解 説

Multi-static Inverse Wave Scattering Theory and Microwave Mammography

Kenjiro KIMURA* and Noriaki KIMURA†

1. Introduction

With the highest incidence occurring in women, breast cancer causes about 520,000 deaths worldwide [1] and about 14,000 deaths in Japan alone [2]. If discovered early, the 5-year survival rate is 93% [3]. Throughout the history of development of breast cancer screening technology, there is no doubt that X-ray mammography has survived as the most superior breast-cancer-screening technique in comparison to other techniques, including ultrasound, nuclear magnetic resonance imaging, and positron emission tomography. Unfortunately, despite advances in the field, X-ray mammography is still deficient when it comes to early and accurate detection of tumours, especially in cases where breast tissue densities are higher than average. This is because when collagen fibres are compact and highly concentrated, a condition known as "dense breasts," X-rays cannot produce the contrast of the breast tumor due to both the large X-ray absorption and its large fluctuation of the collagen density, thus smaller cancer tumours are not easily detected. Since dense breasts are found in about 79% of women under 50 in Asia (61% in Caucasians, 57% in Black, and 51% in Hispanic) [4], a new breast-cancer-imaging technique is desperately needed.

2. Electromagnetic Properties of Breast Cancer

Breasts are mostly fat tissues by volume; the aforementioned collagen fibres and mammary glands, which serve to generate and transport breast milk, are found in these fat tissues. Unfortunately, cancer tumours can infiltrate the abovementioned mammary glands, where they have easy access to the surrounding tissues and are well supplied with blood capillaries. Interestingly, when this is viewed in light of the theory of electromagnetic properties, most breasts largely comprise insulating macromolecules with low relative permittivity, whereas breast-cancer tumours have a high relative permittivity. If we consider such properties, it becomes clear that the microwave range, with relatively long wavelengths that do not absorb well at the molecular level, is ideal for visualizing breast cancer tumours.

However, microwave mammography cannot be achieved if one important problem is not first addressed: the issue of inverse wave scattering. The challenge of visualizing breast cancer tumours when breasts are irradiated with microwave, referred to as the "scatterer," lies in the fact the microwave are scattered in various directions by breast cancer tumours with high relative permittivity. In other words, if we could develop a mathematical theory and algorithm that visualizes the three-dimensional structures of a scatterer based on multi-static (multi-static) scattering data obtained on a curved surface such as the surface of a breast, the use of microwave mammography as a tool in early detection could be realized [5]. In our research, we have achieved to establish the world's first multi-static inverse scattering theory against the unresolved issue.

3. Four-dimensional Partial Difference Equation of Scattering Field

In this solution, it is assumed that the visualization target is a cone with a linear generatrix (Fig. 1); thus, antenna elements are linearly arranged. Let us consider the tangent plane of a cone, including its array antennas. On this tangent plane, we define the x axis on the reference plane, the axis of the antennas as the y axis, and the z axis is seen as being perpendicular to these two axes. Thus, the x axis rotates on the reference plane by θ degrees around the Z axis from the X axis. Assuming that the hypothetical tangent plane rotates and the scattering data obtained for all θ, we present the theory for reconstructing three-dimensional structures within a cone from multi-static time-series data on the cone's surface

If we define the multi-static coordinate y_1, y_2 on the y axis, a reconstruction theory can be established on the fact that data are only obtained at one point $(x=0, y_1, y_2)$ for the x coordinate along the tangent plane.

Below, we describe a method for obtaining the relevant differential operator. Let us think of a situation in which one-dimensional array antenna (Fig. 2) shifts to the x axis direction along the $x-y$ plane. As shown in Fig. 2, let us consider a situation wherein a microwave emitted from the point $P_1(x, y_1, z)$ is reflected at the point $P(\xi, \eta, \zeta)$ and received at the point $P_2(x, y_2, z)$. When Point P moves throughout Range

* Kobe University
† Integral Geometry Science. Inc
Key Words: microwave mammography, analytical solution, multi-static inverse scattering theory, dense breasts, relative permittivity.

