Interference Reduction and DOA Estimation in GSM Systems

Nsionu I I, Onoh G N, Ekeh J, Eneh I I

Abstract- This paper considers improvement in the performance of mobile wireless communication through interference reduction in the system. By deploying Adaptive Uniform Linear Arrays in the latest generation of mobile communication systems, it is possible to achieve enhancement in the array output in the direction of a given desired mobile terminal while at the same time suppressing undesired signal from another mobile terminal which may or may not be operating with the same carrier frequency. It is understood that a single signal can have different propagation paths and therefore different directions of arrival at a given receiver. The implication is that for several transmitters, each source potentially creates many multipaths at the receiver which will now have to select from the multiple inputs. There is therefore the need for the system to decipher which sources are present and their possible directions. The data obtained in the process will be used to either eliminate or combine signals for greater fidelity through deliberate signal enhancement or suppression. The technique of Multiple Signal Classification shall be used in this paper to find signal Direction of Arrival.

Index Terms: Interference Reduction, Adaptive, Uniform Linear Array, Multiple Signal Classification, Direction of Arrival, Multipath,

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1.0 INTRODUCTION

There is an unprecedented growth in the demand for wireless communication services. The obvious challenge for network providers is the provision of quality voice and high speed data services. Following initial system deployment, subscribers enrollment tend to increase on daily basis and attempts to accommodate every new subscriber gives rise to unavoidable interference. As a result, network capacity drops.

Interference is of three categories: Intersymbol-signal delay which arises due to multipath. This results in poor BER performance. Next is Co-channel interference which arises due to multiple access. This results in limitation in network capacity. Then Adjacent Channel interference which arises due to signals adjacent in frequency to the desired signal. This also results in network capacity limitation.

Interfering signals arrive at the receiver from different directions in space. Therefore, spatial processing will be required to check the menace. Each interfering signal has distinct spatial signature which will be exploited by adaptive uniform linear arrays (or Smart Antennas). One of the spatial signatures is the Direction of Arrival, DoA which will be explored using intelligent signal processing algorithms.

The two main functions of the adaptive antenna are Direction of Arrival Estimation and Array Pattern Synthesis. This paper concentrates on the Direction of Arrival Estimation. This spatial signature enables the system to determine which signal to accept or reject.

2. PROBLEM SETUP

Let us consider 4 signals impinging on 32 element arrays with element spacing 0.5λ, where λ corresponds to the carrier frequency. Let the directions of arrival of the signals be $\theta_1 = 14^o, \theta_2 = 28^o, \theta_3 = 35^o \, and \, \theta_4 = 55^o$

The goal of DoA estimation is to use data at array to estimate $\theta_1, \theta_2, \theta_3 and \theta_4$. Of course, the inherent challenges in situations like this in real time are (1) unknown number of signals, (2) unknown directions (3) unknown amplitudes (4) signal corrupted by noise.

3. METHODOLOGY

This paper shall consider the adoption of the subspace based method called *music* which stands for Multiple Signal Classification. The *space* is divided into *signal* and *noise* subspace. *Music* exploits the noise eigenvector subspace. The noise space is spanned by eigenvectors corresponding to the smallest eigenvalues of the array correlation matrix. Given that D signals impinge on M elements; the number of signal eigenvalues and eigenvectors is D, and the number of noise eigenvalues and eigenvectors is M – D.

The array correlation matrix, R_{xx} is given by [1],

$$R_{xx} = A * R_{ss} * A^H + \sigma_n^2 I$$

Where R_{ss} = source correlation matrix

$R_{nn} = \sigma_n^2 I$ = noise correlation matrix

$A = [a(\theta_1) \quad a(\theta_2) \quad a(\theta_3).... \quad a(\theta_D)]$ is an $M \times D$ steering vector.

$R_{ss} = [s_1(k) \quad s_2(k) \quad s_3(k)... \quad s_D(k)]^T$ *is* a $D \times D$ matrix.

