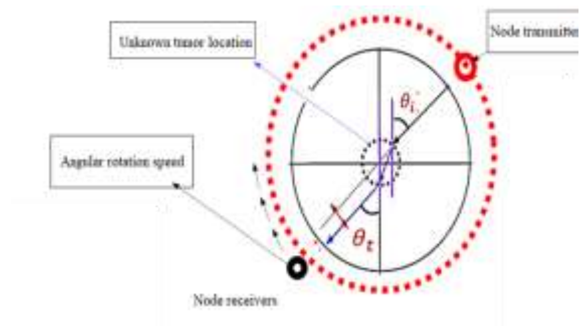

Fig. 1. Tumor-free radiation and Tumor-free radiation.

3. SOLVE THE TUMOR LOCATION PACKAGE

To obtain the position of the tumor from zinc, there is an angle and a difference. First, the radar cross-section of the tumor is extracted, and then the tap, range (Snell's law), and the number of received waves are extracted.

As shown in Figure 1. If the radar cross section of the target is not detected, the transmitted frequency is changed so that at a certain frequency the tumor resonates and reflects the signal. As a result, the frequency is adjusted so that the wavelength of the target frequency is proportional to the frequency in the resonance region, and the radar signal can be returned from the tumor [6] [7]. As a result, the received frequency and wavelength are obtained and then a circle with a wavelength radius of $\lambda \approx r$ is drawn in the chest. It is determined, but its direction and location are unknown [5] (so the cross-sectional area of the target radar is equal to the resonance region).

The radar cross section of an object is geometrically on the one hand in terms of its geometry and material, and on the other hand it is a function of radar and radar operating frequency parameters, the angle of wave radiation. Low frequency zone, resonant zone and high frequency zone, In this definition, the meaning of low or high frequency range is not the separation of areas in terms of frequency, but the separation based on the ratio of dimensions to wavelength. If the spherical target is smooth with respect to the wavelength, that is, it does not have large unevenness with respect to the wavelength and its radius is a. Frequency zones can be defined as follows: 1) Low frequency zone($\lambda \gg a$): In this range, If the phase of the radiation wave is small during the target. The induced current on the body is almost constant in terms of phase and amplitude. In this case, the object behaves like a compact circuit and all its components are coupled together and the radar echo depends very little on the shape of the target. 2) Resonance zone($\lambda \approx a$): In this range, the phase of the current along the body contributes to the scattering pattern, it is called σ and it is called Mai region. 3) High frequency zone($\lambda \gg a$): In this case, different parts of the body act independently. Thus, there are several cycles of current phase change throughout the body. As a result, the scattering field will be strongly dependent on the angle and the maximum scattering will be related to certain points. In this region, σ may be independent of the wavelength and is called the optical region.

$$\sigma = 4\pi r^2 \quad imum\ point$$
$$\sigma = 0.26\pi r^2 \quad imum\ point$$

By changing the frequency of the wave as it passes through the tumor, it fails and the propagation path of the wave changes. So the information we got is the position of the tumor in terms of angle, angle and difference. As we said, we get the signal reception angle according to the speed of the moving node angle and the time difference according to Snell's law and the number of received waves. At each rotation we know the angle of the radiation, so the angle of reflection is calculated relative to the time when the light is refracted if we do not have light refraction.

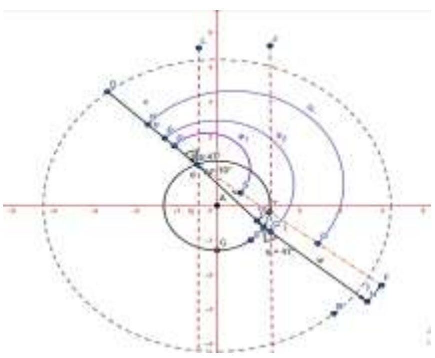

Fig. 2. General Geometry of the problem.

$$\lambda \approx r \;\Rightarrow\; DTOA = TOA_i - TOA_1 \tag{1}$$

$$r = CTOA_i \overset{c=\frac{nc_0}{\sqrt{\varepsilon_r}}}{\Rightarrow} r_1 = ct_1 \Rightarrow \begin{cases} r_i = ct_i \\ (TOA = t_1) \square \begin{cases} r_i = ct_i + \tau_i \\ r_1 = ct_1 + \tau_1 \end{cases} \\ c = \dfrac{nc_0}{\sqrt{\varepsilon_r}} \end{cases} \tag{2}$$

In Equation 2, light refraction causes the wave propagation velocity to decrease. This wave velocity reduction is defined according to the tumor permeability coefficient. Table 1 shows the characteristics of tumor tissue.

