Comparative Study of MIST & TSAR Techniques for Breast Cancer Detection at an Early Stage

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***Abstract*—Microwave Radar imaging is one promising technique used in place of X-ray and MRI for detection of breast cancer. The Ultra-Wideband (UWB) pulses are used to detect the tumor in the breast from the backscattered signals, which are transmitted sequentially from the array of antenna. The UWB Microwave imaging (MWI) is applied for detection of small malignant tumors inside the breast due to its high resolution and capability of detection and classification. The UWB imaging exploits the significant contrast in dielectric properties between malignant tumors and normal fatty tissues. The MIST (Microwave imaging via space-time beam-forming) and TSAR (Tissue sensing adaptive radar) are different Radar approaches for cancer detection. These are based on the different antenna setup at the transmitter and receiver side of the breast, called monostatic, bistatic and multistatic.**

***Keywords*—Breast cancer detection, microwave imaging, multistatic, ultrawide-band(UWB) radar,backscattered signals**

I. Introduction

Breast cancer is the most common cancer among the women and it can cause death of the patient. The breast cancer must be diagnosed at the early stage to save the patient. Mammography is the method used to diagnose the breast cancer, X-ray imaging of the breast. This technique has been satisfied to be relatively sensitive to the presence of lesions in the breast. Though, this diagnose technique may lead to painful breast compression and unhealthy exposure to ionizing radiation may prevent patients from early-stage assessment, which is the best and valuable phase for medical behavior. Approximately 15% of all breast cancers are missed by conventional mammography while 75% of identified breast lesions turn out to be benign [1]. These concerns provoke motivation for engineers to introduce new breast imaging techniques [2]. Microwave imaging technique provide no. of advantages over X-ray imaging, it can be nonionizing, reduce unnecessary breast compression, less invasive than x-rays, and is low cost. The physical basis for microwave detection is the significant contrast in dielectric properties between normal tissue and cancerous tissue [3]. The dielectric contrast between normal and malignant tissues ensures that any tumor present in the breast tissue will provide backscattered energy that may be used to detect of the presence of the tumor when illuminated by microwave radiation.

The studies carried out by Hagness et al. initiated the recent high level of research activity in microwave imaging of breast cancer [19]. The active microwave imaging techniques have been proved as corresponding modalities to X-ray Mammography. The basic theory of microwave imaging is the significant dielectric-properties contrast between malignant tumors and normal breast tissue at microwave frequencies [4]–[5]. Recently, Lazebnik et al. and Zastrow et al. performed essential studies in the ultra wideband microwave dielectric properties of normal, benign and malignant breast tissues [20, 21]. This technique can be divided into two general categories: microwave tomography and ultra wideband (UWB) radar techniques. The tomography image reconstruction technique is used to illuminate the breast with microwaves and then measuring transmitted or reflected microwave signals, to quantitative compute the spatial distributions of the dielectric constant and/or conductivity [6]. The UWB approach is current approach, where UWB pulses are transmitted from antennas at different places near/on the surface of the breast and backscattered signals are recorded to form an image.

The Ultra-wideband is proved very significant alternative to mammography. It is safe, simple and more comfortable for patients. The UWB microwave imaging technique relies on two fundamental properties. Firstly, dielectric properties of malignant tumor is higher as they have higher water content in compare to normal breast tissues, which have relatively lower water content. Thus, strong scattering takes place at the boundary between normal tissue and lesions. Secondly, microwave attenuation in normal breast tissue is less than 4 dB/cm up to 10 GHz [2]. Thus in this frequency band microwave devices provide high sensitivity and by selecting appropriate bandwidth, it can give better resolution.

