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Detection of Low Power Signal in Presence of Interference Signal

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ABSTRACT: Beamforming is a technique of receiving signal using more than one antenna to efficiently remove noise and attain desired isolation from nearby interferences. In this paper MVDR beamforming technique is used to remove interference of corrupting signal with higher power compared to low power of desired signal. The message signal is recovered efficiently without much loss in information in presence of both channel noise as well as interference from nearby antennas

I. INTRODUCTION

Beamforming is the process of using a spatial filter to process the data obtained from an array of sensors so as to enhance the amplitude of the target signal waveform relative to the noise and interference present. Beamforming has also been delineated in different ways to separate the target signal from a mixture of signals which also contains interference and noise.

There are mainly two approaches to beamforming namely Conventional beamforming [1] and Adaptive Beamforming [2,3]. An adaptive filter has an adaptation algorithm, which is meant to monitor the environment and vary the filter transfer function accordingly. The transfer function of the filter can be modified by changing the weights which will suppress the noise and enhance the signal strength. Conventional beamforming is the simplest approach to beamforming in which the weights remain constant and does not depend upon the incoming signal. In Adaptive beamforming the algorithm correlate the weight according to the incoming signal and the weight vectors are optimized to achieve the detection of the desired signal in a noisy environment.

In this paper, beamforming technique used is MVDR (Minimum Variance Distortionless Response) beamforming. It is a technology that picks the weight in such a way to make the output power and the gain in the desired direction as unity. This weight optimization leads to effective interference rejection as the direction of strong interference is nulled out.

The MVDR beamformer[4,1] offers a much better performance than a phaseshift beamformer[4,5] which was earlier used. In a phaseshift beamformer interference from a nearby radio tower can blind the antenna array in that direction.This occurs when the desired signal is received by a sidelobe. MVDR beamformer addresses this problem as it preserves the signal arriving along a desired direction, while trying to suppress signals coming from other directions.

In the practical scenario, the received signal at the sensor array may contain the desired signal, interference and ambient noise. This paper explains how MVDR beamforming can be used to recover the target signal in the presence of interference. Practically it is impossible to remove the interference completely without distorting the target signal. The complete removal of interference will lead to amplification of ambient noise. Here we attempt to recover the low power target signal in the presence of high power interference and analyze the performance of the system when various parameters are varied. Here the performance of the system is highly improved by training the receiver according to the prior information that we have about the interferences that might be present.

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II. TWO KNOWN INTERFERENCE SOURCES

Suppose we have three network providers at a particular location. Let the network providers be X,Y and Z(Fig 1). Consider you are using the network Y so the signals X and Z are interferences which disrupts the communication.

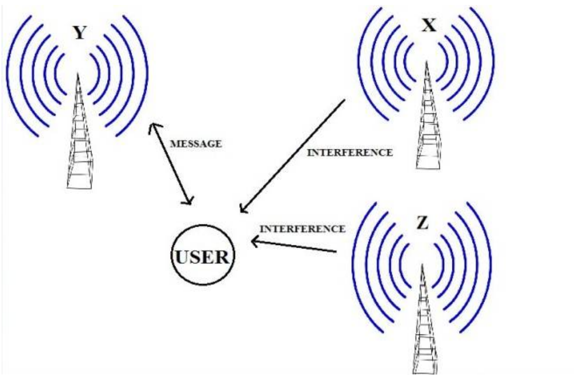

Fig. 1: Single user in interference environment

In such cases we can make use of the technology proposed in this paper to receive the target signal efficiently by doing MVDR beamforming at the receiver which eliminate the interferences. Since, exact location and exact angle of arrival of interferences are known, these are included to train and obtain weights of MVDR to retrieve signals from Y even when the interferences from X and Z have much higher power signals compared to desired signal from Y. This is the need of the hour as all service providers are installing their towers at small intervals for better service. This would lead to smaller spatial isolation between adjacent towers of different service providers.

