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x2 Scale Breast Phantom for Reproducing Human Breast Cancer Tissue

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1. Introduction

Breast cancer is a common form of cancer in both developing and developed countries and one of the main causes of death among women [1]. Early detection is necessary for a high chance of successful treatment and long-term survival. In recent years, breast cancer detection using radar-based technologies has been considered a promising diagnosis method.

However, experiments using radar-based technologies for early breast cancer detection could not be performed on a real human patient at the engineering departments where the electrical components including the antenna systems are mainly studied and investigated. Therefore, it is important to develop an alternative measurement method that is able to simulate a real human patient for the study of antenna-related components of radar-based technologies. Also, magnified scale models of the antennas undergoing testing are commonly used as alternative measurement solutions at laboratories. By using the scale-up model technique, the fabrication process of the phantom and delicate parts of the antenna system such as the feeding point could become less difficult, resulting in a higher accuracy of measurement results.

In this paper, the replication of the permittivity and conductivity of cancer and glandular tissues is studied using a scale-model phantom technique for the efficient assessment in the antenna system for radar-based cancer detection technologies.

2. Dielectric properties for scale model phantom

Scale models are commonly used during antenna measurements at laboratories for several purposes. The advantage of the scale-up model includes a magnified measurement set-up of the antenna, which in turn helps to facilitate the measurement process due to a lower measurement frequency. It also has a relatively easier fabrication process by which to duplicate the actual shape of each human tissue and the feed point area of antenna, resulting in higher accuracy for the measurements. Table 1 summaries the required relationship between the scale model and full-scale model for electrical parameters.

Table1 : Parameters for the scale model

Parameter	Full-Scale Model	k-Scale Model
Wavelength [m]	λ	$k\lambda$
Frequency [Hz]	f	f/k
Relative Permittivity	ε_r	ε_r
Conductivity [S/m]	σ	σ/k

3. Adjustment of electrical characteristics

The proposed breast phantom is composed of four type of tissue: 1) glandular, 2) fat, 3) cancer, and 4) skin tissues. The frequency characteristics of the electrical parameters for the four target tissues were determined by Cole-Cole-model fitting based on the measurements of electrical parameters of human tissues obtained by the actual removal of breast cancer samples in cancer surgery[2][3]. These frequency-dependent electrical parameters were then adapted to a x2 scale model phantom using Table 1. Among the four types of tissue, a x2 scale fat phantom and a x2 scale skin phantom have been reported in previous studies [4][5]. Therefore, a x2 scale glandular phantom and a x2 scale cancer phantom are studied in this paper.

3.1 Glandular phantom

Fabrication of glandular phantom involves five types of material: 1) water, 2) silicon emulsion, 3) glycerine, 4) sodium calcium, and 5) agar. The major materials for the glandular phantom are water and silicon emulsion. Glycerine was mainly used to control the slope of the frequency characteristics for relative permittivity. Sodium chloride was also used for the minor adjustment of both relative permittivity and conductivity. Lastly, agar was added to control the solidity of the phantom for experiments.

3.2 Cancer phantom

The fabrication of the cancer phantom used the same major materials as the glandular phantom, since both the glandular and cancer phantoms have similar frequency characteristics in dielectric parameters. However, the relative permittivity of cancer tissue is higher than that of glandular tissue, necessitating adjustments for the amount of glycerine, sodium chloride, and water to determine the final composition of the cancer phantom.

4. Composition and measurement results for the x2 scale model phantoms

Table 2 shows the final composition of the fabricated x2 scale phantoms for glandular and cancer tissues. The measurement frequency range was set from 1 to 6 GHz, which corresponds to the UWB frequency band for a x2 scale model phantom. As shown in figure 1 and 2, the measurement results for relative permittivity and conductivity for the x2 scale phantoms demonstrate that the tolerance range of 25-75 percentile has been achieved. Figure 3 shows the fabricated cancer phantom. Also, a cross-sectional view of the fabricated breast phantom is shown in fig 4.

