International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 2, Issue 10, October 2015

Broadband Beamformer Combined With Dcd Weighting

[1] Meenu Unnikrishnan, [2] Jayaraj U Kidav
[1] Communication Engineering Department [2]VLSI Engineering Department
[1] Rajagiri School Of Engineering And Technology [2] National Institute Of Electronics And Information Technology
[1] meenuunnikrishnan@yahoo.co.in, [2] jayaraj@nielit .com

Abstract:— **Medical electronic technology has developed to a great extend in last few decades. Ultra sound imaging has been one of the greatest gift to medical science technology. In last few decades, ultrasound imaging technology has revolutionized the field of medical science. Adaptive beam-forming method has contributed much to the resolution and contrast of image. In this work, minimum variance (MV) beamforming for broadband data is proposed. We implement it in frequency domain and for each of these frequency sub band a set of complete, adapted apodization weight is provided. The simulation is done in FIELD ll environment. The simulation is done on point targets as well as on cyst phantoms. We aim at showing that the resolution and image clarity in the case of MV beam former is more when compared to the conventional DAS (delay and sum) beam former, even for fewer number of emission. Investigation on different methods for computation of inverse of the covariance matrix has been done. Also in this work we make use of DCD algorithm for computing the apodization weight and also we aim at showing that the DCD algorithm finds the best place compared to the other iterative algorithm for hardware implementation.**

Key Wards: **Minimum Variance (MV) beam forming, FILED II, Apodization DCD (Dichotomous Co-Ordinate Descent Algorithm**

I. INTRODUCTION

Medical electronic technology has developed to a great extend inlast fewdecades. Ultrasound imaging has been one of the greatest gifts to medical science technology. Ultrasound imaging is less costly and safe than the CT and MRI. Ultrasound imaging requires only little energy which makes it applicable for hand held application. In the case of ultrasound imaging, even though conventional delay sum beam former is being used, the adaptive minimum variance beam forming has brought about revolutionary change in terms of resolution and contrast. The paper covers, minimum variance beam forming for broad band data. Conventional beam forming in medical ultrasound beam forming is carried out using Delay sum beam former (DAS). The DAS beam former maximizes the output by delaying, weighting and summing the individual sensor signal [1]. Adaptive beam formers are data dependant beam formers [1]. It updates a new set of apodization weight for each point in the image. These apodization weights are dependent on input data [1]. The MV method developed by CAPON, also called Cap on beam former, updates a set of apodization weight such that it minimizes the variance, so that the signal emerging from the point of interest is passed without distortion.

In ref[1], Holfortet. al suggests that in medical ultra sound imaging. The adaptive beam forming provides improvement in image quality in terms of lateral resolution and contrast .In the case of MV beam forming, the computational complexity is O[M^3] followed by the inversion of spatial covariance matrix. So even if the performance is good, computational overhead is to be taken into consideration. As a remedy to this problem an adaptive beam former, this uses several predefined windows, and uses the minimum variance optimization criterion to decide which window to use at a specific point in the image is taken [2].

In medical ultrasound imaging most of the energy is scattered from angles close to steering angles, therefore spatial stationarity can be considered as a good approximation. Hence we assume Toeplitz structure for estimated covariance matrix .Toeplitz structure is applied to the spatially smoothed covariance matrix by averaging the entries along all sub diagonals. Because the inverse of the resulting Toeplitz covariance matrix can be computed in O (L^2) operations, this technique results in a greatly reduced computational complexity[3]. The MV beam former combined with adaptive CF weighting to medical ultrasound imaging outperforms the standard DAS as well as adaptive MV beam former in overall image quality enhancement. This method can significantly improve the resolution of the ultrasound images due to the narrow main lobe of the MV beam former; improve the side lobes, resulting in more interference suppression, due to the low side lobes of the

International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 2, Issue 10, October 2015

MV beam former and the power of CF (coherence factor) in reducing the focusing errors. Here sub band beam forming of ultrasound imaging is performed. The computation of inverse of the covariance matrix is really challenging. Different methods were investigated for performing the inverse operation and in our paper apodization weight computation has been performed with DCD algorithm.

II. DETAILS EXPERIMENTAL

A. Sub band Beam forming

Here sub band beam forming of ultrasound data is being performed. In the case of narrowband beam forming, Adaptive beam forming is similar to delay sum beam forming, except that the weight adaptation depends on the delayed sensor signal.
The block diagram of sub band beam former is as shown below [1].

