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A STUDY ON ADAPTIVE CONSTRAINT GENERALISED SIDELOBE CANCELLER FOR OPTIMIZING BEAM AND THE SPECTRUM ANALYSIS OF NARROW BAND AND WIDE BAND SIGNAL.

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Abstract—In this paper, we analyse a generalised side lobe canceller structure which has two parallel paths, one for conventional beamformer and the other for adaptive beamformer. The conventional beamformer path is subjected to the specific constraints while the adaptive beam path is cascade of a fixed signal blocking matrix and a set of tapped- delay line filters. It employs a gradient -based weight adjustment algorithm. Blocking matrix does not allow incident waves to reach tapped delay lines. So, unconstrained Least mean square (LMS) Algorithm is used to adapt the delay line weights. This paper has analyzed the effect on side lobes levels (-13.2dB) by increasing the number of elements in the array.
Keywords—SLL, LMS, HPBW, FNBW.

Introduction

To understand the efficiency of a communication system. We have analyzed various parameters. This paper provides in-depth understanding for the various bands of transmission and the formation of sidelobe. Depending upon transmission rate of data the system can be classified as Narrow band, wideband and Ultrawide band. These narrow band systems have low data transmission rate and are less complex where as this wide band system has fast data transmission rate but it requires more diverse network circuits. The frequency spectrum of narrowband antenna is divided into many channels whereas for wideband complete frequency spectrum is available for the users. The formation of channel and the side lobe greatly affect the system performance. The directivity of the system depends upon the development of main beam and suppression of side lobes.

The Beamforming technique is used in Radar for transmitting and receiving signals in massive MIMO systems. These arrays of antenna use signal processing algorithm [1]. In order to not only steer the main lobe towards a desired signal and place radiation pattern nulls towards respective interference signals, but also to achieve a desired side lobe level (SLL) [2].Due to interference, noise and jamming of the signal, it has high sidelobes (at -13.2dB) associated with them and this result in masking of weaker targets [3][4]

• Minor lobes, are the lobes other than the main lobe in the pattern, which includes sidelobes and back lobes. Main lobe can be characterised according to its half power beamwidth (HPBW)-3db point

• Similarly, another important parameter about the radiation pattern is the first null beamwidth (FNBW), it is the angular spread of the two first nulls [5].

By changing the number of arrays elements beam width can be narrowed but sidelobe level will not reduce. In paper we have considered different array size, i.e., a Uniform linear array with number of elements 10 and 50.For analysing side lobe level two beamforming algorithm i.e., Phase shift and Minimum variance distortedness method (MVDR) is considered.

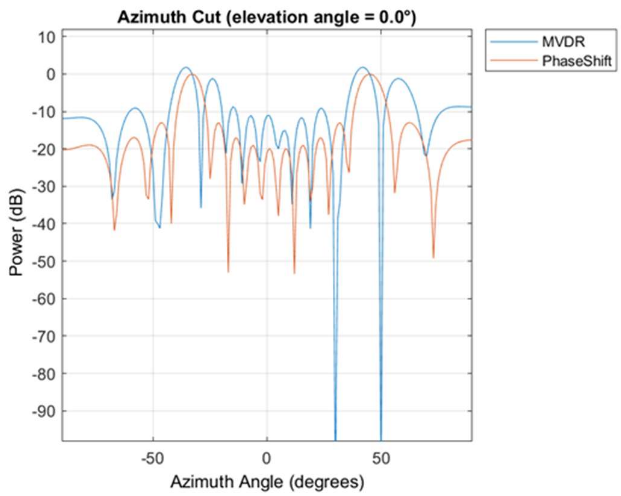

Fig 1. Sidelobes level for no. of array elements 10

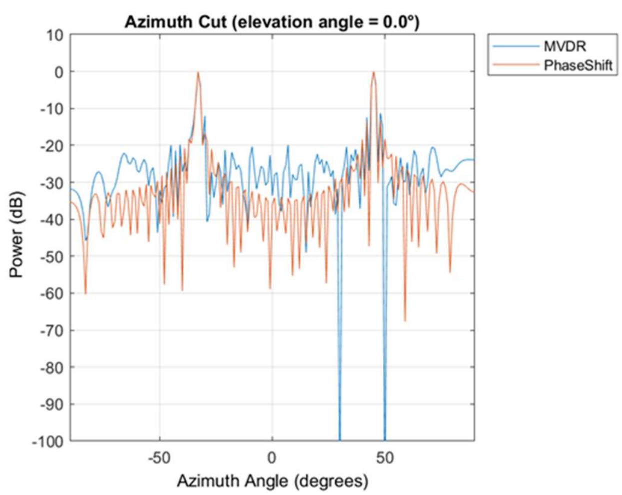

Fig 2. Sidelobe level for no. of array element 50.

