Imaging for Detecting Breast Cancers Using UWB Radar Technology

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ABSTRACT
Ultra wide band (UWB) microwave imaging has recently been proposed for detecting small malignant breast tumors and is expected to detect breast tumors with safety, comfort and precision for high resolution of UWB pulse. In this paper, we propose a new imaging method that uses circle approximation to detect the cancer in order for automatically detection without doctors' analysis. Our proposal method measures a radius of a cancer, and decides the center point of cancers on the circumference. The method is simulated by 2D FDTD method. As the result, our method showed higher detection accuracy of a center position and a radius of a circle formed cancer than conventional method.

Keywords
Breast cancer, ultra wide band radar, microwave imaging, FDTD methods

1. INTRODUCTION
The average life term of the Japanese is the top in the world. However number of deaths with cancers continuously increase year by year. Now 30ĄŞ of all deaths are from cancers in Japan, and cancer is a top threat for a long time around the world. To decrease number of death by cancers, early detection is very effective. In the near future, it's assumed that demands for high-precision imaging method increase more and more.

Currently, X-ray mammograpy is mainly used to detect breast cancers. However, there are many limitations and problemsĄD

- Detection sensitivity of X-ray isn't enough to detect cancers without fail, and interpretation of radiograms by the expert is needed.
- long time and high costs are wasted
- gives a patient a severe pain
- worry about X-ray exposure

UWB radar techniques are used in many subsurface sensing applications, such as estimating the underground structures and medical implanted devices [1]. The transmitted electric magnetic wave penetrates into the region under inspection and are scattered by any targets that exhibit a mismatch in dielectric properties. Recently, UWB radar techniques have been proposed to detect early stage breast cancer[2][3][4][5][6]. Breast cancers detection by microwave has following good features and is expected to become alternative detection device.

- A difference between breast fat and cancers in the microwave frequency range is more significant than in X-ray range, so Detective sensitivity is higher.
- X-ray exposure doesn't occur.
- doesn't give a patient a pain

In this paper, we focus on imaging of UWB Ground Penetrating Radar (GPR) and detecting the breast tumors more precisely than before. We point out the unsolved problems and propose improved algorithm and microwave imaging via Space-Time Beam forming (MIST) method.

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2. CONVENTIONAL STUDY

2.1 MIST beamforming method

Microwave Imaging via Space-Time Beamforming (MIST)[3] is application system of Kirchhoff migration[7] which is one of imaging methods of GPR. Kirchhoff migration method uses data of multiple receiving points and obtain the image of backscattered energy or amplitude as a function of scan location (**c**) by applying Delay and Sum (DAS) beamforming algorithm, which is a basic and well known method[8] [9].

Explain about DAS. In this situation, we think to process the signals of multiple receiving points which are obtained after undesired clutter signals removal. First, appropriate time-delays T_i for all received signals are computed. The time-delay T_i for a given transmitting and receiving antenna is calculated based on the antenna's position and position of scan location c=(x,y,z) , which uses an estimated average wave propagation speed. During the focusing, the scan location moves from one position to another within the breast, resulting in spatial beamforming. At each location, all time-shifted responses are coherently summed and integrated or obtained one amplitude of summed data which is estimated to show peak point of summed data when the reflector is existed at each location[4].

Explain about MIST for 2-dimension image. Fig. 1 shows the flow chart of MIST. MIST assumes multi antenna monostatic radar system, which is the multi antenna radar system whose transmitting and receiving antenna is the same. An analysis space is divided into multi pixels after measurement. Signal processing flow of MIST follows flow of DAS. The main different point is using FIR filters to equalize path length dependent dispersion and attenuation, because a living body is Frequency-dependent loss material. Being different from free space, waveform distortion happens when radio waves propagate through a living body because of dispersion and attenuation. Then, scattering energy of all pixels of analysis area is calculated using equalized data, and mapped. We can detect breast cancers to translate this map. We think the model which outputs the imaging result

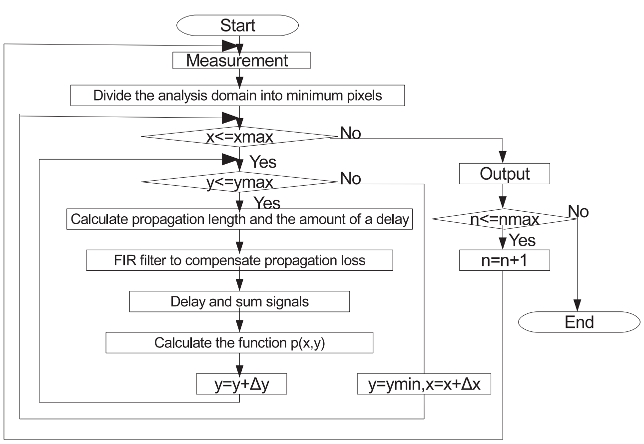

Figure 1: Flow of MIST beamforming method

every one transmitting antenna's measurement, so Fig. 1 is different from [3]. We assume that measurement data is accumulated.