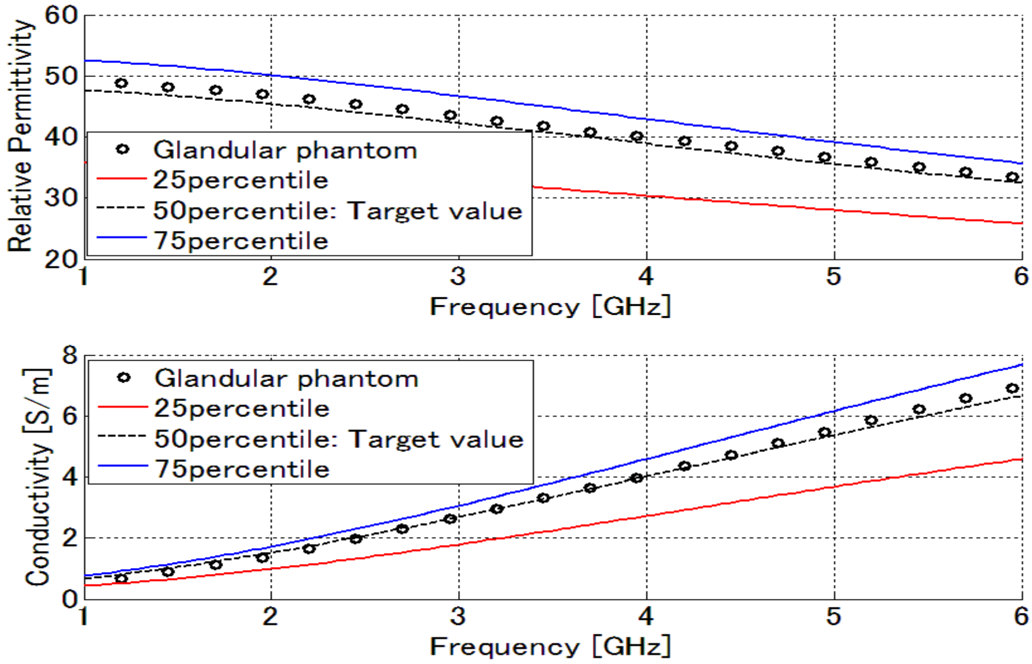

Figure 1: Dielectric properties of x2 scale glandular phantom
The measurement frequency for the x2 scale phantom was 1 to 6GHz.

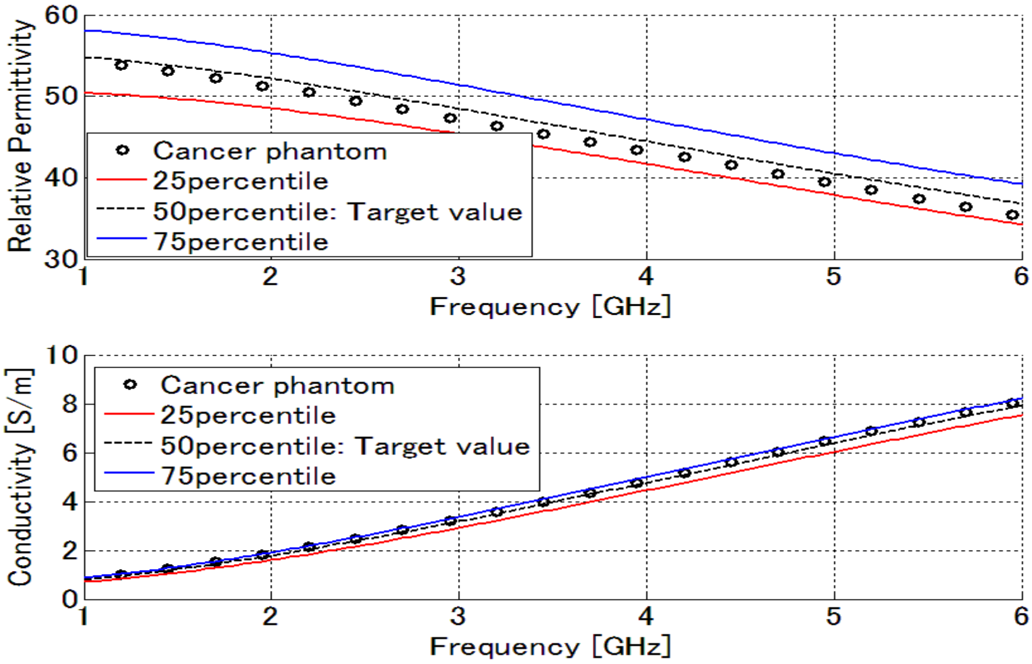

Figure 2: Dielectric properties of x2 scale cancer phantom
The measurement frequency for the x2 scale phantom was 1 to 6GHz.

Table2: Composition of x2 scale phantoms

Material	Cancer	Glandular
Water	250 g	125 g
Glycerine	150 g	100 g
Silicone Emulsion	150 g	150 g
Sodium Chloride	3 g	1 g
Agar	27.5 g	18.5 g

5. Conclusion

In this paper, a new composition for a x2 scale phantom stimulating both cancer and glandular tissues for the replication of the dielectric properties of real human tissue in the UWB frequency band was presented. Both phantoms consist of 5 materials; water and silicon emulsion as the main composition; glycerine to control the slope of relative permittivity; sodium calcium for minor adjustments of electrical properties; and agar to solidify the phantom. Finally, the fabricated cancer phantom and glandular phantom have a tolerance range of 25-75 percentile, meeting the requirement to be used for wide-band radar and electromagnetic experiments for medical applications.

Acknowledgments

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References

[1] Thoughts from The Mayor of Worldwide Breast Cancer Mapping the Journey of The Worldwide Breast Cancer Project, September 13, 2007.