From Fig 1 and Fig 2, we have seen the side lobe pattern. By changing the number of elements in array, beam is getting narrower but the sidelobe level is not getting reduce.

Generalised side lobe canceller is the implementation of LCMV beamforming algorithm. This LCMV beamformer preserves the output power in one particular direction and suppress the output power in all other direction. This type of beamforming is known as constrain beamformer. Computing the weights of the beamformer is costly when the number of array element are more. The GSC computation convert the adaptive constrain optimization LCMV problem into adaptively unconstrained optimization problem.

GSC Algorithm

The incoming signals is received by the array of sensors which are then split into two paths.

Conventional beamformer path this is the upper part of the system

Adaptive unconstrained beamformer path. It is the lower part of the system

In this pre-steer of input signal is done by time shifting the incoming signal of sensor elements. This shifting depends upon arriving angle of the signal

These pre-steers signal splits into two upper and lower paths

This pre-steer's signal passes the signal through upper path and then pass it to conventional beamformer path with fixed weight.

It also passes the signal through lower path and then into blocking matrix B. This blocking matrix removes the signal from the lower path as it is orthogonal to the incoming signal.

This lower path signal passes through the bank of filters. These filter coefficients are filter adaptive weights.

Generalized sidelobe cancellation = Difference of upper and lower signal path

The output beamformed is feed again to the filters. These filters adapt the weight using LMS algorithm [4]

Least Mean Square Algorithm

$$e(k) = d(k) - w^H(k)x(k)$$

$$w(k+1) = w(k) + \mu e^*(k)x(k)$$

Signal error=e(k)

Reference signal=d(k)

Weight vector=w

Hermitian constant=H

Input signal=x(k)

Time varying step size=μ (scalar constant)

Simulation and Result

Generalized sidelobe canceller is a side lobe suppressing technique in which two channels are formed for the received signal [7]. A GSC splits these signals into two channels, beamformer path and the sidelobe cancellation path. GSC system pre-steers the array of antenna in the direction of beamforming and by choosing the weights to suppress or minimise power of the side lobe at the output. By adaptively choosing the weights of the filter main beam is formed with high gain, directivity and power while the sidelobe is suppressed to lowest level. LMS algorithm is used for computing the adaptive weights. Final beamformed is the difference between the output of the two paths [8].

SIGNAL MODEL

Consider a uniform linear array ULA of N elements. Let a desired signal come from far field to the sensor array. These signals arriving to array from different direction called as direction of arrival (DOA) $\{\theta_1, \theta_2, \ldots, \theta_M\}$ and desired signal steering vector is

$$a(\theta_0) = \left[1, e^{i\tau\theta_0}, e^{i2\tau\theta_0}, \ldots, e^{i(N-1)\tau\theta_0}\right]^T$$

$$\tau_{\Theta 0} = (2\pi d/L_\lambda)\sin\theta_0$$

where d is the element spacing, L_λ is the signal wavelength.

$$a(\theta_m) = [1, e^{i\tau\theta_m}, e^{i2\tau\theta_m}, \ldots, e^{i(N-1)\tau\theta_m}]^T \ (1 \le m \le M)$$

$$\tau_{\theta_m} = (2\pi d/L_\lambda)\sin\theta_m$$

$$x(k) = a(\theta_0)s_0(k) + \sum_{m=1}^{M} a(\theta_m)s_m(k) + n(k)$$

$$\triangleq s(k) + i(k) + n(k)$$

Here components are assumed to be spatial white and gaussian noise. $s_0(k)$, $s_m(k)$ denotes desired and interference signal.

$$s(k) = a(\theta_0)s_0(k)$$

$$i(k) = \sum_{m=1}^{M} a(\theta_m)s_m(k)$$

n(k)=additive noise

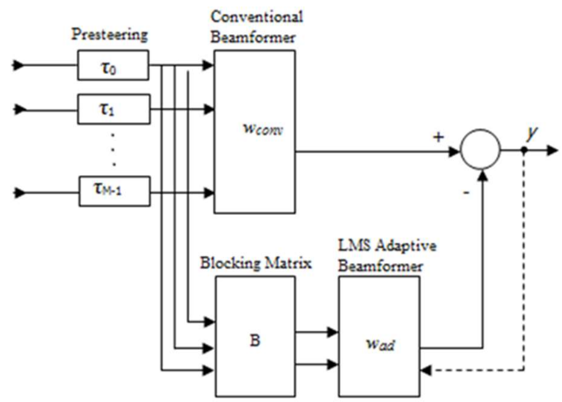

Fig 3. Genralised side lobe canceller [6]