II. Different Configurations For Transmitting & Receiving Antenna

In this paper we have discussed only two RADAR techniques mainly, which are Synthetic Aperture Radar (SAR) based techniques such as Tissue Sensing Adaptive Radar (TSAR) [8, 9] and Microwave Imaging via Space Time Beam forming (MIST) [10, 11] are proposed. At a time of simulation of both the systems for improved matching, breast and antenna model are immersed in a substance similar to breast tissue [12]. The ability of these systems to detect tumors relies on the increased backscatter caused by malignant tissue. The ability of these systems to detect tumors relies on the increased backscatter caused by malignant tissue [13]. The UWB radar technique is also defined as time domain techniques. These techniques radiate low power pulses, which are received at different positions with a probe antenna or by group of antennas. The time delay between radiated and received pulses is used to measure the scattered signal and collect the information [18]. As same in frequency domain system, there are three different approaches in time domain system monostatic, bistatic and multistate in ultra-wideband (UWB) radar imaging technique, each defined by how the backscattered energy is acquired.

In the monostatic method, there is only one antenna used as transmitter to generate the ultra-wideband pulses and record the backscattered signal itself. Often the transmitting antenna is moved across the breast to produce a synthetic aperture. In the bistatic case, two antennas are used, a single transmitting antenna and a single receiving antenna. At last, in the multistatic configuration, the tissue is illuminated by one transmitting antenna while the backscattered signals are recorded at several antennas placed at different positions around the breast [7]. In the multistatic approach, a real aperture array (see Fig. 1) is used for data collection. In compare to monostatic and bistatic configuration, the multistatic approach is proved better.

As described by Xie et al. [14], the multistatic approach can produce improved imaging results when the actual aperture used in the multistatic system is close to synthetic aperture used in the monostatic case. A multistatic imaging system has been developed by Craddock et al. [15, 16], while several other multistatic imaging algorithms have

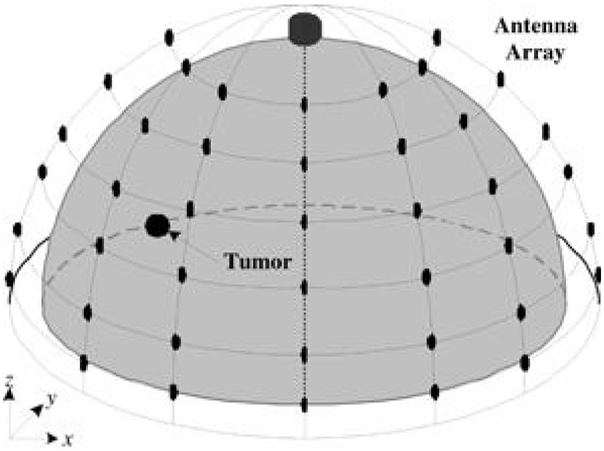

Fig. 1. Antenna array configuration (for Multistatic system) [6].

been developed and demonstrated, including a simple Delay and Sum (DAS) [17] and a Robust Capon Beam forming (RCB)-based adaptive method. The multistatic approach acquires additional information about the tumor using received signals that transmit via different paths [7]. The ultra wide band radar techniques have different advantages which occupy a simple approach, it locate strong scattering in the breast area thus avoiding the full wave electromagnetic analysis [18].

III. MIST (Microwave Imaging via Space Time Beam Forming) Technique

In recent times a method proposed called microwave imaging via space-time (MIST) beamforming for breast cancer detection [22]. The MIST technique uses the multistatic configuration for transmitting and receiving the backscattered signals for imaging. The reason of better imaging is that the multistatic approach exploits multiple received signals that transmit using different routes, accruing more information about the tumor. It is assume that space-time beamformer transmit consecutively a low power ultra wideband (UWB) signal into the breast with the help of each antenna in an array and records the backscatter signals. The beamformer then spatially focuses the backscatter signals to differentiate against clutter generate by the heterogeneity of normal breast tissue [1].

In contrast to narrowband tomography [23]–[24], the MIST beamforming technique provide the advantage of identifying the presence and location of malignant breast tumors by imaging backscatter signal energy as a function of location, instead of reconstructing the dielectric-properties profile of the breast. Therefore, by using the strong signal processing techniques, it is not necessary to solve the nonlinear inverse scattering problem.

