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Implementation of Narrowband Conventional and Adaptive Beamformers for Smart Antenna Systems

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***Abstract* - This study presents three important narrow band Beamformers for smart antennas; conventional phases shift, adaptive Minimum Variance Distortion less Response Beamformer (MVDR) and adaptive Linear Constraint Minimum Variance Beamformer (LCMV). The conventional phases shift beamformer in presence of strong interference signals we cannot exactly extract the signal content. Based on the received signal weight vector these beamformers form beam pattern. In self-nulling condition LCMV beamformer is efficient than the MVDR beamformer even though the interference signal direction is close to the desired signal direction. The nine elements uniform linear array (ULA) with λ/2 element spacing smart antenna is used in our simulation program.**

Index Terms— LCMV, MVDR, Narrowband Beamformer, Smart antenna, ULA.

1. INTRODUCTION

The capacity of modern wireless communication network is increasing day by day. To handle this situation the service providers have to hence signal quality and increase the coverage area [1]. Smart antenna can adjust the array pattern towards the desired signal direction by using smart signal processing algorithms [2], [3], [4]. To enhance the reception of smart antenna system different narrowband beamforming algorithms are analyzed [5], [6] and these algorithms are also used for noise reduction [7].

II. NARROWBAND BEAMFORMING

A beamformer is a spatial filter that allows the signal of interest in the desired direction and rejects the interference signals from other. To arrive the signals to all the antenna elements at the time a conventional beamformer delays the received signal at each antenna element. To archive this in narrowband Beamformers, the signal received at each antenna is multiplied by a phase factor. For Narrowband beamformers the Signal bandwidth is narrow.

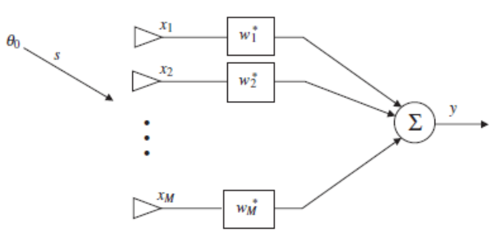

Fig.1 General conventional narrowband Beamformer system

Fig. 1 shows general block diagram of conventional narrow band Beamformer for the input simples $x_m(t)$, m=1…..M the array output y(t) is given by:

$$y(t) = \sum_{m=1}^{M} x_m(t) w_m^*$$

In the above equation * indicates the complex conjugate. The beamformer structure is associated with sinusoidal or narrow band signals. Let the signal received by the first sensor is $x_1(t)$ with zero phase. Then the signal received by the m^{th} sensor is given by:

$$x_m(t) = e^{j\omega(t-\tau_m)}$$

Here τ_m is the propagation delay and m=1,2,3,…M. Then the narrow band beamformer output given by

$$y(t) = e^{j\omega t} \sum_{m=1}^{M} e^{-\omega\tau_m} w_m^*$$

The response of narrow band beamformer at τ_0=0 is given by:

$$P(\omega,\theta) = \sum_{m=1}^{M} e^{-\omega\tau_m} w_m^* = W^H d(\omega,\theta)$$

Where the weight vector is defined as:

$$W = [w_1\, w_2\, w_3 \,.\,.\,.\, w_M]^T$$

The array response vector d(ω,θ) can be expressed as:

$$\mathrm{d}(\omega,\theta) = [1 \quad e^{-j\omega\tau_1} \quad e^{-j\omega\tau_2} \,.\,.\,.\, e^{-j\omega\tau_{M-1}}]^{\mathrm{T}}$$

III. PHASE SHIFT BEAMFORMER

The Phase shift beamformer can be applied to narrow band signals. The phase shift beamformer response is obtained from Discrete Fourier Transform (DFT) beamformer by replacing the phase shift with a constant phase shift given by:

$$2\pi f t_{mb} = 2\pi f_0 t_{mb}$$

Here the narrow band signal centre frequency is f_0. By applying a N-point Discrete Fourier Transform to each sensor output $x_m(n)$, results in frequency transformed data, $X_m(k)$ where $f_k = kf_s/N$, such that

$$X_m(k) = \sum_{n=1}^{0} x_m(n)e^{j2\pi nk/N} \quad where\ 0 \leq k \leq N - I$$

Where $X_m(k)$ is an estimate of $X_m(f)$.