Modelling Parameter

TABLE I. Modelling Parameters

Parameters	***Assigned Value***
No. of Elements	10 Elements
Azimuth Angle	-45 degree
Elevation Angle	0 degree
Signal Propagation Speed	300e3
Sampling Rate	8 khz
Filter Length1	15

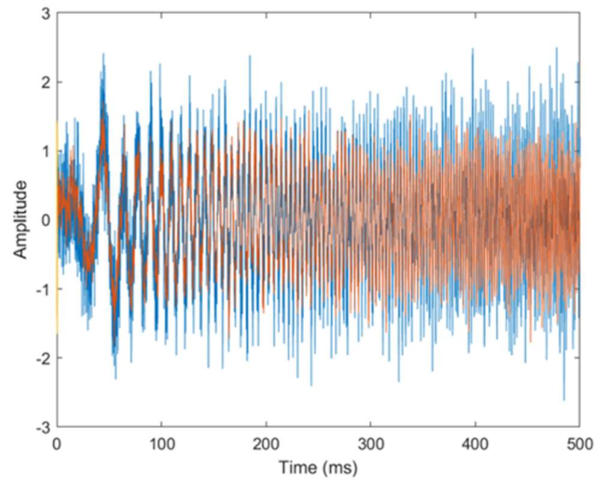

Fig 4. Beamformer output after GSC is performed

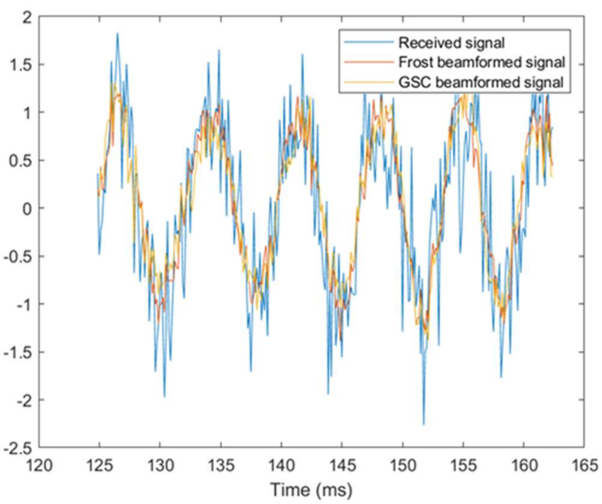

Fig 5. Zoom for all small portion of the output.

Fig 4 shows the output of the beamformer against the frost beamformer output and the signals which do not formed the beam arrives at the middle element of the array.
Above simulation is done for computing the beamformed signal for a direction, we can extend our study to two directions, i.e., in the direction of incident wave and in another direction.
Generalized Sidelobe Cancellation in Two Directions