2.2 Problems

We can point out two major problems of MIST beamforming method. First, this method is the algorithm to detect small cancers like 1 or 2 millimeter. So, this method isn't good for detecting a size of cancers like 5 or 10 millimeter and so on. Second, analysis by a professional person is needed to detect cancers. Some way to analysis may be able not to estimate a size and a position of a cancer correctly.

So, we propose the breast cancer detection algorithm which can detect a size and a position of a cancer automatically without analysis of an expert doctor. We show that out algorithm can also detect a cancer like 5 or 10 millimeter precisely.

3. PROPOSED SCHEME

3.1 System model

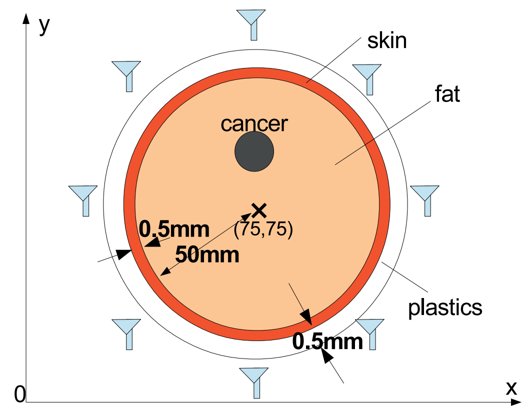

Figure 2: The system model

The system model is shown in Fig. 2. The analyzing space is divided into multiple pixels, and the coordinates is assigned. Antennas are set as array along the breast, and every antennas transmit signals by TDMA. When one antenna transmits the signal, only neighbor antenna that be at counterclockwise receives scattered signals. After each antenna transmits the signal, the received data is collected, and measurement result is updated.

Imaging of the interior of women's breast with radar which has multiple antennas, can detect cancers on their clothes, plastic cup or direct on the human's skin.

Two dimension breast model is assumed, and electromagnetic scattering is analyzed to measure cancer. Around the outside of breast, multiple antennas are positioned at even intervals. We analyze the electromagnetic scattering with FDTD method which does not consider frequency dispersion of the breast, get backscattered signals by the only cancer by subtracting received signals in the model that the cancer does not exist from them in the model that the cancer exists. By normalizing the amplitude of scatted signal, compensating propagation time, we can compare performance of conventional method and our method. In our system, the imaging of the interior of women's breast with radar which has multiple antenna, can detect cancers on their clothes or plastic cup that covers the breast.

3.2 Proposition of a breast cancer detection algorithm with approximate circle

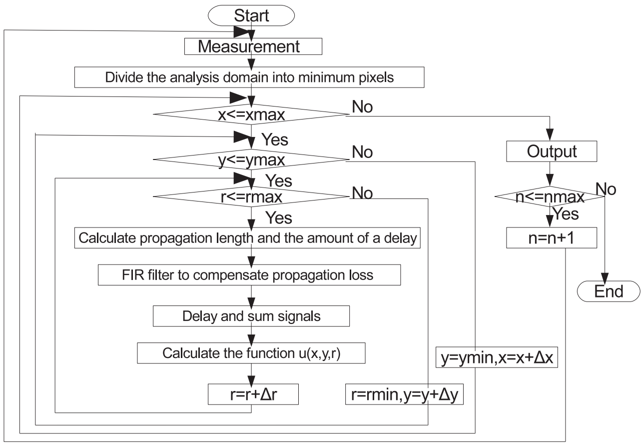

Figure 3: Flow of proposed method

The flow chart of out proposed method is shown in Fig.3ĄD Distinct differences between MIST and our method are next two points. First is how to define reflect points and amount of delays of received date. Second is how to output a result of detection.