The phase shift Beamformer output response in frequency domain is given by:

$$Y(f, \psi_b) = \sum_{m=1}^{M} a_m X_m(f)e^{-jw_0 t_{mb}}$$

The Inverse Fourier transform of the above equation give the output of phase shift beamformer in time domain given by:

$$Y(t, \psi_b) = F^{-1}[Y(f, \psi_b)] = \sum_{m=0}^{M-1} a_m X_m(t)e^{-jw_0 t_{mb}}$$

IV. MINIMUM VARIANCE DISTORTIONLESS RESPONSE (MVDR) BEAMFORMER

Phase Shift Beamformer cannot extract the signal content exactly in strong interference environment. To overcome this interference problem, a popular adaptive beamformer MVDR beamformer is used. The MVDR Beamformer suppresses the interference signal with low noise and high signal to noise ratio (SNR). The output of the array is given by:

$$y = w^H X$$

The expression for the output power is given by:

$$P = \{E|y|^2\} = E\{w^H xx^H w\} = w^H E\{xx^H w\} = w^H R$$

Here the received signal covariance matrix is R and H denotes hermitian transpose. The array output power P_{MVDR} is minimized by selecting the optimum weights and by maintaining the unity gain in the desired signal direction. The adaptive MVDR Beamformer algorithm is given by:

$$min_w\{w^H R w\}\ subject\ to\ w^H a(\theta)$$

Where a(θ) is the steering vector given by:

$$a(\theta) = \begin{bmatrix} exp\{j\frac{2\pi}{\lambda}(\sin\theta_i)d\} \\ \\ exp\{j\frac{2\pi}{\lambda}(\sin\theta_i)(m-1)d\} \end{bmatrix}$$

In the above equation *d* represents array element spacing and the desired angle θ_i is, and *m* is the number of elements.

For weight vector calculation the MVDR beamformer does not require the knowledge of the interference signals directions. It only requires desired signal direction. Then the optimization weight vector is given by:

$$W = \frac{R^{-1}a(\theta)}{a^H(\theta)R^{-1}a(\theta)}$$

V. LINEAR CONSTRAINT MINIMUM VARIANCE (LCMV) BEAMFORMER

Signal self-nulling problem in MVDR beamformer is avoided in LCMV Beamformer by considering the following constraints:

- Preserve the incoming target signal direction and
- The beam former output does not deviate from +/- 2° of the accepted direction.

The weights of LCMV Beamformer are estimated as:

$$W = g^* \frac{R^{-1}a(\theta)}{a^H(\theta)R^{-1}a(\theta)}$$

When the gain constant g = 1 the above equation becomes optimum weights MVDR Beamformer.

VI. SIMULATION RESULTS

For simulating the received signal we considered a rectangular pulse train as the incoming signal for the uniform linear array (ULA) with 9 isotropic antenna elements which are separated with λ/2 spacing. Assume that the incoming pulse train as shown in figure 2 is

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arriving at the array from 30^0 azimuth angle and 0^0 in elevation angle. Also assume that the SNR of 3dB at each antenna element. In the presence of thermal noise the magnitude plot of the signals for each antenna element is shown in figure 3.