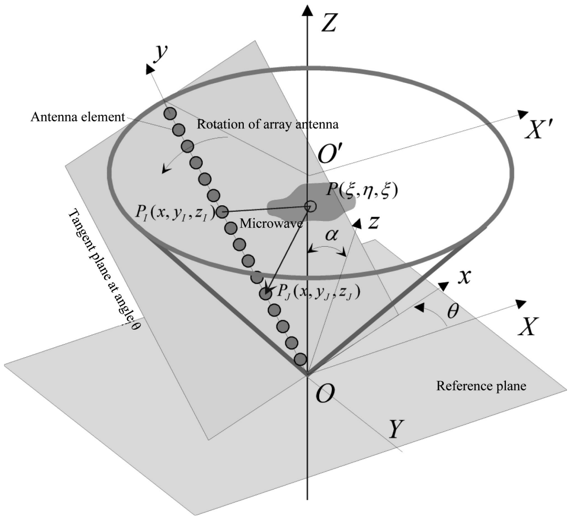


Fig. 1 Linear antenna array and a cone

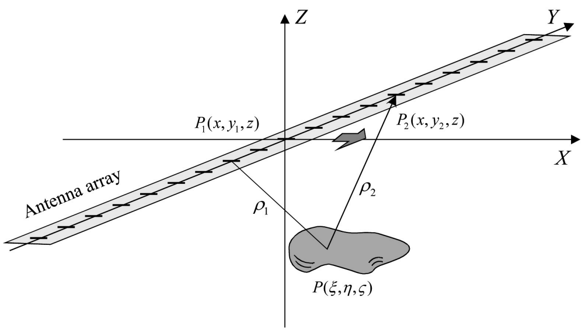


Fig. 2 One-dimensional array antenna

D, the signal received at P_2 can be expressed as follows:

$$\varphi(x,y_1,y_2,z)=\iint_D \frac{e^{ik\rho_1}}{\rho_1}\frac{e^{ik\rho_2}}{\rho_2}\varepsilon(\xi,\eta,\zeta)d\xi d\eta d\zeta$$
$$\rho_1=\sqrt{(x-\xi)^2+(y_1-\eta)^2+(z-\zeta)^2} \quad (1)$$
$$\rho_2=\sqrt{(x-\xi)^2+(y_2-\eta)^2+(z-\zeta)^2}$$

where k is the wave number of the microwave, and the factor of time is assumed to be relative to $\exp(-i\omega t)$. Let the kernel function in the integration term of the above Equation ϕ, then:

$$\phi=\frac{e^{ik\rho_1}}{\rho_1}\frac{e^{ik\rho_2}}{\rho_2} \quad (2)$$

Thus, a partial differential equation is obtained in which this equation or the differentiation and integration of this equation with respect to ξ,η,ζ gives an asymptotic solution. To that end, higher order terms for $1/\rho$ created by the differentiation should be ignored in the calculation; we then define the abbreviation for differentiation as

$$\frac{\partial}{\partial t}\to\partial_t,\frac{\partial}{\partial x}\to\partial_x,\frac{\partial}{\partial y_1}\to\partial_{y_1},\frac{\partial}{\partial y_2}\to\partial_{y_2},\frac{\partial}{\partial z}\to\partial_z \quad (3)$$

Then, we obtain the following equation about the kernel function ϕ:

$$\Big[\frac{1}{4}\{\varDelta_4-2(ik)^2\}^2-\partial_{y_1}{}^2\partial_{y_2}{}^2+ (ik)^2(\partial_{y_1}{}^2+\partial_{y_2}{}^2)-(ik)^4\Big]\phi=0 \quad (4)$$

Though this equation is derived under the assumption of steady state, it can be easily expanded to include an unsteady state by substituting a variable as seen below:

$$-ik\to\frac{1}{c}\partial_t \quad (5)$$

Where c is the speed of light. Ultimately, we obtain the following equation:

$$\{\varDelta_4{}^2-\frac{4}{c^2}(\partial_t{}^2\partial_x{}^2+\partial_t{}^2\partial_z{}^2)-4\partial_{y_1}^2\partial_{y_2}{}^2\}\phi=0$$
$$\varDelta_4=\partial_x{}^2+\partial_{y_1}{}^2+\partial_{y_2}{}^2+\partial_z{}^2 \quad (6)$$

By applying the derivative to the integral kernel, φ satisfies the above-described partial differential equation. This equation is a four-dimensional psuedo-wave equation consisting of five variables (t,x,y_1,y_2,z).