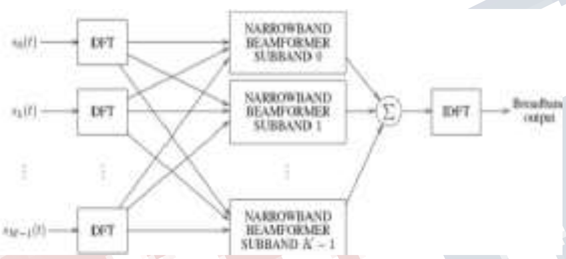

Fig 1: Sub band beam former

Adaptive beam forming can be applied to broadband signal by dividing the signal to frequency sub band using DFT. The processisshowninthe figure(1) . The signal from each of the sensor that is the transducer element is taken and Fourier transform of each of the sensor signal is taken. That is each of the sensor signal is divided into frequency bins. Each of the sensor signal is multiplied with the steering vector. The steering vector is given by $e=e^{j\omega o \tau}$.where τ is the delay. [1]

$$\tau=\frac{F}{c}\{[1+\left(\frac{N*d}{F}\right)+\frac{2*N*d}{F}*\sin\theta]^{1/2}-[1+\left(\frac{(n-N)*d}{F}\right)^2-2n-N*dF*\sin\theta]1/2\} \quad (1)$$

F→Focal length
C→Wave speed (1540 m/s)
N →(no: of elements-1)/2
d→ Center to center spacing
Θ→Steering angle

B. Methodology

1.Pre-steering

The sensor signals are pre-steered at the focus point, so that the sensor responses will add in-phase, and the output is maximized at the point. Pre-steering is carried out at point $(\gamma_p) = (x_p, zp)$. [1] mth pre-steered signal is given by[1]

$$Ym\ (t) = s_m\ (t+\tau\ (\overrightarrow{\gamma}))\ (2)$$

In the beam former, the pre-steered signals are weighted and they are added. The beam- former output is given by [1]

$$b\ (\overrightarrow{\gamma_p})=\Sigma\omega_m * s_m(\tau_m(\overrightarrow{\gamma_p})) \quad (3)$$

For a given focus point, the beam former output is given by:[1]

$$B(\omega,\overrightarrow{\gamma_p})=\Sigma\omega_m(\omega)Y_m(\omega) \quad (4)$$

Where $Y_m(\omega)$ is the Fourier Transform of the mth segmented sensor signal.

2 *Minimum Variance Beam forming*

The MV continuously updates the weight in such a way that the power of the beam former output is minimized and the response from focus point is passed without any distortion. [1]
The power of the beam former output is given [1]

$$P\ (\overrightarrow{\gamma_p}) = \varepsilon\{|B(\omega, \overrightarrow{\gamma_p})|^2\}(5)$$

$$P\ (\overrightarrow{\gamma_p}) = \varepsilon\{|W(\omega)^H Y(\omega)|^2\}(6)$$

$$P(\overrightarrow{\gamma_p}) = \varepsilon\{W(\omega)^H Y(\omega)Y(\omega)^H W(\omega)\}(7)$$

$$P\ (\overrightarrow{\gamma_p}) = W(\omega)^H R(\omega)W(\omega)(8)$$

MV beam former can be expressed as
Minimize

$$W^H RW \text{ subject to } W^H e=1\ (9)$$

e is called the steering vector. The steering vector defines the signal that should be passed distortion less. [1]

The constraint optimization problem can be solved using Lagrangian multiplier theory. The MV optimized apodization weight is given by[1]

$$W = R^{-1}e / e^{H}R^{-1}e \qquad (10)$$

In this paper, computation of inverse is done using the DCD algorithm. Here we make use of cyclic DCD algorithm and real valued leading DCD algorithm. The weight computation using equation(10) is compared with the weight obtained using cyclic DCD and leading DCD algorithm and the misalignment is plotted.

C.Results And Discussion

Simulation is done using MATLAB , FIELD ll simulation tool

1. BROADBAND MV BEAMFORMING

PARAMETERS USED FOR FIELD ll SIMULATION

1. Transducer type-Linear Array
2. Tranducer element pitch-110µm
3. Tranducer element kerf-35µm
4. Tranducer element height-6mm
5. Center frequency,fo-7Mhz
6. Velocity of sound-1540m/s
7. Wavelength,λ=c/fo- 220µm
8. Excitation pulse-two cycle sinusoid at fo
9. No: of transmiting elements-32
10. No: of receiving elements-32

The sensor signal from the transducer element is first converted to frequency domain by finding its Fourier transform. The delay is computed using the formula given above. Each of the signal is multiplied with the steering vector which is given by e^ (-j*ω*Ʈ), where Ʈ is the delay. Likewise sub band beam forming is performed. Figure (2) shows the signal from each of the transducer element. After the application of delay, the signals will become in phase. The plot of signals after it has applying the delay is also done. Summed response before and after computing the response is also plotted. The beam formed output is also plotted. After performing narrowband beam forming, the IDFT of the signal is found out by performing inverse Fourier transform. The sum of the response after computing the inverse transform is found out and the plot of the signal is done.

