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Compressive sensing for Radar imaging via DAS Beam forming Method

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ABSTRACT
The signals in the microwave breast cancer imaging are ultra-wideband. Because of this, according to the nyquist theorem, the sampling rate of the signal is very high. In this paper a novel radar-based microwave breast cancer imaging method using compressive sensing (CS) is proposed. In this method, the received signals are sampled with a rate less than the nyquist rate, then using compressive sensing; we reconstruct the original signals and perform the delay-and-sum (DAS) beamforming for breast cancer imaging. Comparing the results of the proposed method with the results of the previous delay-and-sum beamforming method, we conclude that using our method we can detect the tumor place with lower samples than the nyquist rate.
Keywords: *Microwave imaging, ultra-wideband (UWB) radar, delay-and-sum beamforming, breast cancer, compressive sensing.*

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INTRODUCTION

UWB microwave imaging has been proposed as a method for early stage detection of breast cancer. There are two methods for UWB microwave breast cancer imaging, namely tomography and radar imaging [1]. In tomography, maps of the electrical properties of the tissues are formed to create an image of the breast, but in radar imaging methods, images of the presence and location of strongly scattering objects are created. DAS beam forming is a radar imaging method which is used for microwave breast cancer imaging [2]. On the other hand, the sampling rate of the signals used in this method is very high because these signals are UWB. In many applications of UWB radar systems the A/D conversion technology is a limiting factor because the desired performance is either too expensive or beyond what is technologically possible [3].

In this paper, we propose a new method for microwave breast cancer radar imaging based on compressive sensing in which the number of samples of the signals are less than the nyquist criterion. In this method, random signal sampling plays a significant role.

The remainder of this paper is organized as follows. First of all, DAS beam forming is described. In the next section, compressive sensing method is introduced. Our proposed method and results are described in the next sections. Finally, conclusions are stated at the end of the paper.

DAS BEAMFORMING

In this paper, a multistate radar is used for imaging, meaning that we have an antenna array with N elements. Each antenna in this array transmits the signal and each of the other antennas receive that signal.

In the first step, we should calibrate the received signals so as to reduce the mutual couplings between the antennas and the reflection from the skin-breast interface as much as possible [2]. In this paper we calibrate the signals by subtracting the responses of the breast with and without the tumor.

Next, the recorded signals are synthetically focused at any point of interest in the breast by time-aligning the signals $y_i(t)$, using the estimated delay T_i from the transmitter antenna A to the receiver antenna B via the point of interest C. Since interchanging transmit and receive antennas would not produce any additional information and monostatic operation is excluded, total number of transmissions recorded is $N(N-1)/2$. The return from the point C is then computed as

$$V = \int_0^{\tau} \left(\sum_{i=1}^{\frac{N(N-1)}{2}} w_i y_i(t - T_i)\right)^2 dt \qquad (1)$$

where w_i are compensation factors that are applied for compensating the differences in the attenuation between the round-trip paths from A to B through the point C. In this paper, all of the compensation factors are equal to one.

COMPRESSIVE SENSING

Consider a one-dimensional discrete-time signal *x* of length *N*. If there exists a sparsity basis $\{\psi_i\}$ that provides a *K*-sparse representation of *x*, then the signal *x* is *sparsely representable*; That is

$$x = \sum_{i=1}^{N} \theta_i \psi_i = \sum_{i=1}^{K} \theta(i_l) \psi_{i_l} \qquad (2)$$

where $\{\theta_i\}$ are the weighting coefficients, *x* is a linear combination of *K* basis vectors chosen from $\{\psi_i\}$, and $\{i_l\}$ are the indices of those vectors. We can write the equation (2) in matrix notation as

$$x = \Psi\theta, \qquad (3)$$

where $\Psi = [\psi_1 | \dots | \psi_N]$, is an $N \times N$ sparsity basis matrix called a dictionary, and θ is an $N \times 1$ column vector with *K* nonzero elements.