Using the Snell relation and changing the frequency, if the wavelength is less than the cross-sectional area of the target radar, it causes the wave to pass.

$$\theta_1 = sin\left(\frac{n_2}{n_1} sin\theta_2\right) \tag{3}$$

In the above equation v is the wave propagation velocity in the environment, n_1, n_2 is the refractive index of the two media, $\sin\theta_1$ is the wave entry angle and $\sin\theta_2$ is the wave exit angle. Here L is the position(x_l, y_l) $l = 1, \ldots, L$, the angle of entry of the radiator $\theta_l$with respect to the x-axis. Assuming that the target position is in the coordinates (x_t, y_t) and the refractive index is $\eta = \frac{n_2}{n_1}$. The following relation will be established for the measured dataθ_l:

$$\theta_l = \eta \tan^{-1}\left(\frac{(rsin\theta\ sin\varphi)_l - (sin\theta\ sin\varphi)_t}{(sin\theta\ cos\varphi)_l - (sin\theta\ cos\varphi)_t}\right) + n_l, \quad l = 1, \ldots, L \tag{4}$$

Where n_l is the noise error of measuring the angle of entry. Here it is assumed that all measurement errors have the same distribution $f_n(n_l)$ and are independent. Objective To estimate the position of the target $((\sin\theta\ \cos\varphi)_t, (\sin\theta\ \sin\varphi)_t)$ from the observed data, the entry angle θ_l. To solve this problem, the ML maximum similarity estimator is used here:

$$(\hat{x}_t, \hat{y}_t) = argmax_{x_l, y_l} f\left(\theta_1, \theta_2, \ldots, \theta_L \,|\, (sin\theta\ cos\varphi)_t, (sin\theta\ sin\varphi)_t\right) \tag{5}$$

4. SUGGEST A NONLINEAR ESTIMATOR

Here, by estimating the equation using the maximum likelihood method, an estimator is proposed.

One of the advantages of this estimator is that while the number of observations is high, it asymptotically tends towards optimization (compatible estimator). Using the condition of independence and the logarithm function, problem (6) is converted to the following form:

$$(\hat{x}_t, \hat{y}_t) = argmax_{x_l, y_l} \sum_{l=1}^{L} \ln f_n\left(\theta_l - \tan^{-1}\left(\frac{(rsin\theta\ sin\varphi)_l - (sin\theta\ sin\varphi)_t}{(sin\theta\ cos\varphi)_l - (sin\theta\ cos\varphi)_t}\right)\right)$$

(6)

This estimator simplifies the noise density function into various forms depending on the choice. Here we use the Gaussian model. Gaussian probability density function$f_n(n_l) = \frac{1}{\sqrt{2\pi\sigma_e^2}} \exp\left(\frac{-n_l^2}{2\sigma_e^2}\right)$:

Selecting this ML estimator distribution simplifies the problem of the least squares of the following error:

$$(\hat{x}_t, \hat{y}_t) = argmin_{x_l, y_l} \sum_{l=1}^{L} \left(\tan^{-1}\left(\frac{(sin\theta\ \ sin\varphi)_t - (rsin\theta\ \ sin\varphi)_l}{(sin\theta\ \ cos\varphi)_t - (sin\theta\ \ cos\varphi)_l} \right) - \theta_l \right)^2 \quad (7)$$

It should be noted that this form of estimator is very common. As can be seen from Form 5, the estimators have a nonlinear form. To optimize it, iteration algorithms must be used, or the best answer must be sought in the coordinate space. Because the search space is so large, the full search method has a high computational volume.

Here we use the SD slope algorithm to LS linear search algorithm for optimization. If we express the optimization problem in the general form of Equation 8:

$$(\hat{x}_t, \hat{y}_t) = \text{argmin}_{x_l, y_l} J(x_t, y_t) \quad (8)$$

Where $J(x_l, y_l)$is a function of the cost of the problem, the minimum value of which must be determined. Equations 9 and 10 express the gradient of the cost function relative to the x_t axis of the target and the y_t axis of the target.

$$\frac{\partial J_2}{\partial x_t} = \sum_{l=1}^{L} 2 \frac{(rsin\theta\ \ sin\varphi)_l - (sin\theta\ \ sin\varphi)_t}{d_l^2} \left(\tan^{-1}\left(\frac{(rsin\theta\ \ sin\varphi)_l - (sin\theta\ \ sin\varphi)_t}{x_t - x_l} \right) - \theta_l \right) \quad (9)$$

$$\frac{\partial J_2}{\partial y_t} = \sum_{l=1}^{L} 2 \frac{(sin\theta\ cos\varphi)_t - (sin\theta\ cos\varphi)_l}{d_l^2} \left(\tan^{-1}\left(\frac{(rsin\theta\ sin\varphi)_l - (sin\theta\ sin\varphi)_t}{(sin\theta\ cos\varphi)_t - (sin\theta\ cos\varphi)_l} \right) - \theta_l \right) \quad (10)$$

Using the Monte Carlo method, the standard deviation of the range can be easily calculated. It should be noted that the analytical calculation of the radiator range deviation is difficult and therefore it is calculated by the Monte Carlo method.