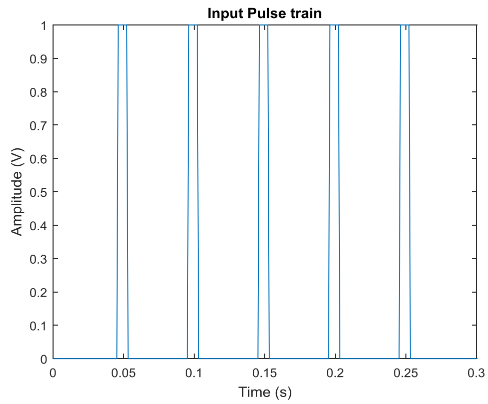

Figure 2 Transmitted signal of interest

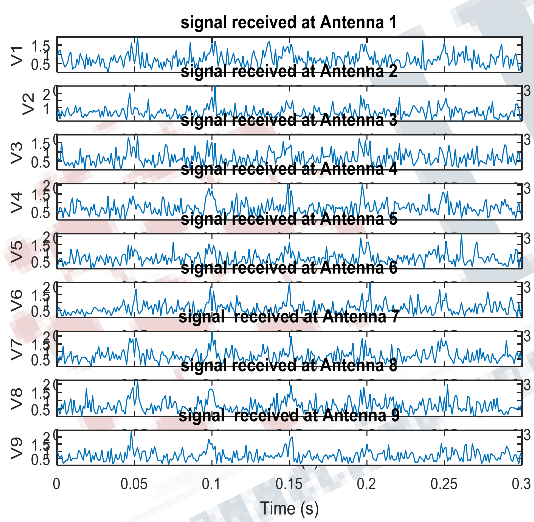

Figure 3 Signals present at each antenna element of 9 element ULA

(a) Phase Shift Beamformer:

Figure 4 shows the beam pattern of Phase shift Beamformer without interfering signals. Here the main beam of phase shift beamformer is pointing towards the desired 40^0 directions. And the Phase Shift beamformer signal is stronger than the noise as shown in figure 5. Next consider the four interference signals along 0^0,20^0,60^0 and 80^0 as shown in figure 6. Here we cannot extract the signal content form the target signal.

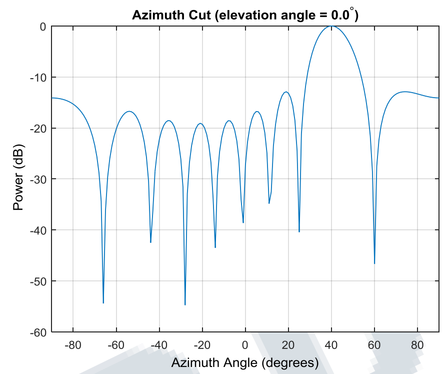

Figure 4 Phase shift beamformer beam pattern

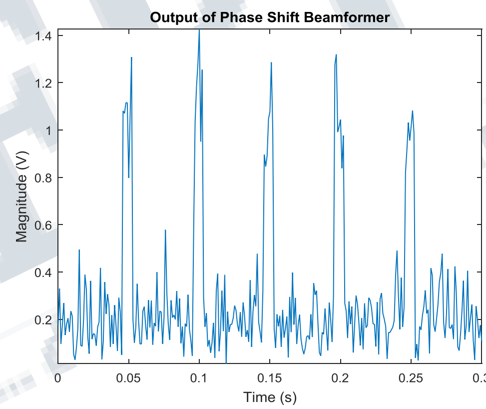

Figure 5 Phase shift beamformer response without interference

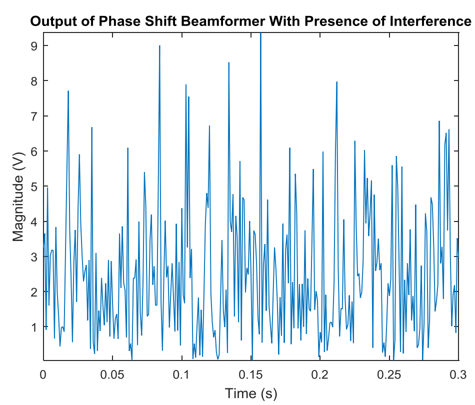

Figure 6 Phase shift beamformer response with interference

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*b) **MVDR Beamformer:***

The output response and beam pattern of MVDR beamformer is shown in figures 7 and 8 respectively. We can observe deep nulls along the interference directions 0^0, 20^0, 60^0 and 80^0. MVDR beamformer preserves the target signal along the desired 40^0 direction (0 dB gain) and suppresses the interference signals. Whereas the Phase Shift beamformer does not place nulls along interference directions..