The MIST technique follows the procedure of scanning the patient, which lies in supine position. The no. of transmitting antenna array or one is situated on the flattened breast surface, and scanned to multiple locations. Special liquid has been used to approximate the dielectric properties of the medium to those of the object [1]. In this technique first, the space-time beamformer time-shifts the returns to arrange in a line the signals from an exact point in space. A finite-impulse response (FIR) filter is use to pass the time-aligned signals and summed to create the beamformer output. Then the output is time gated and energy is calculated. A display of energy as a function of location provides an image of backscattered signal strength. Locations of high energy indicate the presence of significant scatterers, i.e. malignant lesions [22].The beamformer is considered to compensate for the attenuation and frequency-dependent transmission effects encountered as the signal propagates to and from the point of

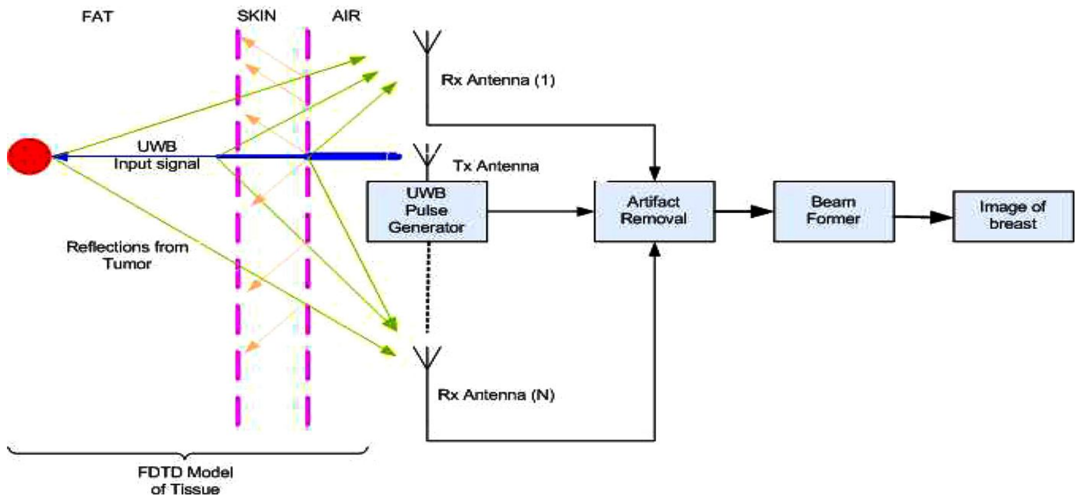

Fig. 1. Block diagram of overall system [7].

interest [7].The beamformer scan to all location of interest and formed an image, which present the produced energy distribution. The MIST beamformer has been revealed as an effective technique and it can detect small tumors (2 mm). It is compulsory to transform the monostatic artifact removal algorithm, in addition to the MIST adaptive beamforming algorithm itself. A block diagram of the overall system is shown in Fig. 2.

IV. Tissue Sensing Adaptive Radar (TSAR) Technique

Fear and Sill developed Tissue Sensing Adaptive Radar as an alternative of MIST technique [1]. However both the systems are similar, but there are some fundamental differences between the two. In the TSAR system, the patient lies in prone position, the breast falls through a hole in the examination table, and antennas are scanned around the breast [26]. Moreover, the TSAR system uses less complicated clutter reduction methods than MIST, which uses advanced clutter reduction algorithms to create an image. In TSAR system, simple time shifting and adding algorithm were used to reconstruct images. The TSAR approach also used monostatic setup. A single antenna is used to scan the breast in the desired region. The recorded scattered signals process to increase reflections from the breast tissue/tumor edge [27].

