A SIMPLIFIED APPROACH FOR RADIO DIRECTION FINDINGS

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1. Introduction

In conventional beamformer, the various sensor outputs are delayed and then summed. Thus, for a single target, the average power at the output of the delay-and-sum beamformer is maximised when it is steered towards the target. The response along a direction of interest however depends not only on the power of the incoming target signal but also undesirable contributions from other sources of interference. A major limitation of this conventional (delay-and-sum) beamformer, however, is that it has no provisions for dealing with sources of interference.

To overcome the limitation of the conventional beamformer, optimal beamformer is introduced through which the weighting factors are made adaptive in such a way that it places nulls in the direction(s) of the source(s) of interference automatically in real time. Hence better target resolution is achieved. To achieve higher resolution in target detection, Schmidt [1] proposes, an algorithm for multiple-signal characterisation (MUSIC), based upon the eigenstructure decomposition of spatial correlation matrix, for estimation direction of arrival of multiple plane wave. Similar works using eigenanalysis techniques have also been reported by Johnson & DeGraaf [2], Pisarenko [3], and Kumaresan and Tufts [4]. In this paper, the application of MUSIC algorithm is extended to multiple frequencies radio direction finding. A simplified approach based on MUSIC is applied at various frequencies for detection of locations of radio stations. The MUSIC algorithm was chosen over other eigenanalysis techniques because it has been reviewed extensively and its performance characteristics are well known.

Section 2 of this paper defines the problem and its mathematical formulation. The sequence of computations for the proposed simplified approach is given in Section 3. The numerical results of computer simulation are discussed in Section 4. The paper is then concluded with some recommendations for further works.

2. The MUSIC Algorithm

The multiple signal characterisation (MUSIC) algorithm [1] is an implementation of the subspace technique multiple source location for signal parameter estimation. For estimation of the direction of arrival (DOA), or for direction finding of radio stations, by means of eigenstructure analysis of the spatial correlation matrix (R) between the individual sensor (antenna) signals, it is possible to decompose the complex vector space of R into the noise subspace (within which no signal lies) and the signal subspace (within which all signals must lie). The signal subspace or the noise subspace contains all the information about the source number and the direction (angles) of arrival, DOA.

Thus the spatial correlation matrix can be written as

$$R = [U_s\ U_n] \begin{bmatrix} A_s & 0 \\ 0 & A_n \end{bmatrix} \begin{bmatrix} U_s^H \\ U_n^H \end{bmatrix} \qquad (1)$$

where U_s and U_n are N x p and N x (N-p) dimensional matrices defined by

$$U_s = [\underline{V}_1,\ \underline{V}_2,\ \ldots,\ \underline{V}_p] \qquad (2)$$

$$U_n = [\underline{V}_{p+1},\ \underline{V}_{p+2},\ \ldots,\ \underline{V}_N] \qquad (3)$$

A_s and A_n are the p x p and (N-p)x(N-p) diagonal matrices given by

$$A_s = \mathrm{Diag}[\lambda_1,\ \lambda_2,\ \ldots,\ \lambda_p] \qquad (4)$$

$$A_n = \mathrm{Diag}[\sigma_n{}^2,\ \sigma_n{}^2,\ \ldots,\ \sigma_n{}^2] \qquad (5)$$

The p largest eigenvectors of R are the p orthonormal vectors which span the subspace containing the signal vertors $\{\underline{S}_i,\ i = 1,\ 2,\ \ldots,\ p\}$, known as the signal subspace. The remaining eigenvectors span the subspace known as noise subspace and which is orthogonal to the signal subspace.

With the noise subspace approach, it is possible to find the source locations (values of θ) for which the following function has nulls

$$g(f_o,\ \theta) = \sum_{i=p+1}^{N} |\underline{S}^H (f_o,\ \theta)\ \underline{V}_i|^2 \qquad (6)$$

where p is the number of incoherent signal source with centre frequency, f_o. N is the number of isotropic element in an array system $\underline{S}(f_o,\ \theta)$ is the steering vector, $\underline{V}$ is the eigenvectors of R.

In MUSIC system deseribed by Schmidt [1], the source locations can be found by plotting

$$S_{MUSIC}(\theta) = [g(f_o,\ \theta]^{-1} \qquad (7)$$

where $\underline{S}(f_o,\ \theta)$ coincides with any one of the source locations, $g(f_o,\ \theta) = 0$ or a peak is obtained using equation (7).

It should be noted that MUSIC algorithm is also valid for multiple source with different centre frequency. However, linear array structure seems to give spurious peaks at other locations in addition to source locations. The simulation results in this paper support the finding.

