# A New Neural Network DOA Estimation Technique Based on Subarray Beamforming

S. Caylar[12]

*Abstract* – **A new neural network DOA estimation technique based on subarray beamforming is proposed. The proposed technique improves previously reported modified neural multiple source tracking algorithm (MN-MUST). MN-MUST algorithm has three stages, the new technique replaces the first two stages of it with a new beamforming stage based on subarrays. The whole direction of arrival angular region is divided into subsectors as in MN-MUST. Detection and filtering stages are replaced by subarray beam forming stage. Subarray beamforming stage filters out the signals outside the sector of interest. Beamforming is not the scope of this study however, the phase differences between virtual subarrays are used in DOA estimation stage. The proposed algorithm dramatically reduces process of MN-MUST algorithm, thus improves the accuracy and speed.**

## 1 INTRODUCTION

In recent years neural network algorithms in both target tracking problem and DoA estimation have become popular because of the increased computational efficiency. The neural multiple-source tracking (N-MUST) algorithm was presented for locating and tracking angles of arrival from multiple sources [1]. Modified neural multiple source tracking (MN-MUST) algorithm [2] improved the performance of N-MUST algorithm [1].

Besides neural network algorithms, there are quite a few numbers of studies on conventional methods, such as multiple signal classification (MUSIC) and estimation of signal parameters via rotational invariance techniques (ES-PRIT). A recent study using conventional method, DOA estimation technique based on subarray beamforming is proposed in [3].

In this study subarray beamforming is used to filter out the signals outside the sector of interest. Every sub-sector in the DOA angular range has its own beamformer. The beamformer for a chosen angular subsector has the summation of the signals impinging from the subject angular subsector.The virtual subarrays are used to create phase differences between the summations of signals. The signals of virtual subarrays are the summations of sources which are needed to be estimated. However, the phase differences between the virtual arrays are still having the direction of arrivals inside the sector of interest.

## 2 SIGNAL MODEL

DOA estimation problem is formulated as follows: $M$ isotropic antenna elements are placed along a line and separated by a uniform distance $d$ as shown in Fig.1. The number of sources (targets) is $K$ . Where $K$ is not known and it is allowed to exceed $M$ . The antenna elements are omni-directional point sources. The angle of incidence of each source is $\Theta_i$ , $i = 1,2,...,K$ which are required to be determined.

The sources are assumed to be located in the far field of the antenna array, so the difference in the viewing angle of a given source by the different antenna element is neglected. The signal received on each antenna element can be written as;

$$X_i(t) = \sum_{m=1}^{K} S_m(t) e^{-j(i-1)k_m} + n_i(t) \qquad i = 1,2,..., M \quad (1)$$

Where $n_i(t)$ is the noise signal received by the i-th antenna element and $k_m = \frac{\omega_0 d}{c}\sin(\Theta_m)$, d is the spacing between the elements of array, c is the speed of light in free-space, and $\omega_0$ is the angular center frequency of the signal.

In matrix form,

$$X(t) = AS(t) + N(t) \quad (2)$$

and each entry of $A$ is defined as;

$$A_{il} = e^{-j(i-1)k_m} \quad (3)$$

## 3 NEURAL NETWORK DOA ESTIMATION TECHNIQUE BASED ON SUBARRAY BEAMFORMING

The virtual subarray geometry and the structure of neural network DOA Estimation technique based on subarray beamforming are shown in Fig. 1. There are T virtual subarrays. The virtual subarrays consist of four elements in this work. The signals of $n$ -th virtual array can be expressed as;

[1] 3rd ASMC, TUAF, 06790 Etimesgut Ankara, Turkey
[2] METU Dept. of Electrical and Electronics Eng., 06531 Ankara, Turkey,
e-mail: s_caylar@hvkk.tsk.tr, tel.: +90 312 2984129, fax: +90 312 2491079.

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$$y_{VSn} = [x_n(t) \quad x_{n+1}(t) \quad x_{n+2}(t) \quad x_{n+3}(t)]^T \quad (4)$$

The whole direction of arrival angular spectrum is divided into $P$ angular subsectors. Therefore there are $P$ beam formers. Each beam former minimizes the signals coming outside the sector interest and passes the signals inside the sector of interest. It behaves such a band pass filter. However, the output signal of the beam former is the summation of the signals inside the angular sector of interest. Each beam forming network runs for only virtual subarrays separately. Hence the uniform linear array is chosen, the beamformer for each virtual array is identical. The output signal of sector-$i$ $(0 < i \leq P)$ beam former for virtual subarray-$n$ $(0 < n \leq T)$ can be defined as;

$$q^i_{sn}(t) = W_i y_{VSn}(t) \quad (5)$$

Where $W_i$ is the weighing vector $i$-th angular subsector beamformer.

The virtual subarrays form a new $T$ element array and the signals of each elements is given by Eq. 6. Then the signal of the new $T$ array in vector form can be defined as;

$$Q^i(t) = [q^i_{s1}(t) \quad \ldots \quad q^i_{sn}(t) \quad \ldots \quad q^i_{sT}(t)]^T \quad (6)$$

noise signals, $\{n_i(t), \quad i = 1:M\}$ received at different antenna elements of the array are assumed to is statistically independent zero mean white noise signals with variance $\sigma^2$ independent of $S(t)$. The spatial correlation matrix $R$ of the received signal (new $T$ element array) for angular sector-$i$ is given by ;

$$R^i = E\{Q^i(t)Q^i(t)^H\} \quad (7)$$

"H" is denoting the conjugate transpose.