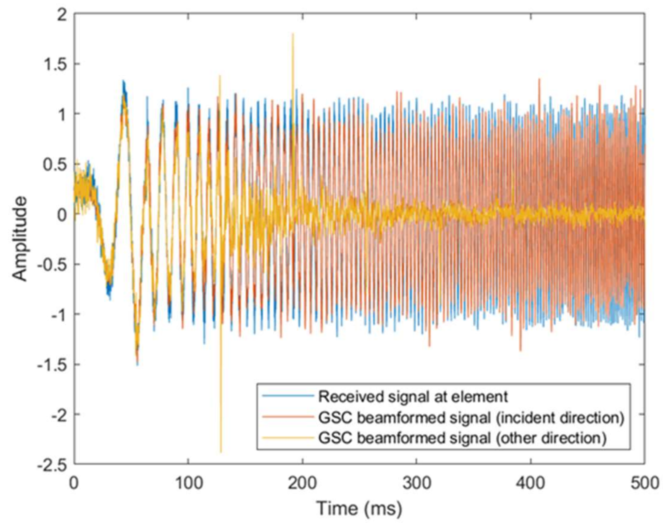

Fig 6. Beamformer output after GSC beamforming is performed

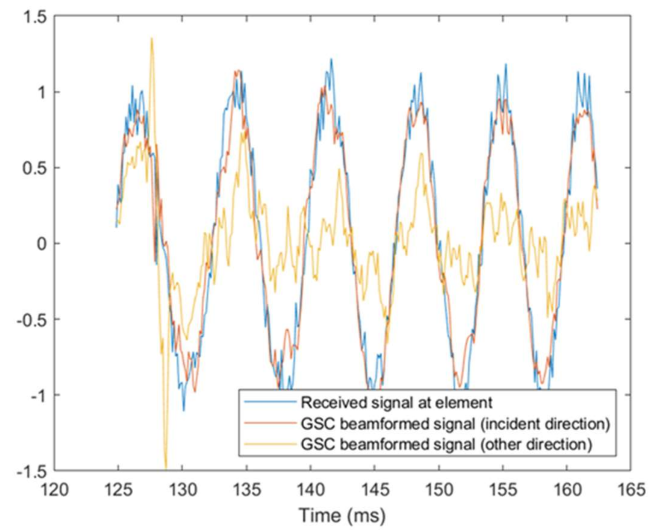

Fig 7. By zooming all portion of output

WIDE BAND BEAMFORMING

Beamforming achieved by multiplying the sensor input by a complex exponential with the appropriate phase shift of the signal. It applies for narrowband signals only. In the case of wideband, or broadband, signals, the steering vector is not a function of a single frequency.

To analysis the behavior of wideband beamformer we Create a chirp signal with a bandwidth of 1kHz and propagation speed of 350m/s. Collect the chirp with a 15 element ULA. Element spacing is half the wave length with sampling frequency 60kHz.The chirp is incident on ULA with an angle of 45degree azimuth and 0degree elevation and carrier frequency of 1500.

TIME DELAY BEAMFORMING OF ULA ARRAY

Apply a wideband conventional time-delay beamformer to improve the SNR of the received signal.

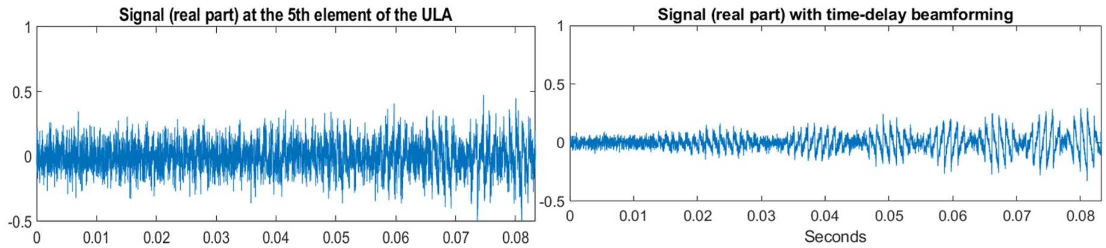

Figure 8: Behavior pattern of the signal after applying time delay

We will analyse the response pattern of the received beam for set of different frequencies.

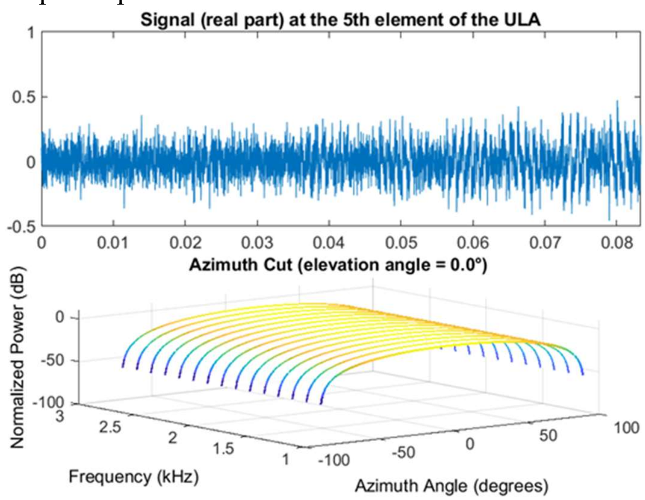

Figure9: Element pattern over a set of frequencies.

From the above figure it is shown that beam pattern of elements of the received signal is constant for the entire bandwidth.

We will analysis the beam pattern of the 15-element array over the same set of frequencies.