In compressive sensing, we measure $M < N$ linear projections of *x* as

$$y = \Phi x, \qquad (4)$$

where y is an $M \times 1$ vector contains the measurements and Φ is an $M \times N$ measurement matrix.

Compressive sensing, states that as long as the dictionary Ψ is incoherent with the measurement matrix Φ, then it is possible to recover the *K* largest from a similarly sized set of $M = O(K \log (N/K))$ measurements *y*, by solving the Basis Pursuit convex optimization problem [4],

$$\min \|\theta\|_{l_1} \; s.t. \;\; y = \Phi\Psi\theta. \qquad (5)$$

The optimization problem in (5) is valid for noiseless case. However, in general, the received signals are noisy, i.e. $y_i^N(t) = y_i + n_i(t)$. It is shown in [5] that a stable recovery of the these signals is possible by solving the following LASSO convex optimization problem

$$\hat{\theta} = \operatorname{argmin}_{\theta} 0.5\|y - \Phi\Psi\theta\|_2^2 + \lambda\|\theta\|_1. \qquad (6)$$

CS FOR DAS BEAMFORMING

Since the signals in the microwave breast imaging are UWB, the sampling rate of the signals used in this method is very high. So it needs a high rate A/D conversion technology. In this section we present a method that does not need a high rate A/D convertor [3].

In DAS beam forming, since the calibrated signals have only the tumor response, they are sparse in the time-domain. Because of this, using the CS theory we can recover the received signals with a number of samples less than the number of samples in the nyquist criterion. We choose the dictionary as an identity matrix and the elements of the measurement matrix as iid Gaussian random variables. Then we recover the received signal by solving the convex optimization problem (5). After that, we detect the tumor location using the DAS beam forming method described in Section 2.

SIMULATION RESULTS

In the simulations done, as indicated in Figure 1, the breast is modeled as a semicircular shape and 30 dipole antennas are used for radar imaging. The total length of each of these dipole antennas is about $4.54\ cm$. S1,1 scattering parameter of one of these dipole antennas is depicted in Figure 2. The frequency of operation is 0.8-3.2 GHz. Breast dielectric properties are considered frequency-independent. Tissue, malignant tumor, and skin dielectric properties are $\varepsilon_r = 9.8$ and $\sigma = 0.4\ S/m$, $\varepsilon_r = 50$ and $\sigma = 7\ S/m$, and $\varepsilon_r = 36$ and $\sigma = 4\ S/m$, respectively. The malignant tumor is modeled as a spiculated random shape with circumscribed radius $R = 4mm$ and average radius $R = 3.5mm$ [6]. Skin's thickness is 1.5mm. The excitation pulse is a differentiated Gaussian pulse of the form

$$V(t) = V_0(t - t_0)e^{(-(t-t_0)^2)/\tau^2} \qquad (7)$$

Where $\tau = 0.3ns$ and $t_0 = 2.5\tau$. The scaled excitation pulse is depicted in Figure 3. The transmitted and received pulse of a dipole antenna is depicted in Figure 4. The position of the tumor is at (-1.5,1.5). The SNR of each of the received signals is 10 dB.

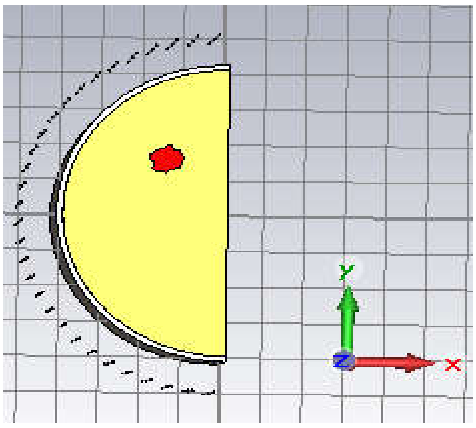

Figure 1. The simulated model

After calibrating the received signals, these signals are sampled at a rate upper and lower than the nyquist rate. Figure 5. shows the result of DAS beam forming obtained using signals sampled at a rate upper than nyquist rate. Figure 6. shows the result of DAS beam forming obtained using signals sampled at a rate below the nyquist rate with -10dB bandwidth, and finally, Figure 7. shows the result of DAS beam forming using our proposed method obtained by recovering the signals forming Figure 6.