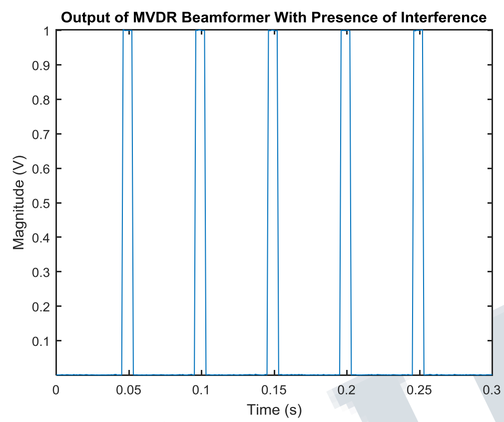

Figure 6 MVDR beamformer response with presence of interference

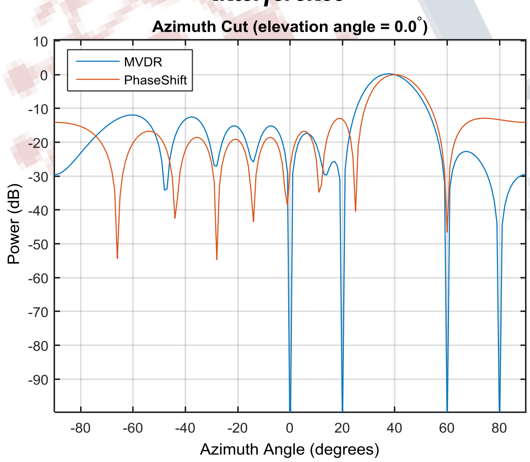

Figure 7 Beam pattern of Phase shift and MVDR beamformers with interference

MVDR beamformer only receives signal in the desired direction 40^0 but suppresses it when it is arrived with slightly different direction 38^0. This effect is known as "signal self nulling". As shown in figure 9 the MVDR beamformer treats the desire signal along 38^0 as an interference signal and suppress it.

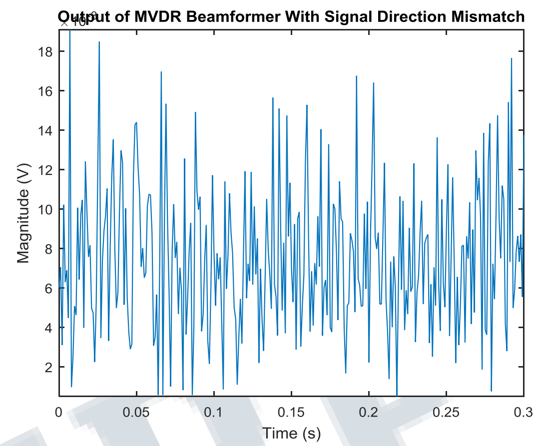

Figure 8 MVDR Beamformer output with signal direction mismatch

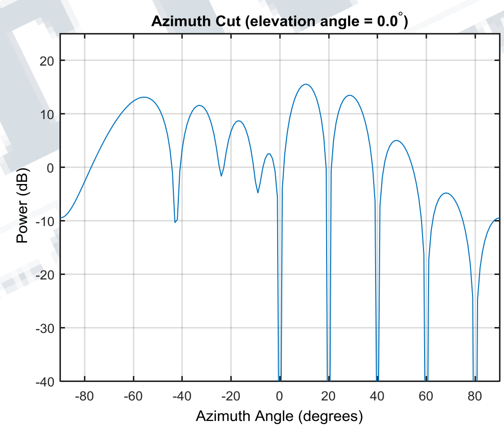

Figure 9 MVDR Beamformer beam pattern with signal direction mismatch

c. LCMV Beamformer

Self Nulling issue in MVDR can be solved in LCMV Beamformer. As shown in figure 10 the target signal is detected again even though the signal direction is mismatched