3.2.1 How to define a reflect point

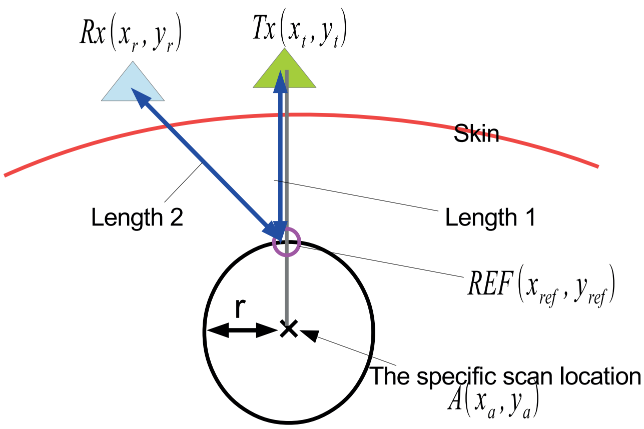

Figure 4: The reflect point

Fig.4 shows the simple figure explaining how to get a reflect point of our methodĄD MIST defines an scan location as a reflect point and decide amount of delays. However, our method defines the intersection point REF as a reflect point. REF is the point of intersection of the line between (x_t, y_t) and (x_a, y_a) with the circumference of a circle whose radius is r at (x_a, y_a). r denotes an assumption radius. When the transmitting antenna is Tx and the receiving antenna is Rx and an an specific scan location A is (x_a, y_a) at Fig.4 and an specific assumption radius is r, this microwave propagation length is defined as $Length$.

$$\begin{aligned} Length(x_a, y_a) &= Length1 + Length2 \\ &= \sqrt{(x_t - x_{ref})^2 + (y_t - y_{ref})^2} \\ &\quad + \sqrt{(x_r - x_{ref})^2 + (y_r - y_{ref})^2} \end{aligned} \quad (1)$$

Proposed method calculates propagation distance for each assumption radius and the scan location. Using the average propagation velocity when breast tissues is assumed as pure substance, proposed method calculates propagation time based on each assumption radius and the scan location.

3.2.2 How to get an image function

This method gets an image function in the same way as Kirchhoff migration method[7]. As mentioned earlier, all received data are summed after equalization of propagation. When a transmitted wave form is gaussian mono palse whose pulse width is τ_i and an scan location is (x,y) and an assumption radius is r, this method store one amplitude of summed data as image function $u(x, y, r)$. This method calculate all image function based on x,y,r.

3.2.3 Decision of a central point and a radius of a cancer

In this method, (x,y,r) which gives image function $u(x, y, r)$ maximum show a central point (x,y) and a radius r of a detected cancer. This algorithm searches that which radius (r) of tumor existing at (x,y) is nearest to the real cancer at breast from all received data. Our algorithm detects reflectors automatically, so there is enough possibility of substituting our method for experts' reading maps which show measurement results of conventional way. And, if we apply an non accurate circle like an ellipse as an additional foundation, we can detect an non accurate circle tumor more precisely. In this paper, the simulation results with only circle as foundations of detection is showed, but analysis of detection with ellipse as foundation is one of important future work for us.

4. COMPUTER SIMULATION

4.1 Simulation model and preconditions

Table 1 shows electric constants of the model. Table 2 shows other simulation parameters.

Table 1: Electric constants

medium	dielectric constant	conductivity[S/m]
fat	9	0.4
skin	36	4
tumor	50	7
plastics	3.6	0

Since the MIST beamforming method can't detect cancer's size and center point automatically, we shows the method to calculate the cancer's size and center point for MIST method. How to get a center point of a cancer (x_e, y_e) by the conventional method is below.

$$(x_e, y_e) = argmax(p(x, y)) \quad (2)$$

Table 2: Scatter analysis simulation parameters

electromagnetic scattering analysis	two dimension FDTD method
Cell size	0.5[mm] × 0.5[mm]
Analysis domain	300[cells] × 300[cells]
Time step	2.2[ps]
Number of time step	1200
Cancer	Circle with the radius of 2[mm],8[mm]
Boundary condition	1st pole Higdon
Transmitted pulse	Gaussian mono pulseĄ@
Pulse width	0.22[ns]
Main frequency domain	0-9[GHz]
Number of antennas	36

$p(x, y)$ denotes energy calculation results by the conventional method. We use a threshold a to get a cancer radius automatically by the conventional way. $p'(x, y)$ is normalized $p(x, y)$ by the max of $p(x, y)$.

$$p'(x, y) = \frac{p(x, y)}{p_{max}(x, y)} \quad (3)$$

$$a \leq p'(x, y) \leq a + 0.05 \quad (4)$$

Among (x, y) which satisfies above equation, we decided that a distance between an estimated center point and farthest (x,y) from an estimated center point is an estimated radius. As the index of assessments, we use an error between the estimated value and the true value.