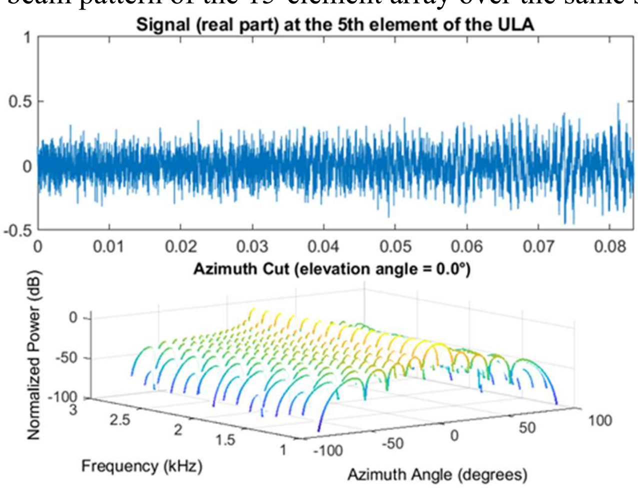

Figure 10. Element pattern for a set of frequencies.

Above plot shown that element pattern of array decreases main lobe with frequencies. Here we will analyse the subband phase shift beamformer response for the array of 15 elements.for our simulation we have considered the direction of interest from 20degree azimuth and 0 degree elevation. The response pattern formed by using the weights and center frequency of 15 element array beam.

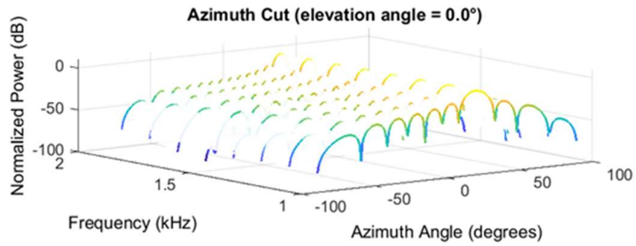

Figure 11. Sub band phase shift beamformer.

Beam pattern response in 2D which show that beam direction remains constant while beamwidth change with change in frequency.

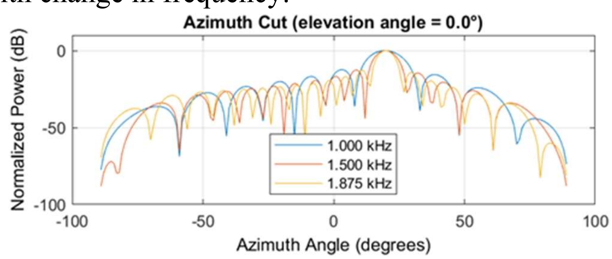

Figure12. Frequency plot in 2D.

NARROWBAND BEAMFORMING

Now we will demonstrate that for digital narrow band Conventional and Adaptive beam forming can be applied. Here we have considered 15 element ULA with input frequency 45 degree and carrier frequency 100e6.

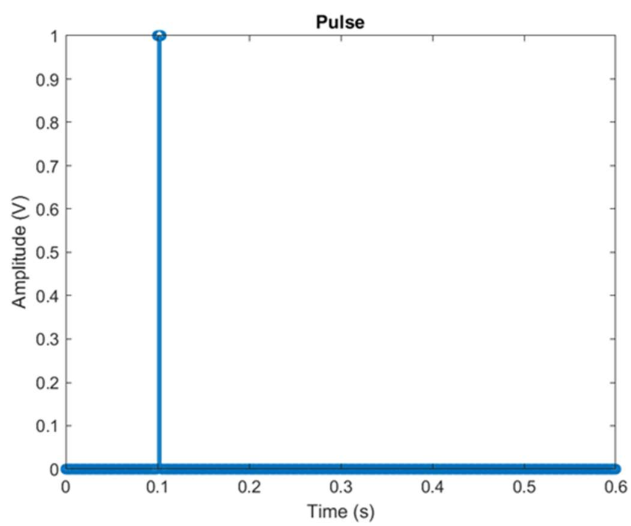

Figure 13.A rectangular pulse

Above figure is a simple rectangular pulse.For our study we have taken signal carrier frequency as 100MHz.Spacing between the elements of ULA is l/2.Simulation is carried out for 45degree azimuth and 0 degree elevation input angle and noise power will be .5 watts which corresponds to 3db SNR.In narrow band the received signal is multiplied by phase factor. This conventional beamformer delay the received signal at each antenna that the output signals will be aligned