Based on Eq. 8, the array can be considered as a mapping, $G : R^K \rightarrow C^M$, from the space of DoA's $\{[\theta_1, \theta_2, \ldots, \theta_K]^T\}$, to the space of antenna element output $\{[X_1(t), X_2(t), \ldots, X_M(t)]^T\}$. In order to construct the inverse mapping, $F : C^M \rightarrow R^K$, a multistage architecture using NNs are employed. The block diagram of DoA estimation is given in Fig. 1.

In general, array-processing algorithms utilize correlation matrix for direction of arrival estimation instead of the actual array output $Q(t)$. In this paper a similar approach is followed. First raw of correlated matrix is used for uncorrelated source case as in [2].

$$R^i = \begin{bmatrix} R^i_{11} & \ldots & R^i_{1T} \\ . & \ldots & \\ R^i_{T1} & \ldots & R^i_{TT} \end{bmatrix} \quad b^i_1 = [R^i_{11} \quad \ldots \quad R^i_{1T}] \quad Z^i = \frac{b^i_1}{\|b^i_1\|} \quad (8)$$

The rest of the algorithm is similar to DOA Estimation stage of MN-MUST algorithm in [2].

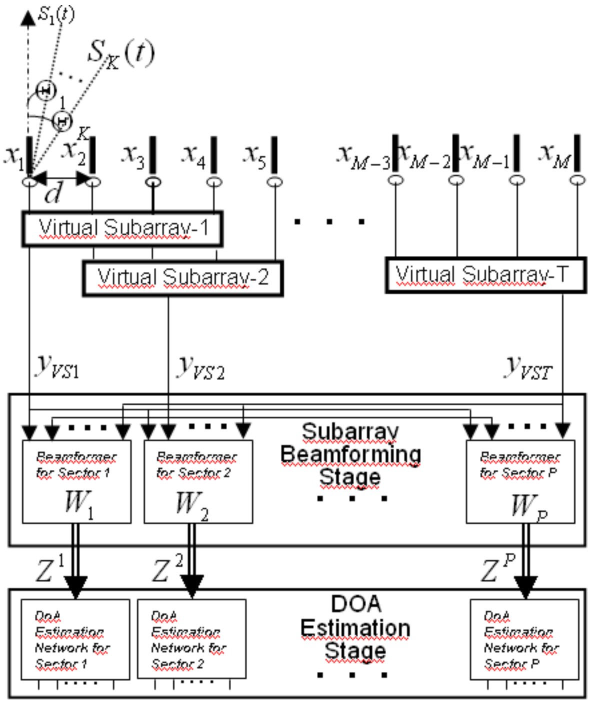


Figure-1 Neural Network DOA Estimation Technique Based on Subarray Beamforming algorithm architecture.

## 4 SIMULATIONS

The proposed technique is implemented on a eight-element uniform linear array. The angular spectrum between $0^O - 59^O$ is divided into 6 angular sectors in 10-degree intervals. The angular separation is 1 degree within each angular sector. Six different beamformer are established for six angular sectors. Virtual subarrays consist of four elements. Four different virtual sub arrays are formed out of eight elements. DOA estimation stage is based on 4 virtual arrays output as four-element array of MN-MUST algorithm. Six separate DoA networks are trained to find the actual targets location within the corresponding sectors. The proposed technique is run for five targets in four angular sectors case. SNR is 20 dB. The results are given in Fig. 2.

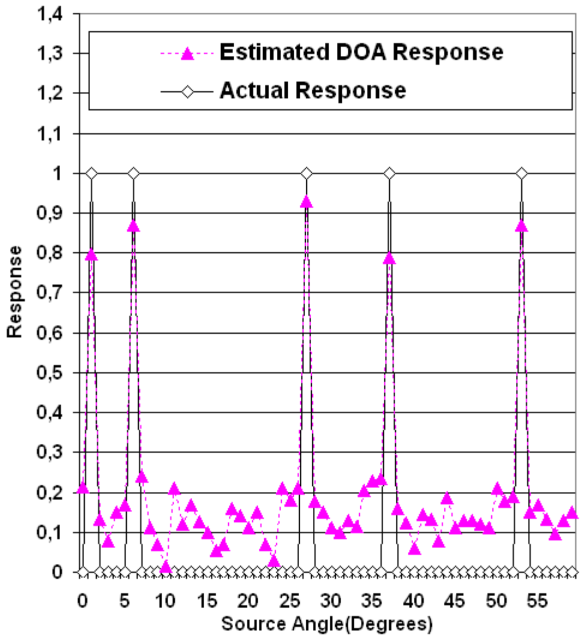


Figure-2 Five targets in four sectors in eight-element array (Targets are at 1, 6, 27, 37 and 53 degrees)

## 5 CONCLUSION

A new neural network DOA estimation technique based on subarray beamforming is proposed. The proposed technique uses subarray beamforming[3] as a first step for DOA estimation problem. The contribution of this study is to improve the performance in both accuracy and speed while keeping the advantages of neural network DOA estimation [1-2] over conventional methods [3].

It is demonstrated through computer simulations that the performance of the proposed technique is quite satisfactory and applicable for real time target tracking and DoA estimation problems.

## References


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