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Robust DOA Estimation and data detection for coherent signals in Wireless Communication systems

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Outline

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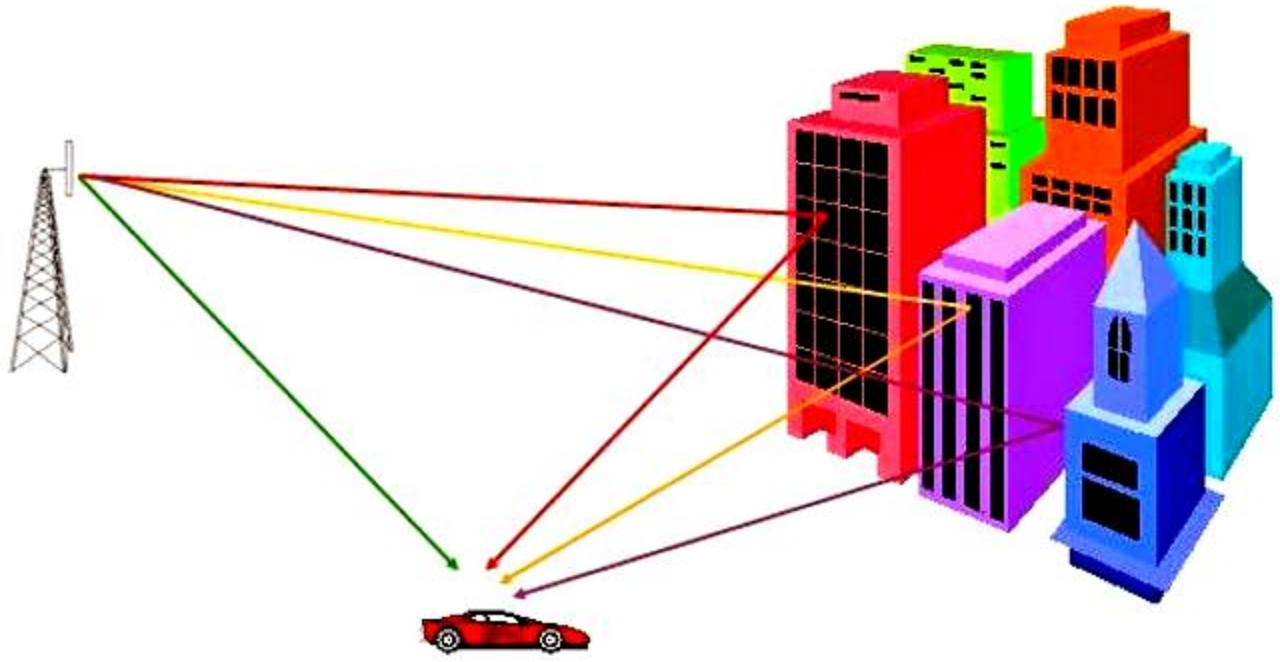
- Robust DOA Estimation
- Results and discussion
  - Angle of arrival estimation
  - Time difference of arrival estimation
  - Bit Error Rate calculation
- Conclusion

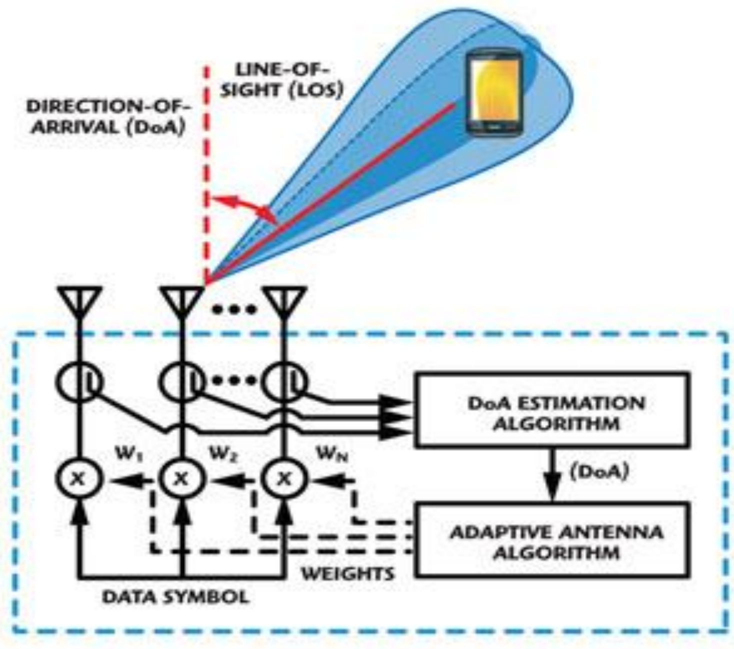
Introduction

In this research topic a new combination for robust Direction of Arrival (DOA) estimation and beamforming methods will be investigated for **smart antennas** used in wireless communication system in multipath environment.

