EFFECTIVENESS OF MICROWAVE TECHNIQUE IN EARLY DETECTION OF BREAST ABNORMALITIES

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Abstract - In this paper, a breast phantom of CIRS Model 010A contains various known masses and sizes is studied. A measurement of S11 signals is taken at few locations on a breast surface using an open-ended coaxial probe. The obtained signals permit the extraction of the dielectric property of the masses. The result has shown that the smallest size detected through this probe is approximately 0.20 mm, small enough to be detected at early stage breast abnormality growth. This method undoubtedly recognizes the presence and location of possible abnormalities such as benign and malignant tissues. Although the model does not contain malignant tissues, this study demonstrates the viability of detecting small breast tumors using this approach.

Index Terms - Breast abnormalities, dielectric properties, microwave technique, open-ended coaxial probe.

I. INTRODUCTION

In 2012, International Agency for Research in Cancer (GLOBOCAN) reported that breast cancer ranks the leading cause of cancer death among women in Malaysia [1]. Early detection of abnormalities could be the warning to breast cancer and if it is the case, intervention of treatment could be done earlier, hence increasing the surviving rate of the breast cancer patients. Nowadays, X-ray mammogram is the most common modality used to detect early stage breast cancer. However, the sensitivity is poor for younger age and denser breast women [2]. A denser breast has more fibrous or glandular and less fatty tissues. This type of breast has been associated to a slightly higher risk of developing breast cancer partly because their tumor is harder to be spotted by mammogram. In mammogram, a tumor appears white like glandular and connective tissues, while dark region indicates fatty tissues [3]. Mammogram is the best used in woman above 40 years old since the density of the breast in most women reduced as they aged. Possible risk of mammography includes false positive, false negative and exposure to ionizing radiation. Several other modalities available are magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound. These diagnostic systems may have better sensitivity but they suffer from low specificity, hence it can potentially leads to redundant and expensive follow-up tests and treatments [4].

A development of a new accurate imaging technique is necessary to address these limitations and to improve both sensitivity and specificity during detection at early stage. Microwave imaging has emerged as one of the promising alternatives to complement mammography due to its significant contrast in dielectric properties between cancerous and healthy breast tissues [4, 5]. The main attractions of microwave technique are relatively low cost compared to MRI and CT-scan, low levels of power and the most important is non-ionizing radiation. Detailed knowledge in dielectric properties plays an important role in understanding interaction of electromagnetic radiation with biological tissues and provides substantial functional information about health. The dielectric properties such as permittivity, conductivity and specific absorption rate can be used to express characteristic of malignant and normal tissues. Cancerous tissue is highly vascular and has more water content that result elevated dielectric properties [5]. When the breast is exposed to microwave frequencies, the elevated moisture content of cancerous breast cause remarkably higher scattering compared to the normal tissues with low moisture content [6].

In this paper, the description of the breast phantom model and measurement procedure is explain in Section II, a brief theory of complex permittivity is given in Section III, whereas Section IV and V report the results of the study and conclusion, respectively.

II. DESCRIPTION OF EXPERIMENT

A. The CIRS Breast Phantom Model 010A

The breast phantom is a tissue-equivalent made of epoxy resin based polymer matrix and calcium carbonate ($CaCO_3$), formulated for performance of mammographic technique in the range of x-ray exposure between 24 to 34 kVp (check). It is manufactured by CIRS, USA. This model has dimension of 2.5 cm x 18.5 cm with thickness of 5 cm and contains of 30% glandular and 70% adipose. The phantom is implanted with various sizes of simulated micro calcifications (calcium carbonate) and glandular acting like tumor masses at different locations. The schematic drawing is depicted in Fig. 1Microcalcification simulate lesion normally found in breast tissue, develops when the cell is growing and

dividing. The area that has more active cells might indicate there is cancer. In most cases, breast calcifications are not linked to cancer. The specks of $CaCO_3$ are labeled from 2-13, contain various sizes ranging from as small as 0.13 mm to 0.40 mm. Label 14-18 comprise of 1.0 cm thickness wedges, composed from different ratios of glandular and adipose. Label 19-23 represents the nylon fiber of size 0.30 mm to 1.25 mm while hemispheric masses of 55% glandular and 45% adipose are labeled as 24-30, with the size of 1.19 mm to 4.76 mm. Details of the specification can be found in model user's guide [7].