[2] M. Lazebnik, L. McCartney, D. Popovic, C. B. Watkins, M. J. Lindstrom, J. Harter, S. Sewall, A. Magliocco, J. H. Booske, M. Okoniewski and S. C. Hagness,"A large-scale study of the ultrawideband microwave dielectric properties of normal breast tissue obtained from reduction surgeries,"Phys. Med. Biol., vol. 52, pp. 2637, 2007.
[3] M. Lazebnik, D. Popovic, L. McCartney, C. B. Watkins, M. J. Lindstrom, J. Harter, S. Sewall, T. Ogilvie, A. Magliocco, T. M. Breslin, W. Temple, D. Mew, J. H. Booske, M. Okoniewski and S. C. Hagness,"A large-scale study of the ultrawideband microwave dielectric properties of normal, benign, and malignant breast tissues obtained from cancer surgeries,"Phys. Med. Biol., vol. 52, pp. 6093, 2007.
[4] N. Sakane, M. Oguri, A. Hata, T. Maeda, "x2 scale model ultra-wideband phantom for Layered-Phantom Applications," IEICE Tech. Report, ABR2008-7, Feb. 2009.
[5] S. Ikei, T.Maeda, "x2 scale fat and bone of human equivalent phantom for UWB application," 2011 Trans. ISS student poster session, IEICE pp. 116, Mar. 2011.

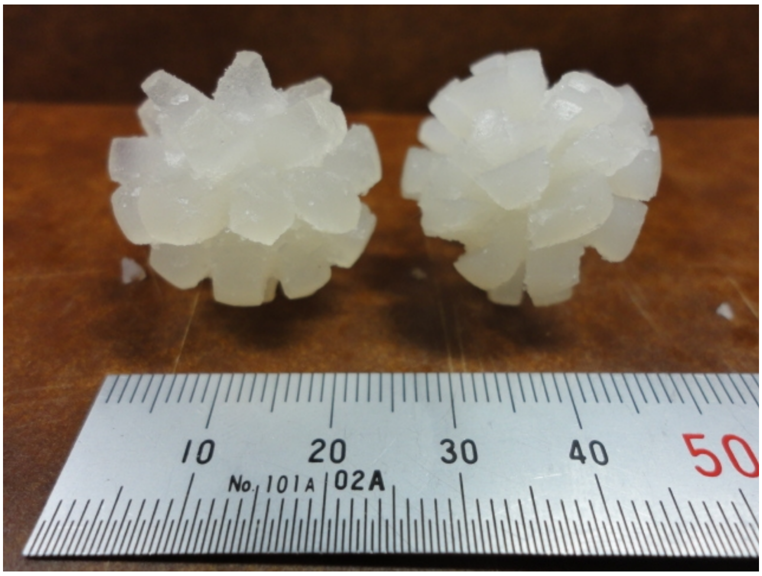

Figure 3: Cancer phantom

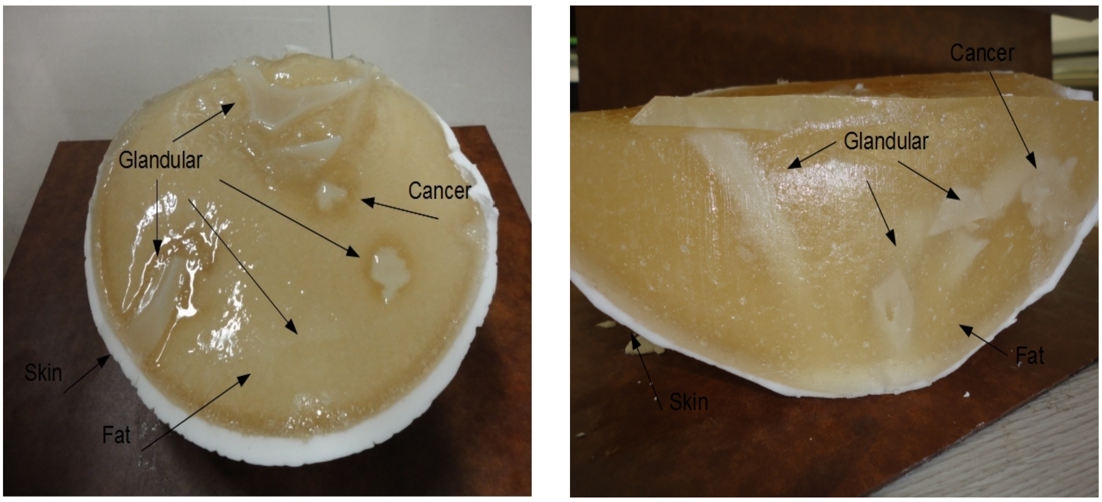

Figure 4: Cross-sectional view of breast phantom(a), (b)