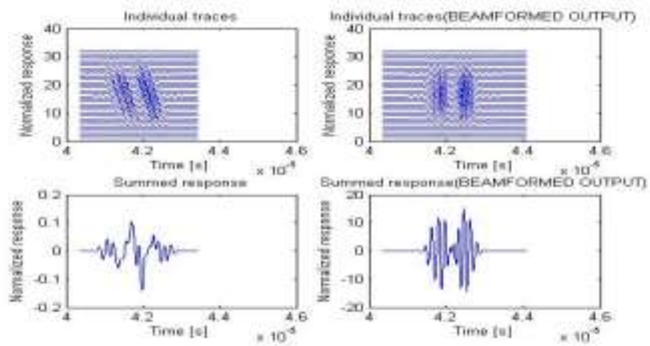

Fig 2: Beam formed output

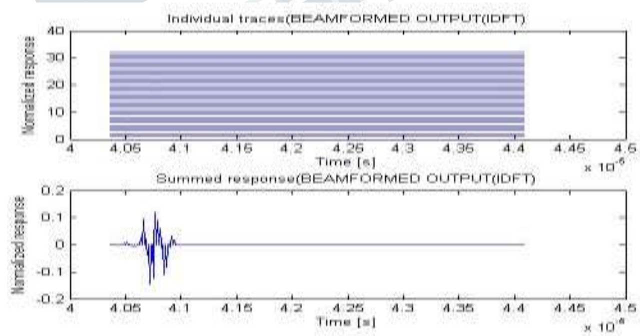

Fig 3: beam formed output after computing IDFT

Now an artificial cyst phantom is created . The signal from each of the transducer elements is plotted. The signal undergoes scattering in the presence of the cyst phantom defined, the delay is computed as the formula (1).After applying the delay to the signal , the signals from each of the transducer element becoms inphase as shown in the figure. The summed response before and after computing the response is as shown in the figure(4).

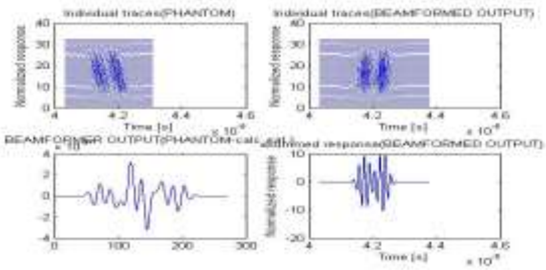

Fig 4: beam formed output after scattering

Figure (5) shows the plot of beam power vs beam angle. Maximum power is obtained at 72 degree. After steering the signal to 72 degree, maximum power is obtained at 72 degree.

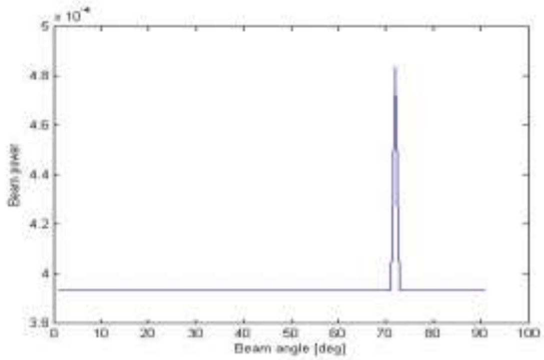

Fig 5: beam power vs beam angle

Artificial cyst phantom has been formed and the image of the cyst using different number of transducer elements has been formed at a depth of 50 mm. Figure (6) shows the cyst image formed when the number of transducer elements is 128.

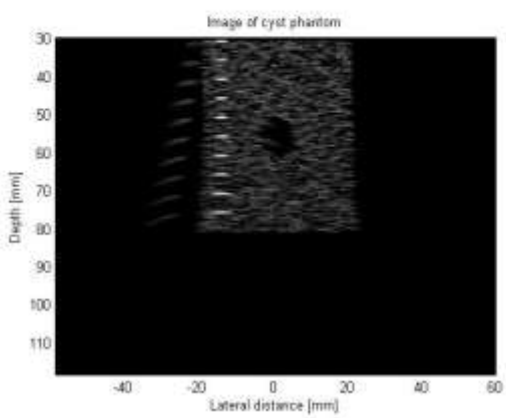

Fig 6: image of cyst phantom

D.DCD ALGORITHM

The Dichotomous Co-ordinate Descent algorithm (DCD) has been used for weight computation. Different methods, like the direct and iterative are there for solving normal equation .here we make use of DCD algorithm for solving the equation. Cyclic DCD and Leading DCD algorithm is made used here and the misalignment of cyclic DCD and leading DCD with original weight computed is found out and is plotted as shown in the figures below. The advantage of using DCD algorithm is that when compared to other iterative methods is that, it makes use of only shift and accumulates operation. No division and Multiplication operation is involved. The complexity is of the order of O (N), where N is the number of addition per each iteration. Implementation of DCD algorithm for weight computation reduces chip area and power consumption.