4. Analytical Solution and Three-dimensional Structure Image of Scatter

Let us now solve this equation using Fourier transform. First, we perform multiple Fourier transform of φ with respect to t,x,y_1,y_2

$$\tilde{\varphi}(k_x,k_{y_1},k_{y_2},z,\omega)=$$
$$\int_{-\infty}^{\infty}e^{i\omega t}dt\int_{-\infty}^{\infty}e^{ik_{y_1}y_1}dy_1\int_{-\infty}^{\infty}e^{ik_{y_2}y_2}dy_2\int_{-\infty}^{\infty}e^{ik_x}\varphi(x,y_1,y_2,z,t)dx \quad (7)$$

If we use D_z for the differentiation with respect to z, we obtain the following formula:

$$\{(D_z{}^2-k_x{}^2-k_{y_1}{}^2-k_{y_2}{}^2)^2+ 4k^2(D_z{}^2-k_x{}^2)-4k_{y_1}{}^2k_{y_2}{}^2\}\tilde{\varphi}=0 \quad (8)$$

where $\omega=c\ k$ is used, the four fundamental solutions for this equation are

$$E_1=e^{i\{\sqrt{(\sqrt{k^2-k_{y_1}{}^2}+\sqrt{k^2-k_{y_2}{}^2})^2-k_x{}^2}\}z}$$
$$E_2=e^{-i\{\sqrt{(\sqrt{k^2-k_{y_1}{}^2}+\sqrt{k^2-k_{y_2}{}^2})^2-k_x{}^2}\}z}$$
$$E_3=e^{i\{\sqrt{(\sqrt{k^2-k_{y_1}{}^2}-\sqrt{k^2-k_{y_2}{}^2})^2-k_x{}^2}\}z} \quad (9)$$
$$E_4=e^{-i\{\sqrt{(\sqrt{k^2-k_{y_1}{}^2}-\sqrt{k^2-k_{y_2}{}^2})^2-k_x{}^2}\}z}$$

Considering that the temporal factor is $e^{-i\omega t}$, phase is added by the microwave path and that the microwave reflected by an object bounces back to the measurement surface, we obtain E_1 as the only meaningful solution. Therefore,

$$\tilde{\varphi}(k_x,k_{y_1},k_{y_2},z,k) = a(k_x,k_{y_1},k_{y_2},k)e^{i\{\sqrt{(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2})^2-{k_x}^2}\}z} \tag{10}$$

By applying Fourier transform to the above equation, we obtain the solution φ for the wave Equation (6):

$$\varphi(x,y_1,y_2,z,k) = \frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y_2)}a(k_x,k_{y_1},k_{y_2},k) e^{i\{\sqrt{(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2})^2-{k_x}^2}\}z}dk_x dk_{y_1}dk_{y_2} \tag{11}$$

Let us now consider that measured data only exists for $x=0$; thus, the following equation stands:

$$\varphi(x,y_1,y_2,0,k) = \varphi_R(y_1,y_2,k)\delta(x) \tag{12}$$

If we apply this to the above equation with $z=0$, we then obtain

$$\varphi_R(y_1,y_2,k)\delta(x) = \frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y_2)} a(k_x,k_{y_1},k_{y_2},k)dk_x dk_{y_1}dk_{y_2} \tag{13}$$

Applying Fourier transform by (x,y_1,y_2) on both sides of the equation, we obtain the following:

$$a(k_x,k_{y_1},k_{y_2},k) = \tilde{\varphi}_R(k_{y_1},k_{y_2},k) \tag{14}$$

Thus, we obtain the solution $\varphi(x,y_1,y_2,z,k)$ of the partial differential equation. We can then take Trace with respect to y_1,y_2 of the function $\varphi(x,y_1,y_2,z,k)$, specifically, if the visual function is defined as $y_1 \to y, y_2 \to y$, where the term k,z is fixed:

$$\varphi(x,y,y,z,k) = \lim_{y_1\to y}[\varphi(x,y_1,y,z,k)]$$

$$= \lim_{y_1\to y}[\frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y)}a(k_x,k_{y_1},k_{y_2},k) e^{iz\left\{\sqrt{(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2})^2-{k_x}^2}\right\}}dk_x dk_{y_1}dk_{y_2}]$$

$$= \lim_{y_1\to y}[\frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y)}\tilde{\varphi}_R(k_{y_1},k_{y_2},k) e^{iz\left\{\sqrt{(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2})^2-{k_x}^2}\right\}}dk_x dk_{y_1}dk_{y_2}]$$

$$= \lim_{y_1\to y}[\frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y)}e^{ik_z z}\tilde{\varphi}_R(k_{y_1},k_{y_2},k)dk_x dk_{y_1}dk_{y_2}] \tag{15}$$