5. SIMULATION AND EVALUATION

The tumor assessor is used for the collected data in different node positions that revolve around the tumor, which is 36 degrees in 36 positions and the distance from each position to the next position is 10 degrees. At each node position, the received signal has a time delay and an angle.

A tumor is a sphere of radius a located at a random location in the breast. Because the signal reaches us by changing the angle and phase, to model the tumor, the breast and skin tissue will act according to Table 1 (due to the rotation of the antenna around the tissue, in some situations the antenna is farther from the tumor and in some situations the antenna is closer to the tumor). The accuracy of location is evaluated according to the RMSE criterion belonging to the target estimate, which is defined as follows.

$$RMSE\,(x_0) = \sqrt{\sum_{l=1}^{L} \frac{\hat{x}_0 - {x_0}^2}{M}} \quad (11)$$

It should be noted that in the above relation $\hat{x}_0$ represents the estimate $x_0$in the execution of m-th and M = 1000 indicates the number of performances in each simulation experiment.

Table 1. Tissue texture profile

Maximum Range	Minimum Range	Random range of tumor position	Tumor Range estimation	Tumor θ estimation
200e3	50e3	1.2357e+05	4.6438e+04	-3.1366
40e3	15e3	2.4969e+04	8.8393e+03	1.1193
40e3	15e3	3.5367e+04	6.8894e+03	1.6472
40e3	15e3	3.4974e+04	3.4938e+04	0.3229

In this section, the performance of the estimation method is evaluated.

1. The frequency of the transmitted wave in the frequency band 2-10GHz changes as a frequency jump.
2. At 3 GHz, the radius of the target dimension is equal to the wavelength, and then the frequency band of the signal is changed.
3. The receiver node in 36 positions, the angle of each position to the next position is 10 degrees.

4. The tumor is in the direction of the x-axis and is measured every 2 mm for a distance of 20 cm of data.
5. The standard deviation of the angle measurement error is considered to be 0.2 degrees.

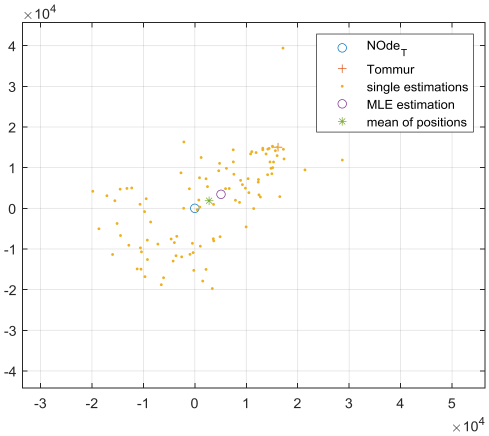

Fig. 3. Round view Estimating the target location using the maximum likelihood method.

Fig. 3 shows the cancerous tumor as a sphere with a radius of $\lambda \approx a$, but its location is not specified. The shape of the tumor is spherical inside the breast (here it is assumed that the breast is circular). It is assumed that each time we receive the signal it has an unknown position in angle and phase using the maximum likelihood estimation of the tumor location.

Table 2. Tumor Location Evaluation Results

Type of texture	Conductivity $\sigma\left[\frac{S}{m}\right]$	Permittivity ε_r
Skin	4	36
Tumor	4	50
Breast	0.36-0.44	8.1-9.9

As can be seen in Table 2, tumor is estimated with different accuracy for different distances and angles. Fig. 3 is shown. Fig. 3 RMSE shows the error for distances of 15 to 40 cm of the tumor, the error at 22 cm has its lowest value. The estimated position through the ML is about 2 mm from the exact position, and considering that the distance of this tumor from the receptor is about 15 to 40 cm. Equation 10 Gradient descent algorithm First, the weight of the algorithm is updated for much iteration. The weight of the algorithm is a random variable, a process that shows us the average of the winner answer process. This algorithm takes steps in proportion to the positive direction of the function gradient to get the maximum value of the function closer [6].

$$W_{k+1} = W_k - \eta \frac{1}{m} \sum_{i=1}^{m} \nabla f_{w_k}\left(x^i\right) \qquad (12)$$

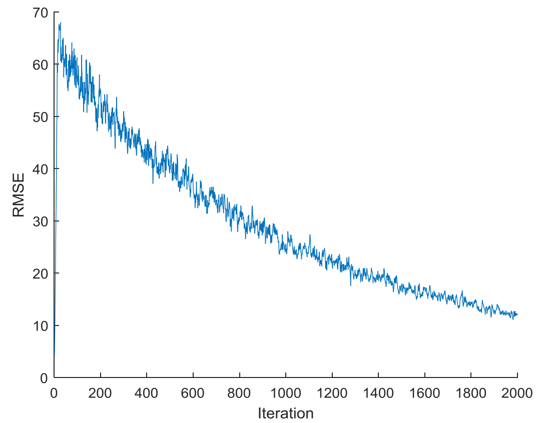

Fig. 4. Steps in proportion to the positive direction of the gradient to achieve convergence.