The array correlation matrix has D eigenvectors associated with signals and $M - D$ eigenvectors associated with noise

The subspace $M \times (M - D)$ is spanned by the noise vectors such that

$$E_N = [e_1 \quad e_2 \quad e_3 \quad e_{M-D}]$$

Noise space eigenvectors are orthogonal to the steering vectors at the angles of arrival $\theta_1, \theta_2, \theta_3......, \theta_D$. MUSIC formula from the point of view of orthogonality condition, can be shown to be [1], [2]

$P_{music} = \dfrac{1}{\left| [a(\theta)^H \cdot E_N \cdot E_N^H \cdot a(\theta)] \right|}$ which yields sharp peaks at the angles of arrival

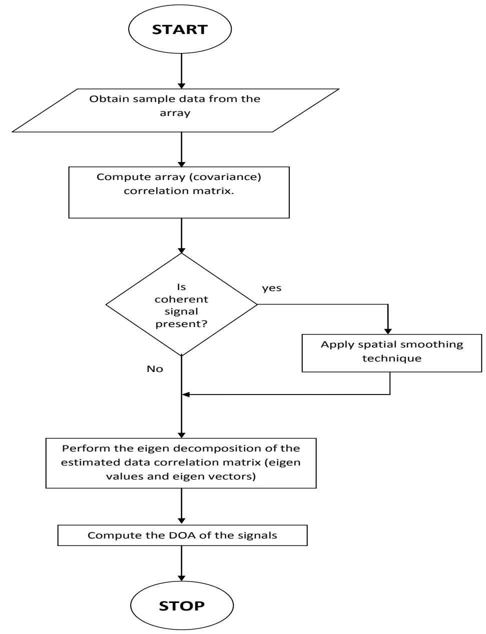

Fig. 1 Direction of arrival estimation flowchart

4. SIMULATION

The *music* technique is simulated using Matlab. The simulation was run for 4 signals coming from different directions as listed in the problem setup and which impinge on a 32 element array. To run the program, it has to be ensured that all files regarding the Music algorithm are in the same directory. The *main* programme is run in Matlab. The number of elements is entered, spacing between elements, number of desired signals with their corresponding angles of arrival. The program gives the estimated number of signals as output along with the array pattern plots. All that is required is to obtain the values of the highest peaks to get the direction of arrival [3]

The flowchart for the estimation of the direction of arrival is shown in fig. 1.

5. RESULTS

All 4 signals and their directions are resolved accurately as shown in the table below containing the desired signal direction and the actual output of the system [4]

Table 1: Table of values of the actual array output and the intended system output

Desired θ (degree)	14	28	35	55
Output θ (degree)	14	28	35	55

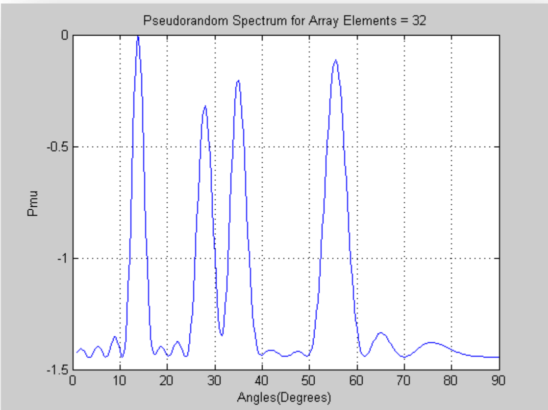

Fig. 2: Plot for estimated directions of arrival

6. CONCLUSION

The estimation of the signal direction was carried using the MUSIC algorithm was carried out in this paper. From the $\theta = 14^o, 28^o, 35^o, 55^o$ along the peak of *music* spectra for 32-element array analysis shown, it is certain that finding the direction of arrival of signals (including the desired and interfering signals) will help a great deal in the problem of interference suppression in gsm systems. Estimates with relatively high accuracy can be obtained with signals closely spaced in angles- co channel interference. This means that interferences in close vicinity of the desired signal can be mitigated

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Nsionu I I – Federal Polytechnic, Oko, Nigeria

Onoh G N- Enugu State University of Science & Technology Enugu, Nigeria

Ekeh J- Enugu State University of Science & Technology Enugu, Nigeria

Eneh I I- Enugu State University of Science & Technology Enugu, Nigeria