III. AN OVERVIEW OF MVDR ALGORITHM

The signal output at the i th element of an array in vector notation is represented by

$$X(t)=A(x)s(t)+n(t) \tag{1}$$

Now the covariance matrix can be computed as

$$R=[XX^H] \tag{2}$$

Where $(.)^H$ is the complex conjugate operation .If the number of snapshots(a snapshot is the state of a system at a particular point in time) are limited to L, the estimated covariance matrix computation becomes

$$R = \frac{1}{L}[XX^H] \tag{3}$$

MVDR algorithm which is also known as **Capon algorithm,** was originally introduced by J. Capon. The main idea of this algorithm is to reduce the total received power in all direction while keeping unity gain in the 'look direction' ie, the direction of arrival of the target signal.

$$\min w^H \hat{R} \quad \text{subject to} \quad a(x) = 1 \tag{4}$$

Where 'w' is the weight to be calculated and 'a' is the steering vector. By applying Lagranges Optimization [6] method the weight can be found out as

$$w = \frac{\hat{R}^{-1} a(x)}{a^H(x)\hat{R}^{-1} a(x)} \tag{5}$$

Using this optimized weight the spatial power spectrum of the MVDR is given by

$$P = \frac{1}{a^H(x)\hat{R}^{-1}a(x)} \tag{6}$$

IV. ANALYSIS

Here we are trying to recover the transmitted signal in the presence of interference and noise. Suppose the desired target signal is coming at an angle of 45 degrees azimuth and the interferences are present at angles 30 degree azimuth and 50 degrees azimuth respectively. The test input signal is pulse signal

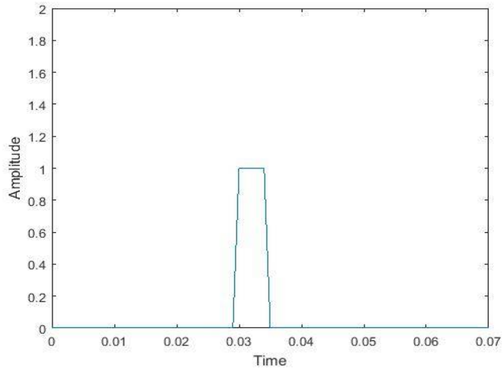

Fig. 2: Input signal

Three cases of interferences are considered to test the program. MATLAB™ 15 is used as platform for testing.

1. Only channel noise is present.

Noise refers to those random, unpredictable, and undesirable signals, or changes in signals, that mask the desired information content. The recovery of the target signal become more and more difficult as the channel noise is increased. Distortions are introduced in the recovered signal as the channel noise increases. In this work, we have considered AWGN noise as channel noise. Simulation is done for different SNR values.

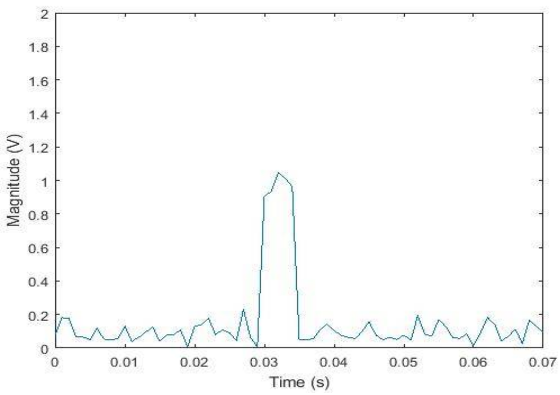

Fig. 3: Output of MVDR beamformer in presence of larger value of channel noise(SNR=6)

A margin of 0.3 is allotted for both signal ripple as well as outside band noise. This gives a good noise margin of 0.7 between presence and absence of signal. Fig. 3 shows the worst case of SNR = 6. Even for such low SNR, signal detection is possible with ripples within tolerable limits.

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2. Only interference is present

In this case modeled interferences are high power signals and target signal is recovered.As the power of the interferences increases, they might cause loss in data.

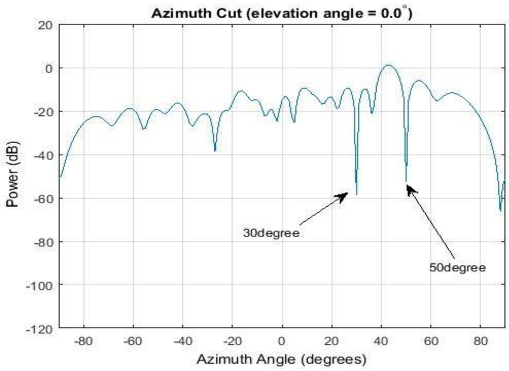

Fig. 4: Antenna radiation pattern in presence of small value(10 times higher) of interference

But if we have prior knowledge of the interference signal then the target signal can be recovered more efficiently. Fig 4 and 5 shows antenna radiation pattern for different values of interference signal. In Fig 4VERY small amount of information is lost due to nulling the interference signals from directions 30° and 50°