Fig. 4 plots the error value for multiple iterations, which minimizes the error function value for each iteration.

6. CONCLUSION

This article is an optimal method for determining the location of a donor tumor. To estimate the location of the tumor, a transmitter node was placed here in a fixed position, the recipient node rotating at a certain angular velocity around the tissue. In this paper, first two types of transmitter node wavelengths are used. At the first transmitted frequency, it is assumed that the reflection is almost complete, so in the resonant region, the tumor reflections are in the resonant region, that is, the dimensions of the tumor are in the order of the transmitted wavelength. It then passes through the tumor by changing the frequency of the signal. The signal passing through the tumor (according to Snell's law) has failed, that is, the received signal has been received with angular deviation and delay. An estimator is suggested by the angle deviation and delay of the received signal. In order to better estimate the tumor location, the target site was estimated using the ML maximal probability method. It is recommended that LS and WLS methods be used to better estimate the tumor.

REFERENCES

[1] J. Sill and E. Fear, **"Tissue Sensing Adaptive Radar for Breast Cancer Detection—Experimental Investigation of Simple Tumor Models,"** *IEEE Transactions on Microwave Theory and Techniques* , vol. 53, no. 11, pp. 3312 - 3319, 2005.

[2] E. C. Fear, J. Bourqui, C. Curtis, D. Mew, B. Docktor and C. Romano, "**Microwave Breast Imaging With a Monostatic Radar-Based System: A Study of Application to Patients,"** *IEEE Transactions on Microwave Theory and Techniques,* vol. 61, no. 5, pp. 2119 - 2128, 2013.

[3] E. P. Evgeny, Kirshin, A. Santorelli, M. Coates and M. Popović, **"Time-Domain Multistatic Radar System for Microwave Breast Screening,"** *IEEE Antennas and Wireless Propagation Letters* , vol. 12, no. 1536-1225, pp. 229 - 232, 20 February 2013.

[4] E. Porter, M. Coates and M. Popović**, "An Early Clinical Study of Time-Domain Microwave Radar for Breast Health Monitoring,"** *IEEE Transactions on Biomedical Engineering,* vol. 63, no. 3, pp. 530 - 539, March 2016.

[5] K. Kanazawa, K. Noritake, Y. Takaishi and S. Kidera, "**Microwave Imaging Algorithm Based on Waveform Reconstruction for Microwave Ablation Treatment,"** *IEEE Transactions on Antennas and Propagation,* pp. Volume: 68, Issue: 7, July 2020.

[6] G. W. STIMSON, Introduction AIRBORNE Radar, MENDHAM, NEW JERSEY: SciTech Publishing, 1983 .

[7] F. M. a. D. T. W. Douglas J. Kurrant, **"Tumor Response Estimation in Radar-Based Microwave Breast Cancer Detection,"** *IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING,* vol. 55, p. 12, DECEMBER 2008.

[8] D. J. Kurrant, E. C. Fear and D. T. Westwick, "**Tumor Estimation In Tissue Sensing Adaptive Radar (TSAR) Signals,"** in *2007 Canadian Conference on Electrical and Computer Engineering,* Vancouver, BC, Canada, 22-26 April 2007.

[9] K. Kanazawa, K. Noritake and Y. T. a. S. Kidera, **"Microwave Imaging Algorithm Based on Waveform Reconstruction for Microwave Ablation Treatment,"** *IEEE Transactions on Antennas and Propagation,* vol. 68, no. 7, pp. 5613 - 5625, 2020.

[10] S. V. Doan, J. Vesely, P. Janu, P. Hubacek and X. L. Tran, **"Optimized algorithm for solving phase interferometer ambiguity,"** in *2016 17th International Radar Symposium (IRS),* Krakow, Poland, 10-12 May 2016.

[11] B. S. Javad. Nooripor, **"Disorder system signal spectrum to steal Velocity Range Gate,"** *Majlesi Journal of Telecommunication Devices,* vol. 2, no. 2423-4117, p. 2, June 2012.

[12] A. H. Sayed, Adaptive Filters, IEEE Books, 2008.