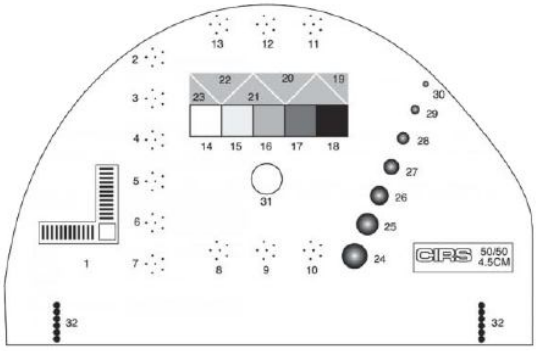

Fig. 1. A schematic drawing of CIRS breast phantom of model 010A [7].

B. Measurement of Dielectric Properties

Interaction of electromagnetic field with biological tissues can be well understood by characterizing their dielectric properties. Open-ended coaxial probes have been broadly used to measure the dielectric properties of biological tissues in radio and microwave frequency ranges. The dielectric properties of the breast phantom were experimentally characterized using a circular flanged open-ended probe Agilent 85070B. This probe is connected to a HP8720B vector network analyzer (VNA) with operating frequency between 1 GHz to 4 GHz at room temperature $\sim 23^{\circ}C$. Measurement was done by simply placing the probe in contact to the surface of breast phantom and the complex reflection coefficient was measured as function of frequency via VNA. The step is repeated at different locations, maintaining the pressure as persistent as possible. The measured data is then converted to a complex permittivity using analytical program associated with VNA. Calibration has been performed before experiment using standard procedure by measuring permittivity of air (open circuit), water (short circuit) and shorting block (load).

III. THEORY

A complex permittivity, e_c describes both dielectric properties and conductivity of material, given as

$$e_c = e - j\frac{s}{w} \qquad (1)$$

where $e = e_r e_0$ is the dielectric property of a material with e_r and e_0 are relative permittivity and permittivity in a free space, respectively, s is electric conductivity and w is the angular frequency. Equation (1) is often written in the form

$$e_c = e' - je'' \qquad (2)$$

which represents the real and imaginary components of the complex permittivity. Here, the real part is taken to be dielectric constant, $e' = e$ and the imaginary part indicates losses in the material $e'' = s / w$.

IV. RESULTS AND DISCUSSIONS

The S-parameter can be extracted using function in VNA. Due to one port terminal measurement, the transmitted signal and the received signal flow at the same port. This would also means the reflection coefficient at the aperture plane (end of the cable) is equal to S_{11}. The conversion of S_{11} to complex permittivity is performed using VNA software package. We have characterized dielectric properties for a CIRS breast phantom model 010A in various sizes for micro calcification specks and mixture of 55% glandular and 45% adipose as well as for different percentage of glandular composition in adipose. Results presented in this paper are taken at frequency of 2.4 GHz.

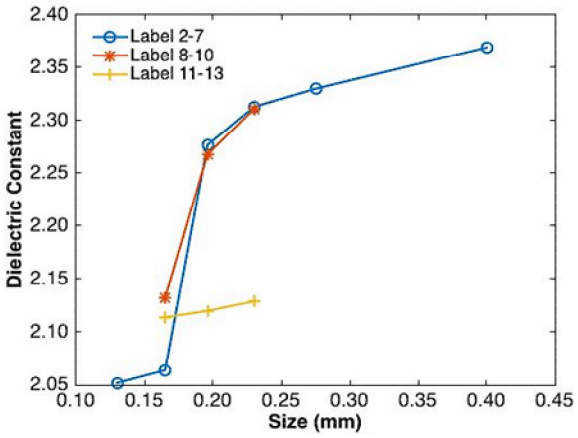

Fig. 2. Plots of measured dielectric constant of microcalcification ($CaCO_3$) operating at frequency of 2.4 GHz in in a function of sizes at different location.

