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# The Estimation of DOA in Smart Antenna Systems

**Adil Majdoubi, Mohamed Essaaidi**

***Abstract*****: *Smart antennas systems are being the key solution to increase the spectral efficiency and improving the system performance in mobile communication. Smart antennas usually consist of a number of radiating elements (i.e. array antennas) whose individual excitation can be controlled by DSP (digital signal processor) in order to achieve the desired radiation pattern. The smart antennas systems estimate the direction of arrival of the signal, using techniques such as MUSIC (Multiple Signal Classification), and ESPRIT (estimation of signal parameters via rotational invariance techniques) algorithms. They involve finding a spatial spectrum of the antenna array, and calculating the DOA from the peaks of this spectrum. These calculations are computationally intensive..***

***Index Terms*****: *DOA, MUSIC, antenna array, spatial spectrum, beamforming.***

## I. INTRODUCTION

The objective of this paper is to give a general view of how an adaptive beamformer is able to automatically update the weight vector, in order to separate desired signals from interfering signals. Adaptive beamforming can be done in many ways. Many algorithms exist for many applications, varying in complexity. A generic adaptive beamformer is shown in Fig.1. The weight vector w is calculated using the signal x(t) received by multiple antennas. An adaptive processor will minimize the error e(t) between a desired signal d(t) and the array output. With the MUSIC algorithm which implemented and tested by MATLAB we can estimate the direction of arrival (DOA).

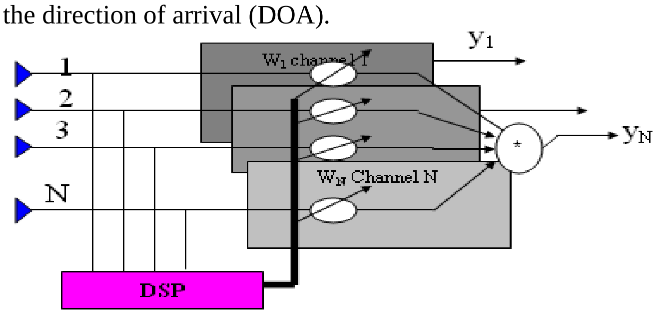


Figure 1. The smart antenna system structure.

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## II. PROCESSING OF PROBLEM

The signal processing algorithms, mainly governed by complex weight $w_k$ shifts the phase $a_k$ sets the amplitude $\theta_k$ for the $k^{th}$ antenna. The output $y(k)$ for time step $k$ is: $y(k)=w^H x(k)$

For nonstatic channels:

At first, we start with an arbitrary value of the weight vector $w(0)$, typically the zero-vector.

Second, we compute the gradient vector with respect to the actual weight vector $w(k)$

Third, we change the values of the actual weight vector by a constant parameter $\mu$ in negative direction of the gradient vector. The mathematical representation is:

$$w(k+1)=w(k)+\mu\left(-\frac{\partial MSE}{\partial W}\right)$$

$$w_{k+1}=w_k+\mu x(k)e^*$$ LMS algorithm

$e^*$ : The instantaneous error between the array output and desired signal.

### A. *DOA (direccional of arrival):*

The DOA estimation: denotes the direction from which a propagating wave arrives at a point of array antenna.

Types of DOA algorithms:

1. Conventional Methods.
2. Subspace Methods (MUSIC, ESPRIT).

Technique based on correlation matrix with eigenvalue decomposition (EVD), it is also called a subspace-based method.

$$R_{xx}=E\{x(t)x^H(t)\}$$

$$R_{xx}=AE\{s(t)s^H(t)\}A^H+E\{n(t)n^H(t)\}$$

$$R_{xx}=ASA^H+\sigma^2 I$$

The correlation matrix $R_{xx}$ it can be decomposed to signal and noise subspaces by the complex-valued as:

$$R=U_S\Lambda_S U_s^H+U_n\Lambda_n U_n^H$$

the eigenvalues are ordered as $\lambda_1\geq\lambda_2\geq\cdots\geq\lambda_L\geq\lambda_{L+1}=\cdots=\lambda_M=0$

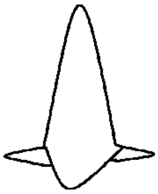
*B. The MUSIC algorithm:*

The noise subspace eigenvectors of corresponding eigenvalues $\sigma^2$ are orthogonal to the array response vectors.

$$U_n^H a(\theta_i) = 0 \ ; \ \theta_i \in [\theta_1 \cdots \theta_L]$$

the cost function: $P(\theta) = \dfrac{a^H(\theta)a(\theta)}{a^H(\theta)U_n U_n^H a(\theta)}$

Excitation vectors



Noise vectors

The peaks $\theta$ in the $P(\theta)$ of the signal, it estimates as the DOA.

### C. Simulation

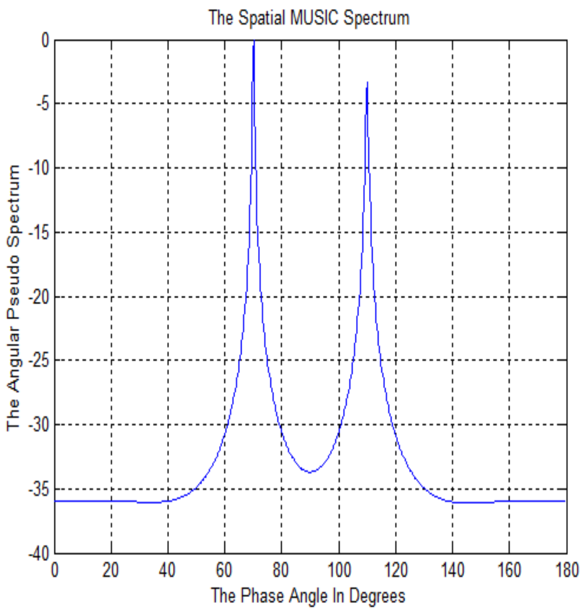



Figure 2. An ULA of 4 elements is used with half wavelength Spacing; N= 100 samples; SNR is 20 dB.