3. A Simplified Approach for Radio Direction Finding

It is common in practice to find two or more radio stations operating at different centre frequencies in the vicinity within a signal environment. In this section, an approach based on MUSIC is proposed for this two dimensional estimation of direction of arrival of signal source. The sequence of computations for this proposed simplified approach is given as follows.

(i) Compute the spatial correlation matrix R, using estimated data obtained from random process simulation.

(ii) Decompose the matrix R into its eigenvectors and eigenvalues.

(iii) Determine the number of source (P) present.

(iv) Scan the signal environment using equation (7) and with the source's centre frequency.

(v) Plot the scan spectrum given in equation (7) for each scan. There should be P plots containing P peaks (i.e. one peak per plot) or p number of radio stations.

(vi) Estimate the directions of these radio stations by determining the positions of the peaks in the plot.

4. Numerical Results

To illustrate the implementation of the proposed simplified approach given in Section 3, computer simulations have been carried out on both a linear and a circular array system each having ten equally spaced isotropic elements. The interelement spacing in the case of linear array, and interring spacing (5 elements per ring) in the case of circular array, were both fixed at 0.5 λ_o, where λ_o is the wavelength and is equal to propagation velocity of wave (c)/centre frequency of signal (f_o). The signal environment is assumed to have three radio stations each operating with different centre frequencies and emitting 0 dB directional power. Uncorrelated sensor noise (white Gaussian) of 30 dB was also included.

In figure 1, 1024 samples were used to estimate spatial correlation matrix for a linear array system, for each of the three plots of equation (7), spurious peaks were observed at locations which are not corresponding to their true locations. This is due to the special characteristic of linear array system where a source if scanned by centre frequency other than its own centre frequency will still give rise a peak but at other location. Therefore there is ambiguity in using linear array system for two dimensional (frequency as well as spatial) spectral estimation of signal parameters.

In figure 2, instead a circular array system was employed with 1024 samples & 64 samples respectively yielded almost identical results. The peaks (three), one for each plot correspond to three different radio stations from three different locations were observed. The source separation is 2^o apart.

5. Conclusion

The paper has verified that MUSIC algorithm can be used for two-dimensional (frequency as well as spatial) spectral estimation of radio direction finding using circular array system. The proposed simplified approach for this application may be extended to multipath or coherent signal sources if some form of frequency or time domain smoothing filtering is incorporated in equation (7). Work on performance of a direction finder is investigated under the conditions of an incorrectly partitioned eigenvector matrix by Johnson [5] for one dimensional case. Further works on the performance of incorrectly partitioned eigenvectors for two dimensional case are under investigation of the authors.

6. References

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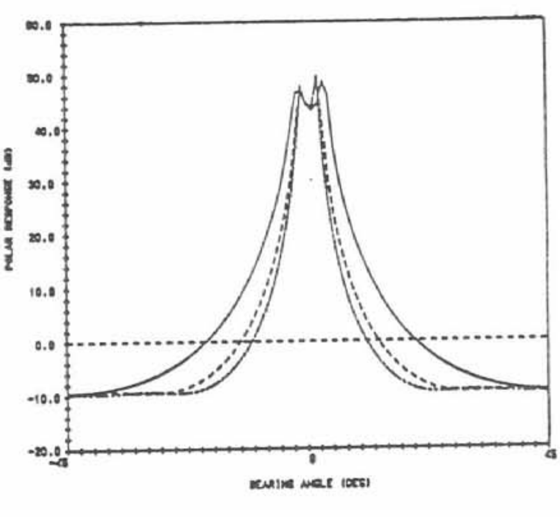

Fig. 1

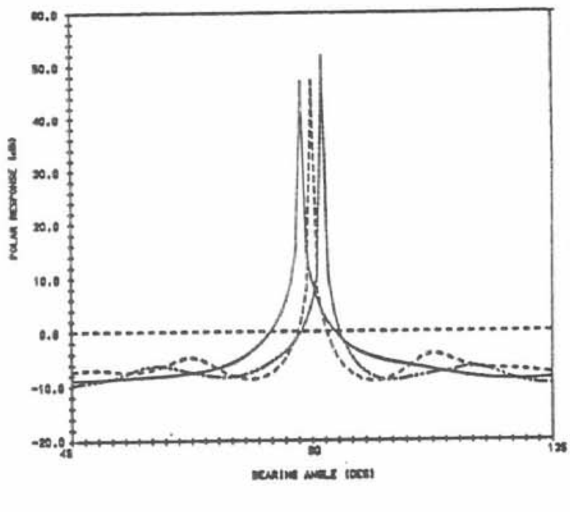

Fig. 2