Problem formulation

- Since the radio channel is highly dynamic, the transmitted signal travel to the receiver by undergoing many detrimental effects (multipath fading) that corrupt the signal and degrade the performance of the system.
- **Adaptive antenna arrays** are very efficient capacity enhancement techniques and also has been investigated to expand service coverage.





A Robust DOA estimation and beamforming used by Adaptive antenna arrays to solve many of those propagation problems

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

- This approach is based upon a recursive implementation of the minimum mean-square error (**MMSE**) framework. that automatically determines the **number of sources**, their respective **DOAs**, and **magnitudes**. Benefits of this approach include robustness to **coherent sources** such as can occur in multipath environments, enable "tracking" of sources with rapidly changing DOA.

System model:

Assume that there are K narrowband signals are received by a uniform linear antenna array of N-elements (K<N):

$$\boldsymbol{y}(t) = \boldsymbol{A}(\theta)\boldsymbol{x}(t) + \boldsymbol{v}(t)$$

$$\boldsymbol{x}(t) = \sum_{i=1}^{K} \alpha_i \, \boldsymbol{s}(t - \tau_i)$$

$$\boldsymbol{A}(\theta) = [\boldsymbol{a}(\theta_1) \quad \boldsymbol{a}(\theta_2) \ldots\ldots \quad \boldsymbol{a}(\theta_K)]$$

$$\boldsymbol{a}(\theta_i) = [1 \quad e^{-j2\pi\left(\frac{d}{\lambda}\right) sin\,\theta_i} \ldots \quad e^{-j2\pi\left(\frac{d}{\lambda}\right)(N-1) sin\,\theta_i}]$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

RECEIVED SIGNAL MODEL

Consider K signals, originating from sources in the far-field**:**

$$y(l) = \sum_{k=1}^{K} r_k(l) + v(l)$$

$$r_k(l) = x_k(l).\left[1e^{j\psi k} \ldots\ldots e^{j(N-1)\psi K}\right]^T = x_k(l)s(\psi_k)$$

by approximating the received signal model $y(l)$ with a parameterized version as:

$$s = [s(0) \quad s(\Psi_\Delta) \quad \cdots \quad s((M-1)\Psi_\Delta)]$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

$$s = \left[s(0) \quad s(\Psi_\Delta) \quad \cdots \quad s((M-1)\Psi_\Delta) \right]$$

$$= \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & e^{j\Psi_\Delta} & \dots & e^{j(M-1)\Psi_\Delta} \\ \vdots & \vdots & \dots & \vdots \\ 1 & e^{j\Psi_\Delta(N-1)} & \dots & e^{j(M-1)\Psi_\Delta(N-1)} \end{bmatrix}$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

being comprised of steering vectors with equally-spaced phase angles specified over 2π at an angular increment of $\Psi_\Delta = 2\pi / M$

RISR determines the N × M adaptive filter bank **W**(*n*) that minimizes the MMSE cost function:

$$J\left\{ \left\| x(n) - \mathbf{w}^H(n) y(n) \right\|^2 \right\}$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

Then:

$$w(n) = \left(SP(n)S^H + R\right)^{-1} SP(n)$$

To enforce the assumption of no temporal correlation, we define the spatial power distribution matrix as:

$$\widehat{\boldsymbol{P}}(n) = [\widehat{\boldsymbol{x}}(n)\widehat{\boldsymbol{x}}^H(n)] \odot \boldsymbol{I}_{M \times M}$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

Using:

$$\hat{\boldsymbol{x}}(n) = \boldsymbol{S}\boldsymbol{y}(n)$$

$$s = [s(0) \quad s(\Psi_\Delta) \quad \cdots \quad s((M-1)\Psi_\Delta)]$$

$$= \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & e^{j\Psi_\Delta} & \dots & e^{j(M-1)\Psi_\Delta} \\ \vdots & \vdots & \dots & \vdots \\ 1 & e^{j\Psi_\Delta(N-1)} & \dots & e^{j(M-1)\Psi_\Delta(N-1)} \end{bmatrix}$$