## III. MIMO SYSTEMS

That means multiple antennas at both transmitter (TX) and receiver (RX).

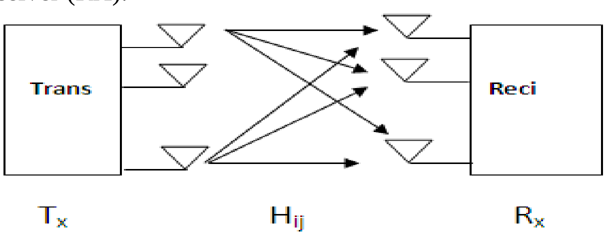



Figure 3. Block diagram of a MIMO link.

$y_j = H_{ij}x_i + n_j$ with $H_{ij}$ is The complex channel matrix.

**Capacity of ( MIMO) systems:**

Shannon: The capacity of one element of these channels is:

$$C \approx B\log_2\left(1 + \frac{N}{M}\cdot SNR_0\right)$$

B: is the bandwidth of channel.

But, since we have **M** of these channels (*M* transmitting antennas), the total capacity of the system is

$$C \approx M.B\log_2\left(1 + \frac{N}{M}\cdot SNR_0\right)$$

From Shannon's equation it would seem that there are two only two ways to increase the capacity of a communications channel:

$$C \approx M.B\log_2\left(1 + \frac{N}{M}\cdot SNR_0\right)$$

Increase Transmission Bandwidth (**B**)

Increase Signal-to-Noise ratio (**SNR**)

### *A. MIMO Techniques:*

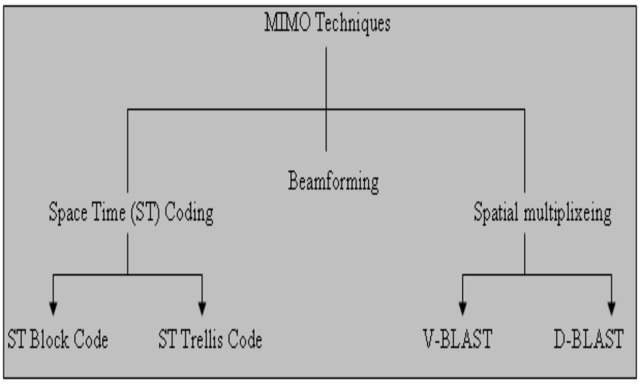



Figure 4. Schemes represented MIMO techniques

### *B. The reception algorithms:*

Algorithms for attained the symbols at the receiver antenna for MIMO systems:

- Minimum mean square error (MMSE) receiver.
- Zero forcing (ZF) receiver.
- Vertical-Bell Labs layered space-time (V-BLAST) receiver**.**

V-BLAST: steps of the V-BLAST algorithm:

1) *Nulling:* an estimate of the strongest transmit signal is obtained by nulling out all the weaker transmit signals.
2) *Cancellation:* These data bits (estimated signal) are demodulated and the channel is applied to estimate its vector signal contribution at the receiver.

### *C. Definition of DSP*

Designed specifically for digital signal processing, generally in real-time computing. Executing mathematical algorithms that are simple combinations of multiply and addition (MAC). The data is processed as streams of vectors.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### *D. Characteristics of DSP TMS320C64x:*

| | |
|---|---|
| MANUFACTURER | TexasInstrument,<br>Announced in February2000 |
| CLOCK (MHZ) | 400-600(MHz) instruction packet every1.67 ns. |
| PERFORMANCE | 3200-4800 (MIPS) |
| PRECISION | IS A 32-BIT FIXED-POINT FAMILY |
| OPTIMIZATION FOR | Fixed point processing power |

Table.1 characteristics of TMS320C64x

The memory system of C64x have a Harvard architecture providing separate address spaces for program and data memory.

## IV. METHODOLOGY OF APPLICATION

Implemented DOA algorithm in digital signal processor especially the (TMS320C64x) of Texas instrument.

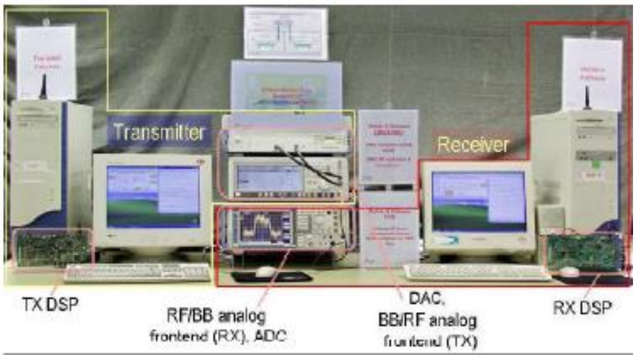


Image 1. Image represented practical study.

## V. CONCLUSION

Beamforming technique they introduce a several advantages for wireless communication. The simulation of the DOA estimation and beamforming algorithms gives an idea of the computational complexity involved for implemented an algorithm in a DSP system. Finally the DSP system especially C64x have more advantages for smart antenna systems.

## VI. ACKNOWLEDGMENT

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