Biocompatible Implanted Dielectric Sensors for Breast Cancer Detection

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ABSTRACT

This article describes the development of a method for a biocompatible sensor device for the intent of in-vivo breast tissue dielectric properties measurements. This article focuses on a specific type of sensor that utilizes an LC circuit with an inter-digital capacitor (IDC) with small size and high sensitivity for early stage breast cancer detection. To meet this objective an IDC was optimized in terms of contrast and miniaturized size via simulation techniques. For experimental testing, a scaled-up prototype inter-digital capacitor and spiral square inductor sensor was fabricated, and tested with known media, such as distilled water and glycerol. The results suggest that there is a need for further development, such as fabrication and testing for the biocompatible, miniaturized sensor for breast tissue application.

Keywords: Biocompatibility Sensor, Breast Cancer Detection, Breast Cancer Imaging, Breast Tissue, Conductivity, In-vivo Dielectric Properties Measurement, Microwave Imaging, Permittivity

1. INTRODUCTION

Breast cancer is the leading cause of cancer death among women worldwide. While the causes of breast cancer are fully not understood, research shows that the risk of developing the disease or dying from it can be minimized through screening. Standard screening includes a yearly mammogram and physical examination by a healthcare provider that for healthy women begins at the age of 40. Ultrasound imaging might be performed to distinguish between solid vs. a cystic mass. Magnetic Resonance Imaging (MRI) is sometimes recommended for women at increased breast cancer risk.

Recently, Microwave Imaging (MWI) has been investigated as a potential breast cancer imaging tool. Microwave images are maps of the electrical property distributions of objects. In a microwave tomography system, microwaves are transmitted and the scattered waves are received. Then, an inverse problem is solved by optimizing (minimizing) the error between measured and estimated scattered fields. Microwave imaging holds great potential. It is non-invasive, simple to perform, cost effective, and causes minimal discomfort. Unlike ionizing radiation, which is

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used in mammography, non-ionizing radiation used in microwave imaging does not damage DNA. Zastrow et al. (2004) investigated the absorption of short microwave pulses in an effort to formally evaluate the safety of microwave breast cancer detection technology. They found that a typical microwave imaging system poses no health risk to the patient. Microwave imaging uses microwave signals to illuminate the breast, and the scattered fields produced are measured at different locations around the breast using a small antenna (Sabouni & Noghanian, 2013).

MWI is commonly used in the frequency range from 1 GHz to 10 GHz due to better penetration depth and resolution (Noghanian, Sabouni, Desell, & Ashari, 2014). MWI is based on two parameters such as, permittivity and conductivity. The dielectric properties, permittivity and conductivity, refers to the ability for an electric field to penetrate a medium, and the speed of electrons from the electric field in the medium, respectively. Low water content tissues such as skin and fat have permittivity values that are estimated to be less than half those of high-water-content tissues such as blood and cancerous tissues. Particularly, in biomedical application of MWI, dielectric properties are of interest due to the differences between normal and malignant tissues (Chaudhary et al., 1984, Joines, 1999).

MWI is a promising technique for imaging normal and cancerous breast tissue, but it is not yet employed in a clinical setting. This is due to the lack of information about in vivo dielectric properties of breast tissues. Dielectric properties have been reported using ex vivo techniques (S. Gabriel, Lau, & C. Gabriel, 1996, Sabouni, Hahn, Noghanian, Sauter, & Weiland, 2013). There are several commercially available methods for ex vivo dielectric properties measurements such as the open-ended coaxial probe, free space probe, and parallel plate probe (Meaney, Fanning, Li, Poplack, & Paulsen, 2000, Kadaba, 1984, Smith, & Foster, 1985). The problem with ex vivo dielectric properties of breast tissue is that when the tissue is excised, the dielectric properties change immediately after excision (Sabouni, Hahn, Noghanian, Sauter, & Weiland, 2013). Therefore, there is a need for the development of a biocompatible sensor device to measure in vivo dielectric properties of breast tissue to be used in MWI techniques. There have been some limited studies on the in vivo dielectric properties of different human and animal tissues (Cho et al., 2006, Peyman, Holden, Watts, Perrott, & Gabriel, 2007, Halter et al., 2009). The technique that is mostly used in these studies is open-ended coaxial probe. These types of probe should be placed on/inside the tissue during a surgery and has to be removed after that. Therefore, for each measurement a surgery is needed. In this paper, we have introduced a sensor capable of measuring the in vivo dielectric properties of breast tissues. The proposed biocompatible sensor may also have potential to be used as a passive method for breast cancer detection at early stage.

2. METHODOLOGY

In this paper we have developed a novel biocompatible sensor to be implanted in the animals, to obtain sequential measurements of the dielectric properties of tissue. This biocompatible sensor consists of three parts: rectenna for energy harvesting (Motjolopane & Van, 2009), capacitive sensor for measuring the dielectric properties of tissue, and miniature antenna for transmitting and receiving signals (Chow et al., 2011) (Figure 1). In this paper we will present the design, development, and measurement results of the capacitive sensor.
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