The TSAR algorithm uses simple clutter reduction methods; though, tumors of 4 mm have been detected in a three-dimensional (3-D) cylindrical breast model [28]. In a reasonable system, practical issues such as antenna manufacture, the electrical properties of breast tissues, and breast shape must be considered. The first experimental system for testing radar-based breast cancer detection was presented in [29].

The TSAR algorithm has a number of different stages: skin sensing, skin subtraction, tumor detection, and show an image. The reflection from the skin is on the order of 50 dB greater than reflections received from tissue interfaces inside the breast [30] and must be reduced to permit tumor detection. As a result, skin sensing and reduction of the skin reflection are key components of the TSAR algorithm [27]. The purpose of this technique, is similar as other radar-based imaging, classify sources of backscattered energy arising from the dielectric property differences between the various breast tissues. The scattered fields (or reflections) are received at the same antenna. The antenna is consecutively moved around the breast in a 3D pattern in order to collect reflections at multiple locations.

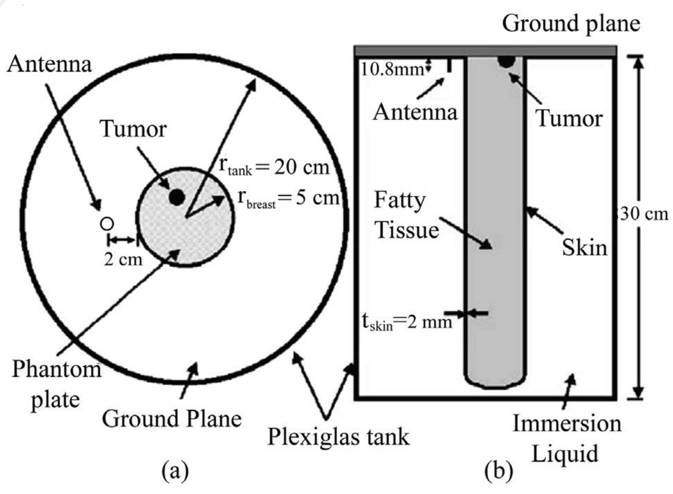

Fig 2. Test setup with a monopole antenna, immersion liquid, and breast phantom. (a) Top-down view. (b) Side view [26].

Early and late-time contributions are supported by scattered fields received at each antenna. Effective suppression of the clutter is required in order to successfully detect and localize tumors; clutter is defined as signals arising from scattering mechanisms other than the tumor [31]. This algorithm is defined as: First, tissue sensing carried out to locate the breast in the tank; secondly, the skin reflections were estimated and subtracted, signals without skin reflections were formed into an image. The results of this technique showed the ability for detecting image, for detecting and localizing tumors of greater than 4 mm diameter [32]. The skin-sensing step involves estimating skin thickness and location relative to the antenna position. Data indicated that skin location was estimated with an error of 4.55% or less. However, error in thickness estimates may exceed 160% for a 1-mm skin layer [27].

V. CONCLUSION

The RADAR techniques are used to detect and localized the malignant tumor in the breast, by transmitting sequentially ultra-wideband pulses using one antenna or an array of antenna and received the reflected signals using different setup of antennas. There are three types of setup used for receiving backscattered signals; monostatic, bistatic and multistatic. The multistatic configuration provide more information about cancerous tumor, hence this setup is used in some techniques. The beamformer approaches are used to focus the tumor at an early stage and these are capable of detecting the millimeter-sized tumor inside the breast.

In this paper the MIST (Microwave Imaging via Space Time Beam Forming) and TSAR (Tissue Sensing Adaptive Radar) techniques are given and compare at different levels, for example the MIST used all three types of configuration for antenna and currently it is using multistatic while TSAR uses only monostatic setup. The MIST techniques can detect tumor of 2 mm size, while TSAR approach detect only the tumor of 4 mm size or greater then this size. Therefore, the MIST technique proved better then TSAR technique in terms of detecting the tumor at an early stage and it uses multi-MIST beamformer which will provide spatial diversity at the transmitter and receiver, provides multiple reflections from tumors that transmit from different paths.

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