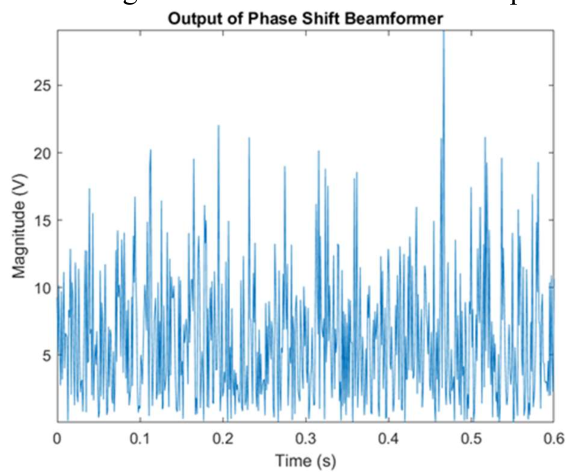

Figure 14. Behavior of the signal after applying Phase shift beamformer.

In the presence of noise Phase shift beamformer retrieve the signal. To see the beam pattern of the signal we have plotted the signal between -90-to-90-degree azimuth.

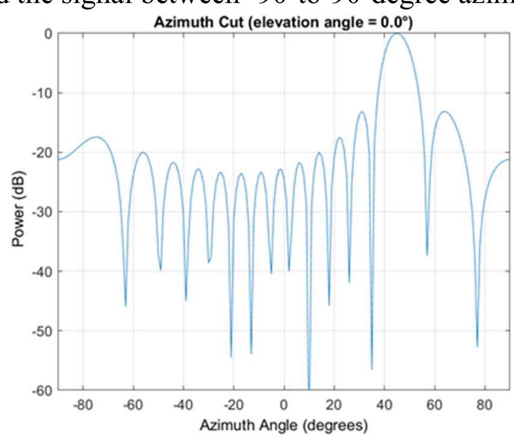

Figure 15. Beam pattern of the received signal.

From the figure we can see that main beam points in the direction of desired direction.

Conclusion

In this paper, we have analysed method of reducing side lobe levels. Level of side lobe -13.2db even not get reduced by increasing the numbers of array elements. Beam gets narrower but side lobe level does not reduce. This paper presents the designing and implementation of adaptive constraint optimised beamformer. Algorithms have employed to achieve minimum output variance subjected to constrains in the steer direction. These constrains allow direct control on the beam pattern so the mismatch will be created between the signals .so, the trade-off can be made between spatial resolution capability of beamformer and degree to which main lobe jammer or interfering signal can be eliminated. By applying time delay in wide band beamforming the SNR of the signal is improved. The behaviour of the element pattern is constant over the complete bandwidth. For the response pattern of 15 element ULA, it has showed that the main lobe decreases with frequency. The effect of sub band phase shift beamformer on the array of signals is the formation beam at the center frequency of each sub band. For the narrow band SNR of the received signal is improved by applying phase shift beamformer to the received signal with noise content.

SCOPE OF WORK

Generalized side lobe canceller reduce the computational cost but it incorporates a spatial domain notch filter. This approach needs a sharp notch filter and a slave array for recovering the desired signal. Ad hoc approaches can be implement to design robust adaptive array.

References

Ali, E., Ismail, M., Nordin, R., &Abdulah, N. F. (2017). Beamforming techniques for massive MIMO systems in 5G : overview , classification , and trends for future research. 18(6), 753–772.

Gravas, I. P., Member, S., Zaharis, Z. D., Member, S., Traianos, V., Lazaridis, P. I., Member, S., &Xenos, T. D. (n.d.). Adaptive Beamforming with Side Lobe Suppression by Placing Extra Radiation Pattern Nulls.Malik, H., Burki, J., & Mumtaz, M. Z. (2022).

Adaptive Pulse Compression for Sidelobes Reduction in Stretch Processing based MIMO Radars. 2, 1–13.

Morgan, C. (n.d.). Introduction to Smart Antennas. https://doi.org/10.2200/S00079ED1V01Y200612ANT005S.

V. Hum. (2018). Radio and Microwave Wireless Systems Course Notes. https://www.waves.utoronto.ca/prof/svhum/ece422.html.

Griffiths, L. J., and Charles W. Jim. "An alternative approach to linearly constrained adaptive beamforming." IEEE Transactions on Antennas and Propagation, 30.1 (1982): 27-34.

Van Trees, H. Optimum Array Processing. New York: Wiley-Interscience, 2002.

Johnson, D.H., and Dan E. Dudgeon, Array Signal Processing, Englewood Cliffs: Prentice-Hall, 1.