Robust DOA Estimation: The Reiterative Superresolution (RISR) Algorithm

After calculation of $w(n)$ then:

$$\hat{x}(n) = w(n)y(n)$$

Again as:

$$\widehat{\boldsymbol{P}}(n) = [\widehat{\boldsymbol{x}}(n)\widehat{\boldsymbol{x}}^{H}(n)]\odot \boldsymbol{I}_{M\times M}$$

then:

$$w(n) = \left(SP(n)S^{H} + R\right)^{-1} SP(n)$$

And so on untill convergence is ocuured

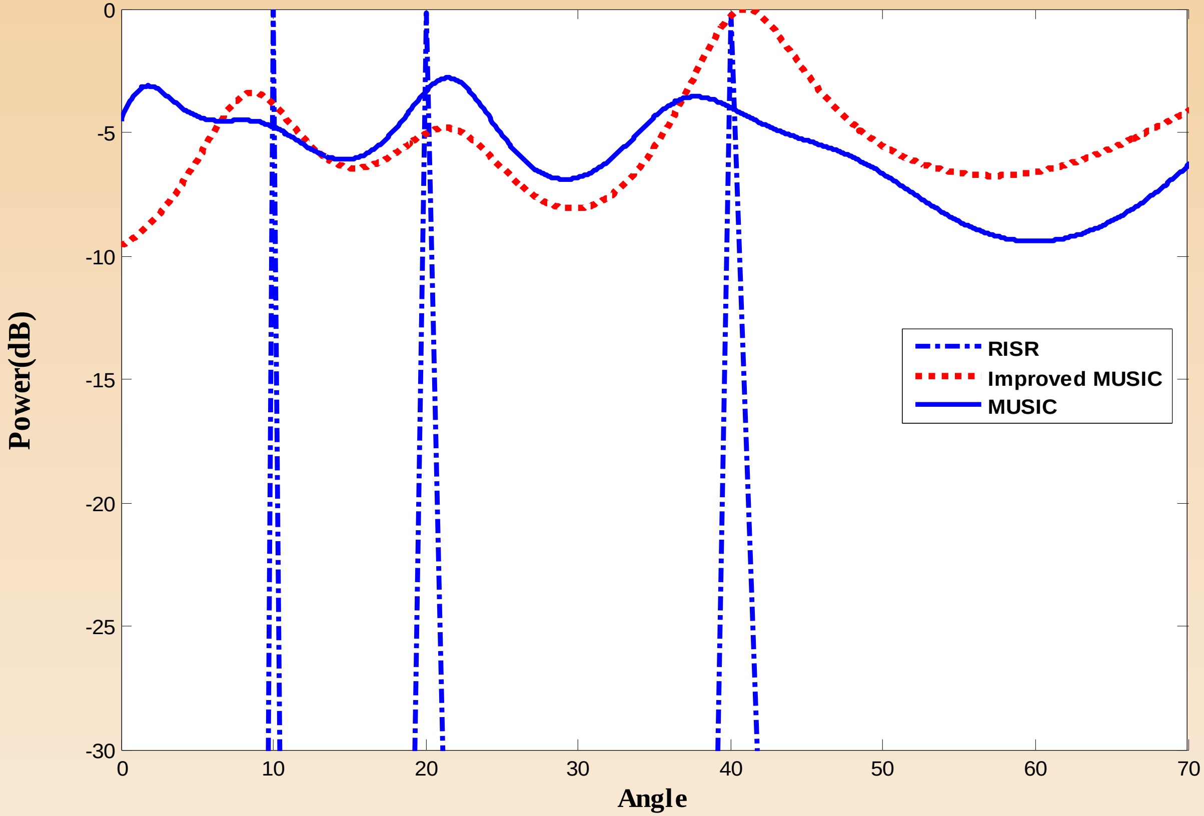
RESULTS AND DISCUSSION

Angle of Arrival Estimation:

Three correlated signals are used to investigate the performance of the proposed algorithm. The angles of arrival are [10^o, 20^o and 40^o] related to delays [0μs, 3μs, 5μs] respectively and the number of receiving antenna elements of ULA are 10 elements having an inter-element spacing of half wavelength corresponding to the operating frequency.