There are two significance outcomes from the results. First, the current study indicates that the dielectric constant increases slightly on the size in both $CaCO_3$ specks and combination of 55% glandular and 45% adipose as depicted in Fig. 2 and Fig. 4, respectively. Bigger size contains more amount of water, hence escalating the value of permittivity due to high scattering factor. It is also interesting to see that the dielectric constant is different even though the $CaCO_3$ specks have the same size. We anticipate that the depth of specks of yellow line is more compared to

red line and blue that has about the same dielectric properties at the same size. The results also show that the dielectric constant increase with the percentage of glandular and there is significant increase at 50% glandular and above. High glandular is associated with denser breast, where it is strongly correlated with high percent of water content in the breast as measured by X-ray mammography and MRI [8, 9]. A high density of breast has been associated strongly with higher risk of breast cancer. We also found that the dielectric properties of 30% glandular and above have higher dielectric properties compared to microcalcification specks.

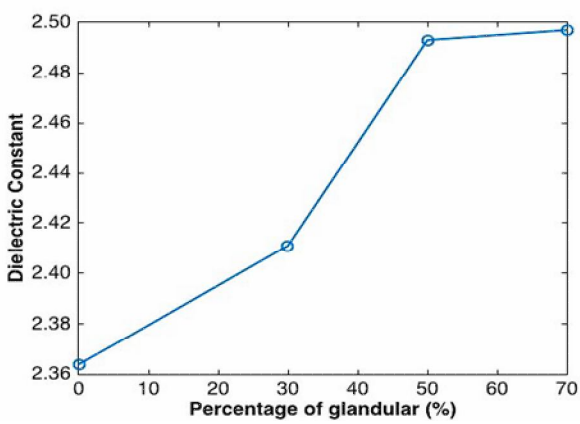

Fig. 3. Measured dielectric constant of 1.0 cm thickness step wedges contain various glandular and adipose compositions operating frequency at 2.4 GHz.

It is also shown in Fig. 2, a size as small as 0.2 mm microcalcification can be detected using the open-ended coaxial probe, which is significant to discover any abnormalities at early stage in the breast. The size of 2 cm and smaller is stage 1 disease in breast cancer, which has five years surviving rate.

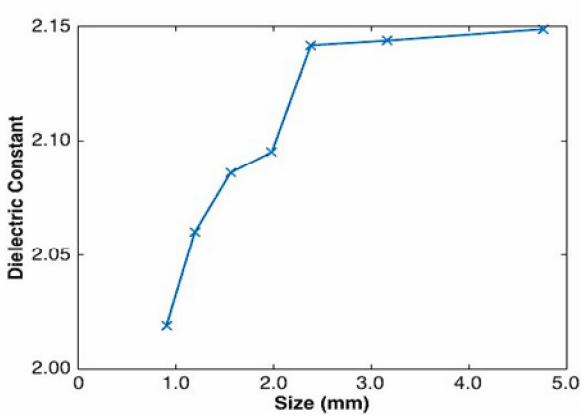

Fig. 4. Measured dielectric constant of hemispheric masses of 55% glandular and 45% adipose in various sizes operating at frequency of 2.4 GHz.

CONCLUSION

These findings suggest that in general the microwave technique using open-ended coaxial probe is effective to detect abnormalities in material, particularly in the breast. Even though the model used in the study does not contain cancerous tissue, this method is found to be reliable in the detection of abnormalities in the breast due to the contrast in dielectric properties between potentially cancerous and healthy tissues.

Further works need to be done to establish breast phantoms that impersonate compositions of adipose and glandular tissues with a presence of cancerous-like matter at various locations and testing the reliability of microwave technique in detecting location and size of the abnormalities.

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