We can now convert the variables to integrate with respect to k:

$$k_z = \sqrt{\left(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2}\right)^2-{k_x}^2}$$

$$k = \frac{1}{2}\sqrt{{k_x}^2+{k_z}^2+\frac{({k_{y_1}}^2-{k_{y_2}}^2)^2}{{k_x}^2+{k_z}^2}+2({k_{y_1}}^2+{k_{y_2}}^2)}$$

$$\frac{dk}{dk_z} = \frac{k_z\sqrt{k^2-{k_{y_1}}^2}\sqrt{k^2-{k_{y_2}}^2}}{k({k_x}^2+{k_z}^2)} \tag{16}$$

Next, we perform Fourier transform on Equation (15) with respect to k, and apply $t=0$. Then, we obtain the visualization function $\rho(r,\theta)$ in the localized coordinate system at the angle θ in Equation (17). We describe θ dependency of $\tilde{\varphi}_R(k_{y_1},k_{y_2},k)$ positively as $\tilde{\varphi}_R(k_{y_1},k_{y_2},k,\theta)$

$$\rho(x,y,z,\theta) = \int_{-\infty}^{\infty}\varphi(x,y,y,z,k)dk$$

$$= \int_{-\infty}^{\infty}\lim_{y_1\to y}[\varphi(x,y_1,y,z,k)]dk$$

$$= \int_{-\infty}^{\infty}\lim_{y_1\to y}[\frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y)}a(k_x,k_{y_1},k_{y_2},k) e^{i\{\sqrt{(\sqrt{k^2-{k_{y_1}}^2}+\sqrt{k^2-{k_{y_2}}^2})^2-{k_x}^2}\}z}dk_x dk_{y_1}dk_{y_2}]dk$$

$$= \int_{-\infty}^{\infty}\lim_{y_1\to y}[\frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x+k_{y_1}y_1+k_{y_2}y)}e^{ik_z z}\tilde{\varphi}_R(k_{y_1},k_{y_2},k,\theta) \left(\frac{dk}{dk_z}\right)dk_x dk_{y_1}dk_{y_2}dk_z] \tag{17}$$

By integrating results for each θ, we obtain images of three-dimensional structures.

5. Conversion from Tangent Space to the Whole Coordinate

We then convert the results calculated in the tangent space to the whole coordinate (X, Y, Z). If we consider the projection of y axis on the (X, Y) plane as y', the following equations are established:

$$\begin{aligned} y &= y'\cos\alpha + Z\sin\alpha \\ z &= -y'\sin\alpha + Z\cos\alpha \end{aligned} \tag{18}$$

Where α is the angle between the coordinate axis z of the tangent plane and the Z axis of the reference plane. The equations converting from (x, y') to (X, Y) are

$$\begin{aligned} x &= X\cos\theta + Y\sin\theta \\ y' &= -X\sin\theta + Y\cos\theta \end{aligned} \tag{19}$$

Summarizing the above gives

$$\begin{aligned} x &= X\cos\theta + Y\sin\theta \\ y &= -X\cos\alpha\sin\theta + Y\cos\alpha\cos\theta + Z\sin\alpha \\ z &= X\sin\alpha\sin\theta - Y\sin\alpha\cos\theta + Z\cos\alpha \end{aligned} \tag{20}$$

We apply these conversion formulas to the following equation:

$$\rho(x,y,z,\theta) = \frac{1}{(2\pi)^3}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x + k_{y_1} y + k_{y_2} y)} e^{ik_z z}\tilde{\varphi}_R(k_{y_1}, k_{y_2}, k, \theta) \left(\frac{dk}{dk_z}\right) dk_x dk_{y_1} dk_{y_2} dk_z \tag{21}$$

We introduce the following variables:

$$\begin{aligned} k_{ye} &= k_{y_1} + k_{y_2} \\ k_{yo} &= k_{y_1} - k_{y_2} \end{aligned} \tag{22}$$