4.2 Results

4.2.1 Conventional method

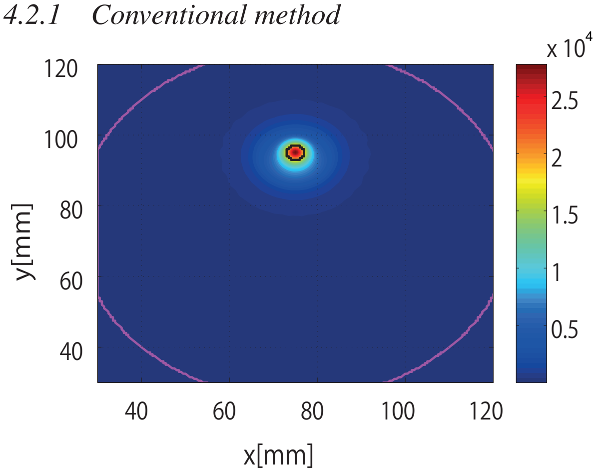

Figure 5: The imaging result(radius 2mm)

Fig. 5 and 6 show imaging results of one cancer by the conventional method. The center point of cancer is (75,95). The black real line shows cancer's existence boundary line. The pink line shows the existence of breast out skin. In Fig.5, the cancer radius is 2mm. In Fig.6, the cancer radius is 8mm. They show the energy function distribution of the analysis domain. Red pixels show strong reflect reaction, and blue pixels show weak one. In Fig.5, the cancer position is easy to read. But in Fig.6, we can't decide easily how big a cancer is and where cancer's center position is.

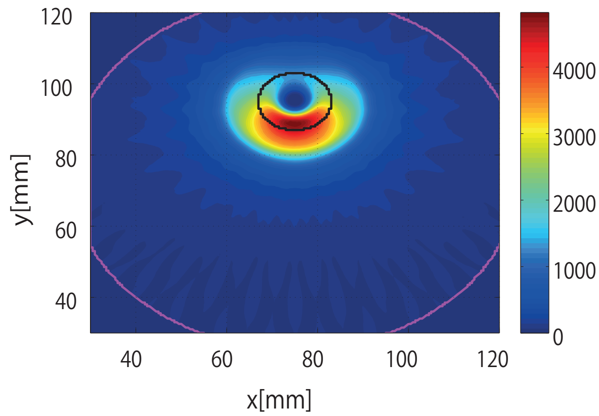

Figure 6: The imaging result(radius 8mm)

4.2.2 Proposed method

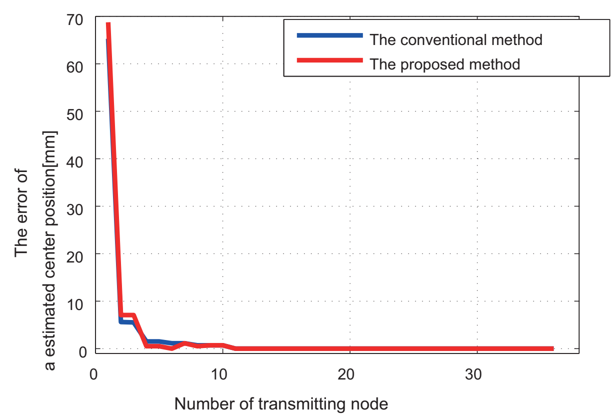

Figure 7: The accuracy of center position detection (radius 2mm)

Fig.7 and 8 are the comparison of the accuracy of center position detection. There is one tumor at (75,95). In Fig.7 and 8, the cancer's radii are 2mm and 8mm. The axis of abscissas is number of transmitting node, and used data is accumulated. Therefore, final imaging result which uses all data of 36 antennas is in the case that number of transmitting node equals 36. The axis of ordinates is the error of an estimated center position, and it shows a error distance between the real coordinates of the cancer and the estimated coordinates of the cancer.