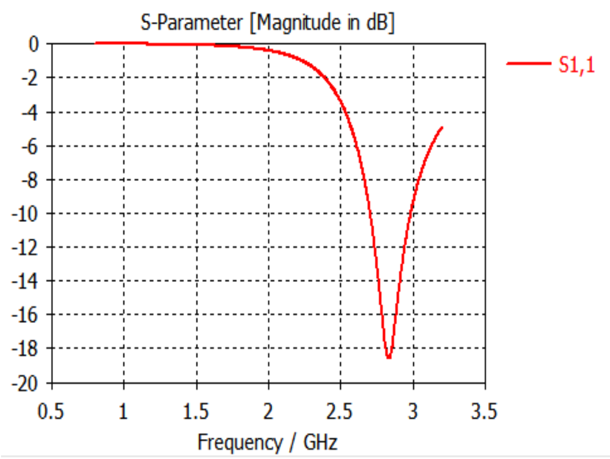

Figure 2. S1,1 scattering parameter of each of the dipole antennas

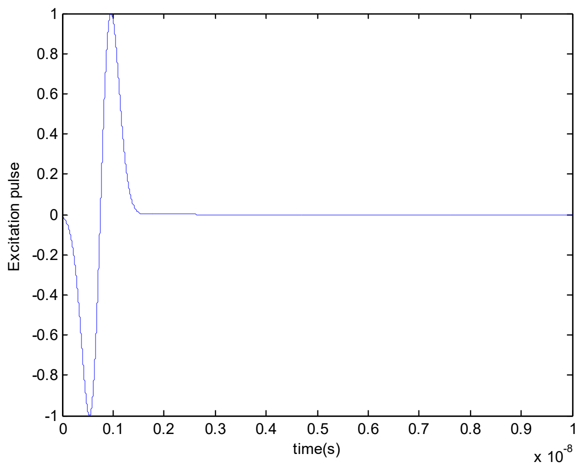

Figure 3. The excitation pulse

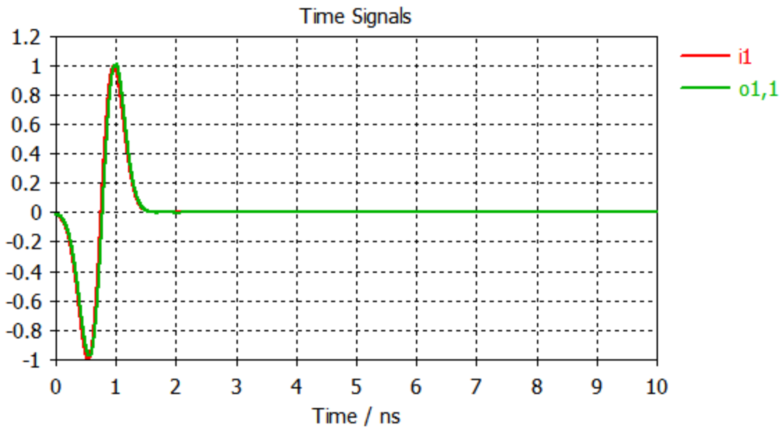

Figure 4. The Transmitted and received pulse from a dipole antenna

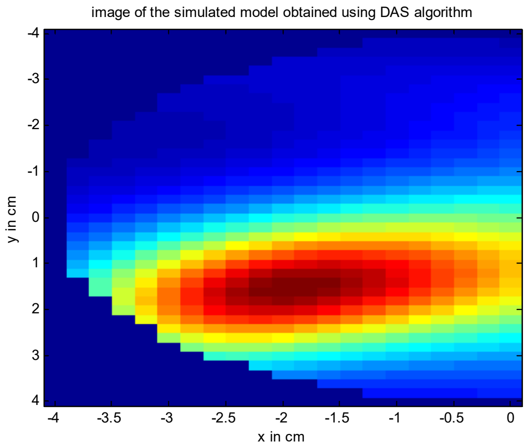

Figure 5. Image obtained using DAS beam forming with signals sampled at a rate upper than the nyquist rate.