The above equation can be written as

$$\rho(x,y,z,\theta) = \frac{1}{2(2\pi)^3}\lim_{y_o\to 0}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i(k_x x + k_{ye} y + k_{yo} y_o - k_z z)}\tilde{\varphi}_R(k_{y_1}, k_{y_2}, k, \theta) \left(\frac{dk}{dk_z}\right) dk_x dk_{y_e} dk_{y_o} dk_z \tag{23}$$

We perform the following variable conversions in the spectral range:

$$\begin{aligned} \xi &= -k_x\cos\theta + (k_{ye}\cos\alpha + k_z\sin\alpha)\sin\theta \\ \eta &= -k_x\sin\theta - (k_{ye}\cos\alpha + k_z\sin\alpha)\cos\theta \\ \varsigma &= -k_{ye}\sin\alpha + k_z\cos\alpha \end{aligned} \tag{24}$$

This inverse transformation gives the following equations:

$$\begin{aligned} k_x &= -\xi\cos\theta - \eta\sin\theta \\ k_{ye} &= (\xi\sin\theta - \eta\cos\theta)\cos\alpha - \varsigma\sin\alpha \\ k_z &= (\xi\sin\theta - \eta\cos\theta)\sin\alpha + \varsigma\cos\alpha \end{aligned} \tag{25}$$

Then the reconstruction function for angle θ becomes

$$\rho(x,y,z,\theta) = \frac{1}{2(2\pi)^3}\lim_{y_o\to 0}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{i(\xi X + \eta Y + k_{yo} y_o + \varsigma Z)}\tilde{\varphi}_R(k_{y_1}, k_{y_2}, k, \theta) \left(\frac{dk}{dk_z}\right) dk_x dk_{y_e} dk_{y_o} dk_z$$

$$= \frac{1}{2(2\pi)^3}\lim_{y_o\to 0}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{i(\xi X + \eta Y + k_{yo} y_o + \varsigma Z)}\tilde{\varphi}_R(k_{y_1}, k_{y_2}, k, \theta) \left(\frac{dk}{dk_z}\right) d\xi d\eta dk_{y_o} d\varsigma$$

$$\frac{dk}{dk_z} = \frac{k_z\sqrt{k^2 - {k_{y_1}}^2}\sqrt{k^2 - {k_{y_2}}^2}}{k({k_x}^2 + {k_z}^2)}$$

$$k = \frac{1}{2}\sqrt{{k_x}^2 + {k_z}^2 + \frac{({k_{y_1}}^2 - {k_{y_2}}^2)^2}{{k_x}^2 + {k_z}^2} + 2({k_{y_1}}^2 + {k_{y_2}}^2)} \tag{26}$$

Since k_x, k_{y1}, k_{y2}, and kz are functions with respect to ξ, η, ς, and k_{yo} as in Equations (22) and (25), these can be converted by performing Fourier transform on data localized in the coordinate of angle θ on the whole coordinate. Finally, the reconstruction image is obtained by integrating with respect to the angle θ:

$$\mathrm{P}(X,Y,Z) = \int_0^{2\pi}\rho(x,y,z,\theta)d\theta$$

$$= \frac{1}{2(2\pi)^3}\lim_{y_o\to 0}\int_0^{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{i(\xi X + \eta Y + k_{yo} y_o + \varsigma Z)}\tilde{\varphi}_R(k_{y_1}, k_{y_2}, k, \theta) \left(\frac{dk}{dk_z}\right) d\xi d\eta dk_{y_o} d\varsigma d\theta \tag{27}$$

In this paper, we describe the multi-static inverse scattering theory that we have developed successfully as the core application for microwave mammography [5–7]. In clinical trials using a 1–14 GHz ultra-wideband microwave mammography system [6,7] with over 350 breast cancer patients and healthy individuals, according to the physics, high detection sensitivity was shown in dense breasts. Fig. 3 shows the demonstration our microwave mammography image. In the fu-