From Fig.7 whose cancer radius is 2mm, when number of transmitting node increased, center position estimating precision in both methods also improved, because of increase of number of accumulated data. Convergence to the true value of the proposed method is almost same as the conventional method, and the estimated center position value of the pro-

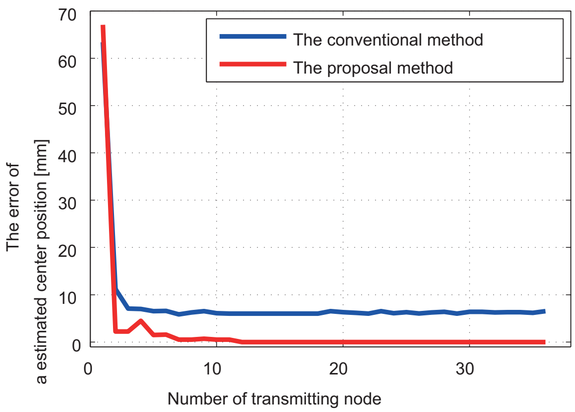

Figure 8: The accuracy of center position detection (radius 8mm)

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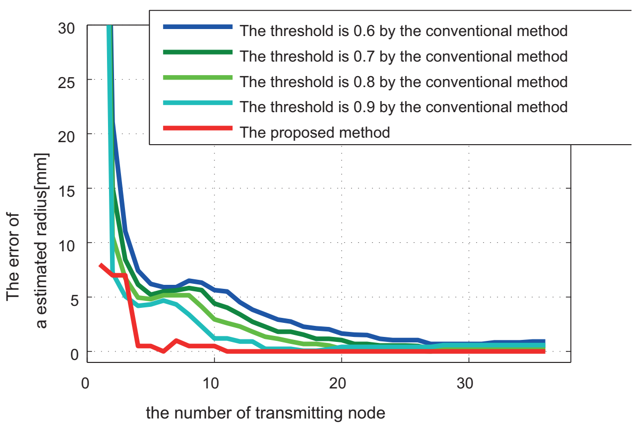

Figure 9: The accuracy of radius detection(radius 2mm)

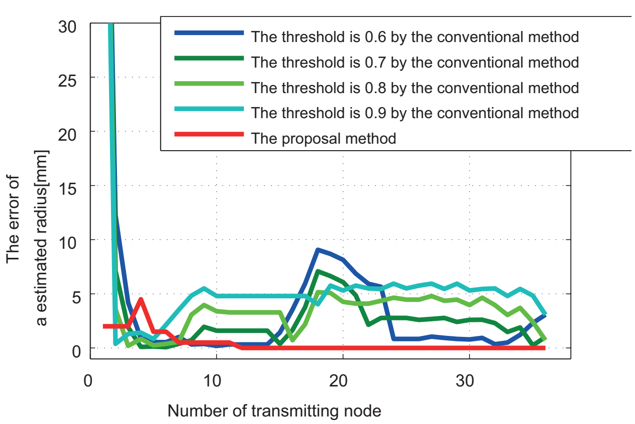

Figure 10: The accuracy of radius detection(radius 8mm)

posed method became the real value from when number of transmitting node is eight.

From Fig.8 whose cancer radius is 8mm, differ from Fig.7, the estimated center position with the conventional method didn't converge to the true value, because the conventional method is detection algorithm focusing on small cancers like 1mm. However, precise detection results were got by our proposal method. Our method improved one problem which the conventional method has.

Fig.9 and 10 are the comparison of the accuracy of radius detection. There is one tumor at (75,95). In Fig.9, the cancer's radius is 2mm. In Fig.10, the cancer's radius is 8mm. The axis of ordinates is the error of a estimated radius, and it shows a error between the real radius of the cancer and the estimated one.

From Fig.9 whose cancer radius is 2mm, when number of transmitting node increased, radius estimating precision also improved with both methods, because of increase of number of accumulated data. Convergence to the true value with the proposed method was the earliest , and finally, our method estimated the most precise value.

From Fig.10 whose radius is 8mm, radius estimating value with the conventional method is not stable. When number of transmitting node equal 18, estimating precision decreased, because no.1 antenna and no.18 antenna were used and these effect was bigger. In the result, energy distribution of conventional method became bigger. However, our method estimated the stable true value.

5. CONCLUSION

In this paper, we introduced MIST method for the conventional study of human breast imaging with UWB radar. We proposed the novel detection method of imaging using an assumption radius which can detect breast cancers automatically, and we showed the comparison of performance between our proposed method and the conventional method. We proposed that we use an ellipse as a base shape, showed that our method has the potential of scalability in the future.

We can give some future works. First, we don't discuss how to get scattered signals from cancers. There are some conventional study, for example [3]. It's one of ideas that we use adaptive filter to get rid of scattered signals from skin and breast wall, but it may be desirable to be able to get rid of them more precisely. Second, we should discuss theoretical analysis. Finally, we should discuss more improvements for breast cancers detection. For example, malignant cancers often have some features that their boundary are indistinct and their shape are indeterminate forms. We should analyze the effect of them.

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