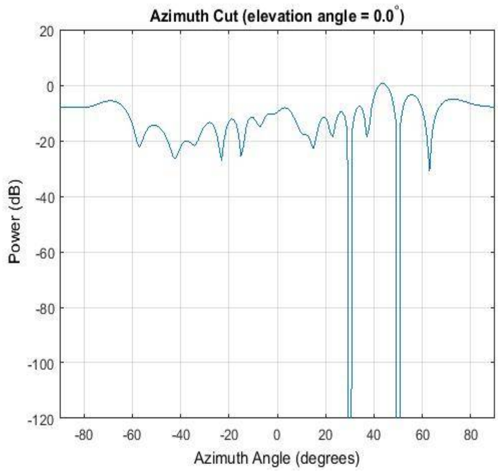

Fig. 5: Antenna radiation pattern in presence of larger value(40 times higher)s of interference

As amount of interference signal increases width of null region also increases. But in the both case we recover the information.

3. In the presence of Interferences and noise

When both interference and noise is present, the system is more effected due to the increase in noise power rather than increase in interference signal power. The channel noise can be reduced by increasing the number of elements in the array.

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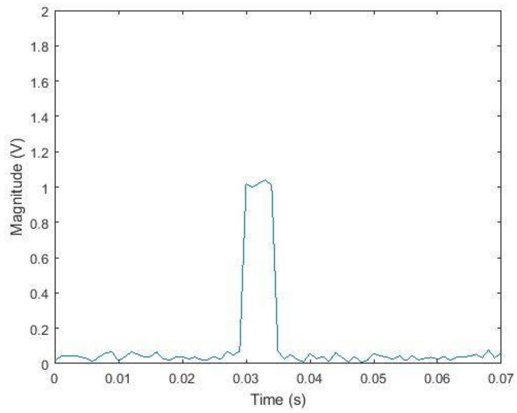

Fig. 6a: Output of MVDR beamformer in presence of high interference and low noise

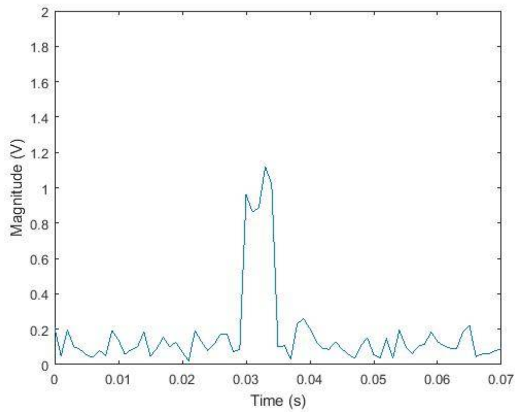

Fig. 6b: Output of MVDR beamformer with presence of high interference and high noise(SNR=6)

V. PERFORMANCE ANALYSIS

A. When direction of arrival of message signal and interference signal over lap

In this case direction of arrival of message siganl overlaps with direction of arrival of interferece signal.As a result of this we fail to recover the information at the end of the reciever unit.Fig 7. Shows output of MVDR beamformer.In this case we fail to recover the information.

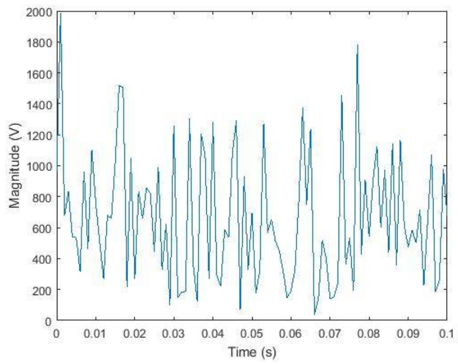

Fig. 7: Output of MVDR beamformer when arrival direction odf interference and message siganal overlap.

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B. Number of array elements

If number of elements increases resolution of the radiation pattern get increases.As the number of elements increases peak became more sharper.