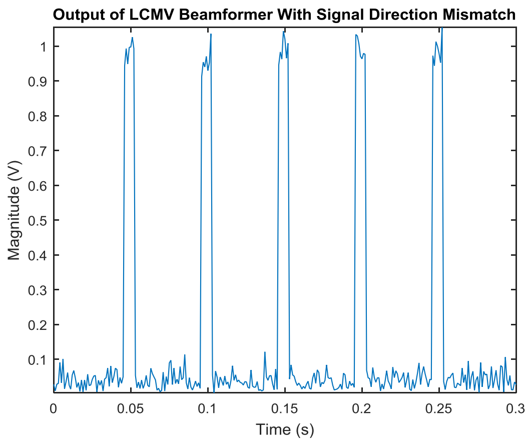

Figure 10 LCMV Beamformer output with signal direction mismatch

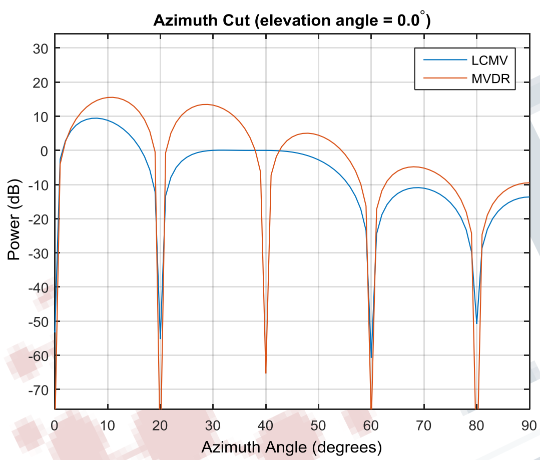

Figure 11 LCMV and MVDR Beamformers beam pattern with signal direction mismatch

Figure 11 compares the LCMV and MVDR Beamformers patterns. We observe that the LCMV beamformer shows a flat response along the desired signal direction but for MVDR beamformer a null is seen along this desired direction.

VI.CONCLUSION

The purpose of this paper is to use digital beamformesr to retrieve the signal from a direction of interest and reject the signal from interference directions using a ULA. Self-nulling problem in MVDR beamformer is addressed by LCMV Beamformer. Interference rejection for Narrow band adaptive beamformers is more compared to narrow band conventional beamformers. The simulations are carried on using MATLAB (R2015a) software.

Future Work: The proposed narrow band beam forming algorithms for smart antennas can be compared with wide band beam forming algorithms and can be extended to uniform rectangular arrays and circular arrays.

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REFERENCES

[1] Amara PrakasaRao and N.V.S.N.Sarma, *‘‘Adaptive Beamforming Algorithms for Smart Antenna Systems’’*, WSEAS TRANSACTIONS on COMMUNICATIONS Volume 13, 2014, E-ISSN: 2224-2864,pp.44-50.

[2] M.Z.Shakir and T.S.Durrani, *‘‘Narrowband Beamforming Algorithm for Smart Antennas”* Proceedings of International Bhurban Conierence on Applied Sciences & Technology,8th - 11th January, 2007,pp.49-54.

[3] Balaem Salem, S.K. Tiong, S.P. Koh and Soodabeh Darzi, *‘‘Avoiding Self Nulling by Using Linear Constraint Minimum Variance Beamforming in Smart Antenna’’* Research Journal of Applied Sciences, Engineering and Technology, Published: April 10, 2013, ISSN: 2040-7459; e-ISSN: 2040-7467, pp. 3435-3443.

[4] Balasem.S.S, S.K.Tiong and S. P. Koh, ‘‘Beam forming Algorithms Technique by Using MVDR and LCMV’’, World Applied Programming, Vol (2), No (5), May 2012, ISSN: 2222-2510, pp.315-324.

[5] Khyati R.Zalawadia,Twinkle V. Doshi and Dr.U D Dalal, ‘‘Study And Design Narrow Band Phase Shift Beamformer”,IISP 2013,pp.238-241.

[6] E. A. P. Habets, J. Benesty, I. Cohen, S. Gannot, and J. Dmochowski, ‘‘*New Insights Into the MVDR Beamformer in Room Acoustics*” IEEE TRANSACTIONS ON AUDIO, SPEECH, AND LANGUAGE PROCESSING, VOL. 18, NO. 1, JANUARY 2010,pp.158-170.

[7] T.Ganesh, R.V.Ch.Sekhar Rao, P.H.V.Prasad, N.Ashok kumar and P.Vasundhra, *‘‘Noise Reduction Using Beamforming Algorithms”,* IJESC April 2016, Volume 6 Issue No.4, ISSN 2321 3361,pp.4390-4392.