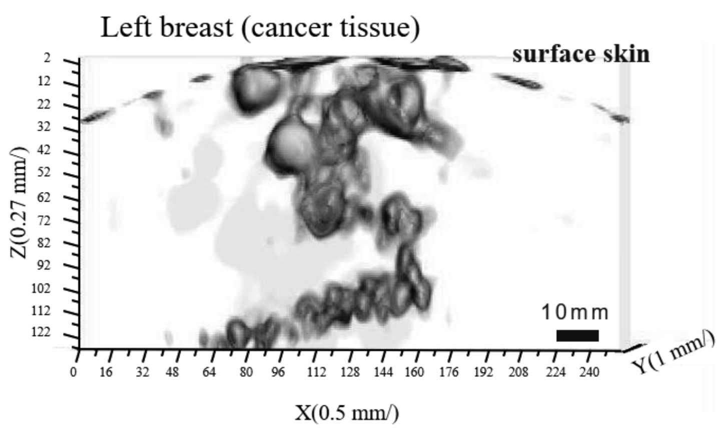


Fig. 3 Microwave mammography image[5]

ture, we hope that this system will become widespread, thus helping many breast-cancer patients.

(2019 年 5 月 30 日受付)

References

[1] World Health Organization(WHO): Global Cancer Statistics, International Agency for Research on Cancer (2012)

[2] National Cancer Center Japan: Cancer registration and statistics, Cancer information service.

[3] Joint investigation of survival rates of the National Cancer Center for Adult Diseases Association (2019)

[4] J. A. Tice, S. R. Cummings, R. S. Bindman, L. Ichikawa, W. E. Barlow and K. Kerlikowske: Using clinical factors and mammographic breast density to estimate breast cancer risk: Development and validation of a new predictive model; *Ann Intern Med*, Vol. 148, No. 5, pp. 337–347 (2008)

[5] K. Kimura and N. Kimura: Research and development of real-time microwave mammography; *ICT Innovation Forum 2016, Strategic Information and Communications R&D Promotion Programme (SCOPE)*, Makuhari Messe International Conference Center, pp. 26–27 (2016)

[6] K. Kimura, A. Inagaki, S. Kono, H. Tanino, T. Hashimoto, T. Sakuma, M. Miki, S. Takao, N. Watanabe, Y. Konishi, K. Okamoto, H. Matsumoto, K. Yamagami, Y. Mima, K. Doi and N. Kimura: Development of microwave scattered field tomographic imaging system and clinical trial results; *the 26th annual meeting of the Japanese Breast Cancer Society @ Kyoto International Conference Center*, p. 259 (2018)

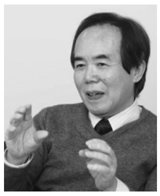
[7] K. Kimura, A. Inagaki, Y. Mima, K. Doi, N. Kimura, N. Yamamoto, T. Tsuruhara, N. Watanabe, Y. Konishi, K. Okamoto, Y. Sachiko, H. Matsumoto and K. Yamagami: Development of microwave scattering field tomography for next-generation breast cancer screening; *31th International Microprocesses and Nanotechnology Conference, Physics* T. J. S. o. A., Ed, The Japan Society of Applied Physics (2018)

Authors

Kenjiro Kimura

1978 年 11 月 28 日生．2006 年 3 月京都大学大学院工学研究科電子工学専攻博士課程修了（工学博士）．2008 年神戸大学大学院理学研究科化学専攻講師，2012 年同大学准教授，2018 年より同大学数理・データサイエンスセンター教授．場の逆解析理論と非破壊画像計測システムに関する研究に従事．世界で初めて応用数学史上の未解決問題である波動散乱逆問題の解析解の導出に成功．2017 年第一回日本医療研究開発大賞受賞，次世代乳がん検査技術としてマイクロ波マンモグラフィを開発．ほか，表面科学会，応用物理学会，分子科学会，全国発明コンテストなど受賞多数.

Noriaki Kimura



1946 年 12 月 16 日生．1981 年東京大学大学院工学研究科工学博士取得．2003 年より 2012 年まで三井造船株式会社技術本部，2008 年蛍光フローサイトメータ装置の技術開発に関し計測自動学会にて論文賞受賞，2007 年より大阪大学大学院工学研究科三井造船共同研究講座招聘教授，2012 年より合同会社 Integral Geometry Instruments（現，株式会社 Integral Geometry Science）代表社員，2015 年株式会社 Integral Geometry Science 代表取締役就任（現任），2016 年 5 月合同会社木村財団代表社員就任（現任）.