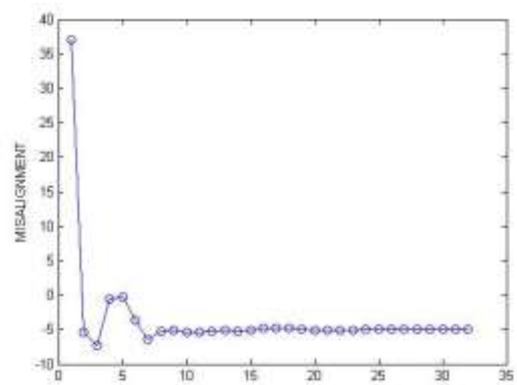

Fig 7: misalignment in cyclic DCD algorithm

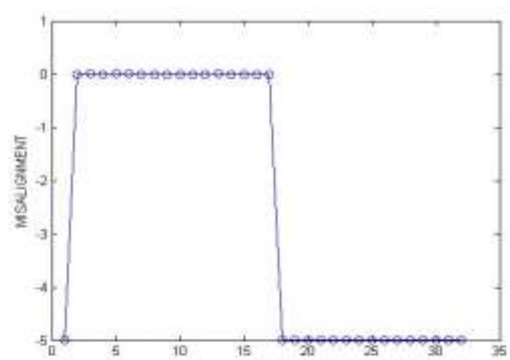

Fig 8: misalignment in leading DCD algorithm

III. CONCLUSIONS

a) MV beamforming provides improvement in image resolution
b) MV beamforming enables the use of reduced aperture and provides higher frame rates
c) Increased depth of penetration is achieved without sacrificing lateral resolution with the aid of MV beamforming.
d) As the number of transducer elements increases, then the image clarity improves
e) Implementation of DCD algorithm for weight computation reduces chip area and power consumption.
f) It involves only shift and accumulate operationDoes not involve multiplication and division

Suitable for real time hardware implementation

REFERENCES

[1] IbenKraglundHolfort, Jrgen Arendt Jensen, ”Broadband Minimum Variance Beam- forming for Ultrasound Imaging” , IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 56, no. 2, February 2009.

[2] Johan-Fredrik Synnevg, Sverre Holm, ”A Low-Complexity Data-Dependent Beam- former”,IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 57, no. 2, February 2010.

[3] BabakMohammadzadehAsl and Ali Mahloojifar,” A Low-Complexity Adaptive Beamformer for Ultrasound Imaging Using Structured Covariance Matrix” ,IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 59, no. 4, April 2012.

[4] BabakMohammadzadehAsl, Ali Mahloojifar,”Minimum Variance Beamforming Combined with Adaptive Coherence Weighting Applied to Medical Ultrasound Imag- ing”,IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 56, no. 9, September 2009.

[5] MinfenShen,QiongZhang,DelaiLi,Jinyao Yang,”Beamspace Sparse Representation Weighting Beamforming for Plane Wave Emission Ultrasound Instrument”,2011 IEEE.

[6] Minfen Shen, Qiong Zhang, Delai Li, Jinyao Yang, and Bin Li,”Adaptive Sparse Rep- resentationBeamformer for High-Frame-Rate Ultrasound Imaging Instrument”,IEEE Transactions On Instrumentation And Measurement, Vol. 61, No. 5, May 2012.

[7] Ming Yang, Richard Sampson, SiyuanWei, Thomas F. Wenisch, and ChaitaliChakrabarti,”Separable Beamforming For 3-D Medical Ultrasound Imaging”,IEEE Transactions on signal Processing, Vol. 63, no. 2, January 15, 2015.

[8] Johan-Fredrik Synnevg, Andreas Austeng, Member, Sverre Holm, ”Benefits of Minimum-Variance Beamforming in Medical Ultrasound Imaging”,IEEETransac- tions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 56, no. 9, September 2009.

[9] Yu Zhang, JianxinWang,”Transmit-Receive Beamforming for MIMO Radar”,2010 2nd International Conference on Signal Processing Systems (ICSPS).

[10]Yang Jian , Zhang Yue, BaoQinlong, Chen Zengping,”Frequency Broadband Sig- nal MVDR Adaptive Beamforming Method and Application”,2010 2nd International Conference on Signal Processing Systems (ICSPS).