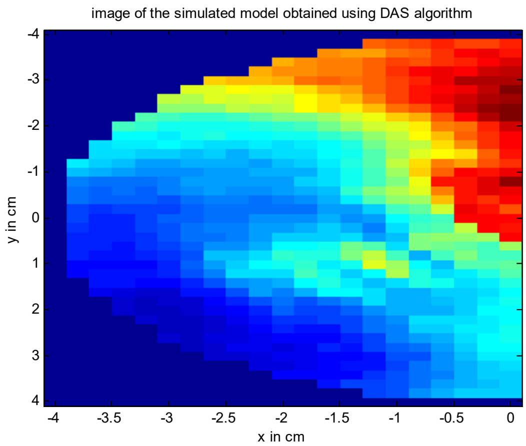

Figure 6. Image obtained using DAS beam forming with signals sampled at a rate below the nyquist rate.

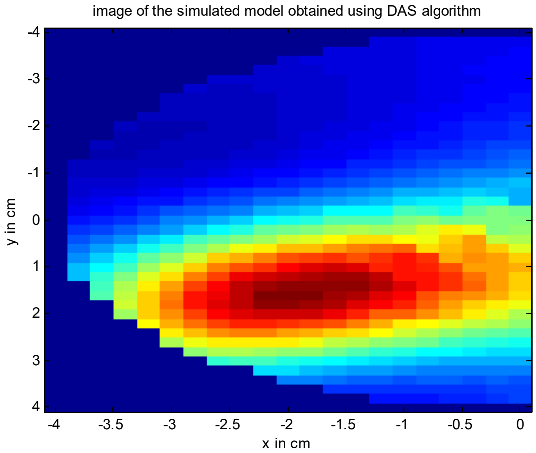

Figure 7. Image obtained using DAS beam forming with signals sampled at a rate below the nyquist rate and recovered with CS using LASSO estimator.

As it can be seen from these images, the received signals could be obtained using compressive sensing without sampling at the nyquist rate and the tumor location could be detected clearly.

CONCLUSION

A novel radar-based microwave breast cancer imaging via DAS beamforming method based on compressive sensing is proposed. In this method, instead of sampling the received signals at the nyquist rate, we recover the received signals with a number of samples less than the nyquist criterion via random sampling and compressive sensing theorem. Simulations show that using the proposed method, we can recover the received signals and detect the position of the tumor very well.

REFERENCES

1. E.C. Fear, J. Bourqui, C. Curtis, D. Mew, B. Docktor, and C. Romano, "Microwave breast imaging with a monostatic radar-based system: a study of application to patients," IEEE Trans. on microwave theory and techniques, vol. 61, no.5, pp. 2119 – 2128, May 2013.
2. R. Nilavalan, A. Gbedemah, I.J. Craddock, X. Li, and S.C. Hagness, "Numerical investigation of breast tumour detection using multi-static radar," Electronic letters, vol. 39, no. 25, Dec. 2003.
3. R. Baraniuk, P. Steeghs, "Compressive radar imaging," IEEE radar conference, pp. 128-133, 2007.
4. S. Chen, D. L. Donoho, and M. A. Saunders, "Atomatic decomposition by basis pursuit," SIAM J. Sci. Comp., vol. 20, no. 1, pp. 33-61, 1998.
5. R. Tibshirani, *Regression shrinkage and selection via lasso*, J. Roy. Statist. Soc. Ser. B, vol. 58, pp. 267-288., 1996.
6. S.K. Hong, "Resonance-based techniques for microwave breast cancer applications," Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, 2012.

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