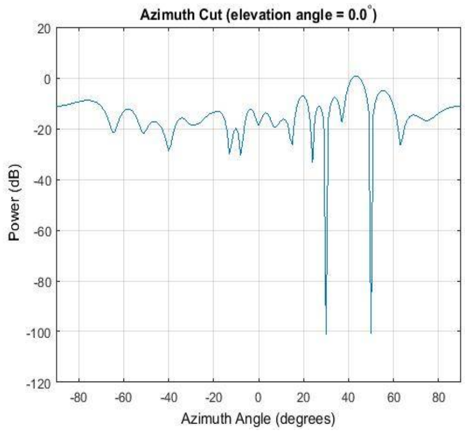

Fig. 8: Number of elements is 20

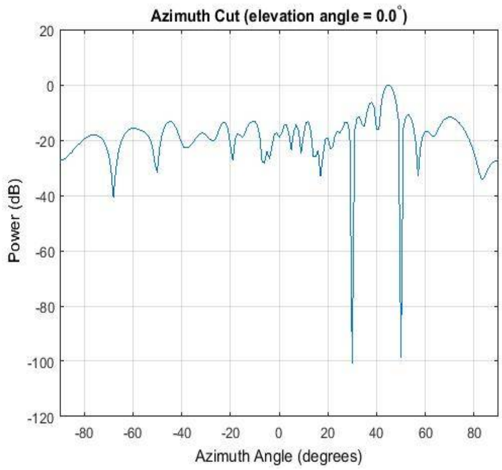

Fig. 9: Number of elements is 30

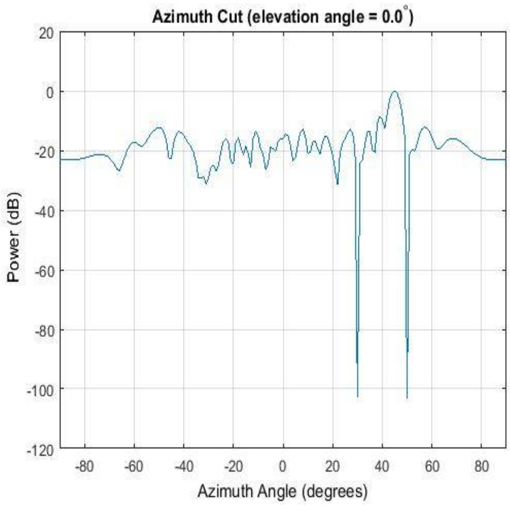

Fig. 10: Number of elements is 40

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Above figures shows the antenna pattern for different number of arrays
From the Figures 8,9, and 10 we can see that there is a peak at 45 degree which is the target signal and there are nulls at at 30 degrees and 50 degrees where interferencs are present
C. When interferences are very close to target signal

If the arrival direction of one of interferences are very close to the target signal for example, if interferences are present at 44 degrees and 60 degrees then also we could recover the target signal with minimum distortion only when SNR=20(for n=15) and the MVDR beamformer output is shown in Fig.11and the recovered.signal is shown in Fig 12

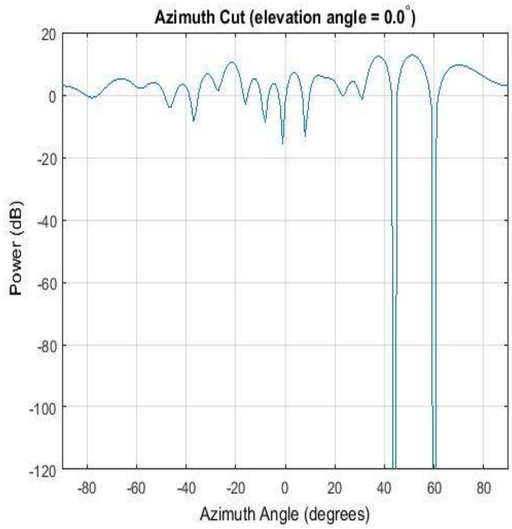

Fig. 11: Antenna radiation pattern for an interference at 44degrees.

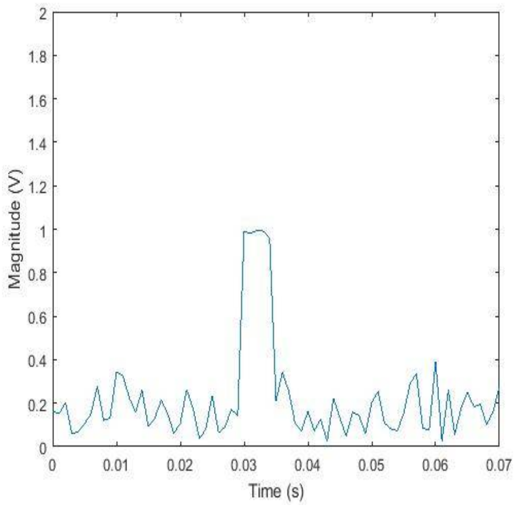

Fig. 12: Output of MVDR beamformer for an interference at 44degrees.

VI. CONCLUSION

In this paper we provided some new insights into MVDR beamforming in the case of noise reduction and interference removal. The noise reduction capability can be enhanced by using higher number of elements in the array.

MVDR beamforming allows this system to elimaimate high power interference and recover the target signal even if their DOA is very close to each other.

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