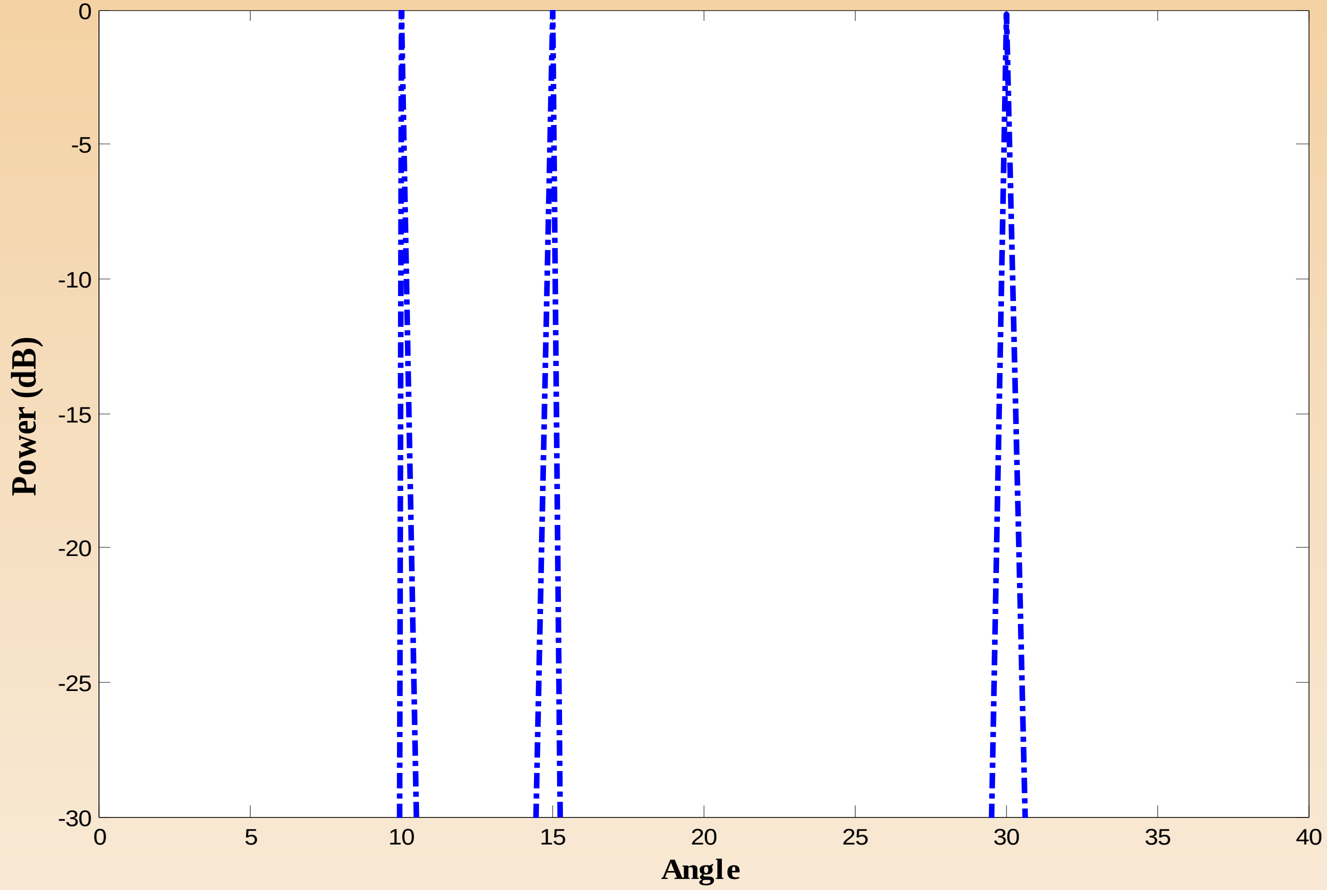
RESULTS AND DISCUSSION

Angle of Arrival Estimation:



➢ RESULTS AND DISCUSSION

Angle of Arrival Estimation:



Time difference of arrival estimation

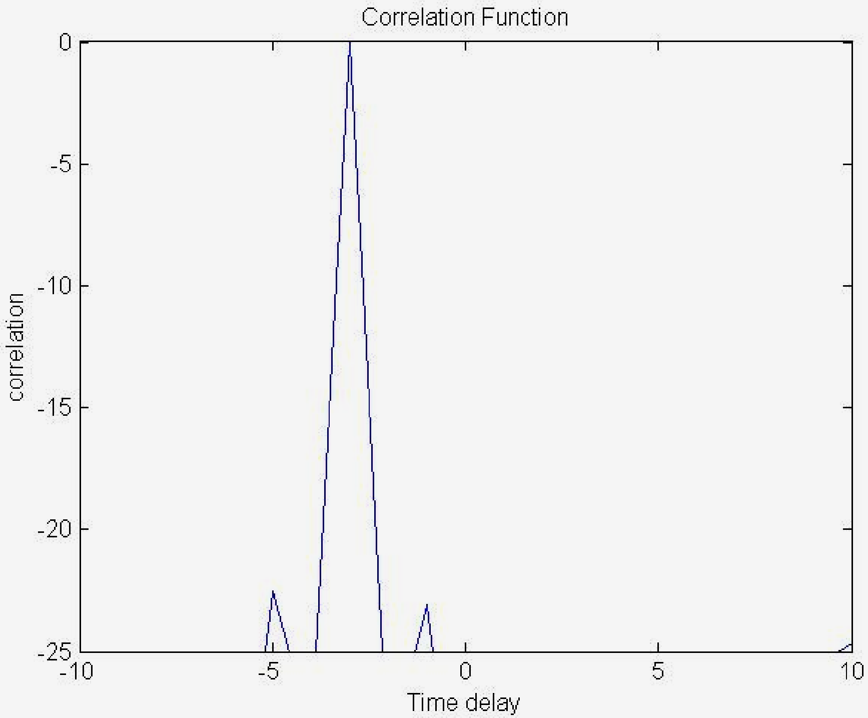
By making a conventional beamforming for the strongest signal, then apply the beamforming for the rest of signals ; and get the correlation between the first signal and the others to get the shortest path.

Assume the first signal time delay is T_d, the second T_{m1} and the third T_{m2}

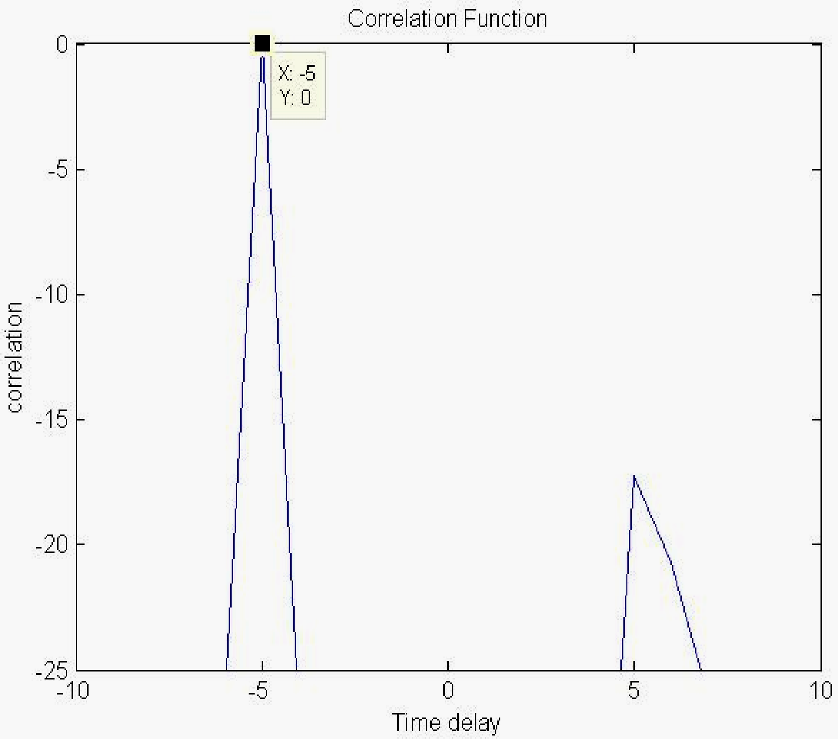
The correlation between the first 2 signals occurs at :$T_1=T_d-T_{m1}$

And The correlation between the first and 3rd signals occurs at :$T_2=T_d-T_{m2}$

Time difference of arrival estimation

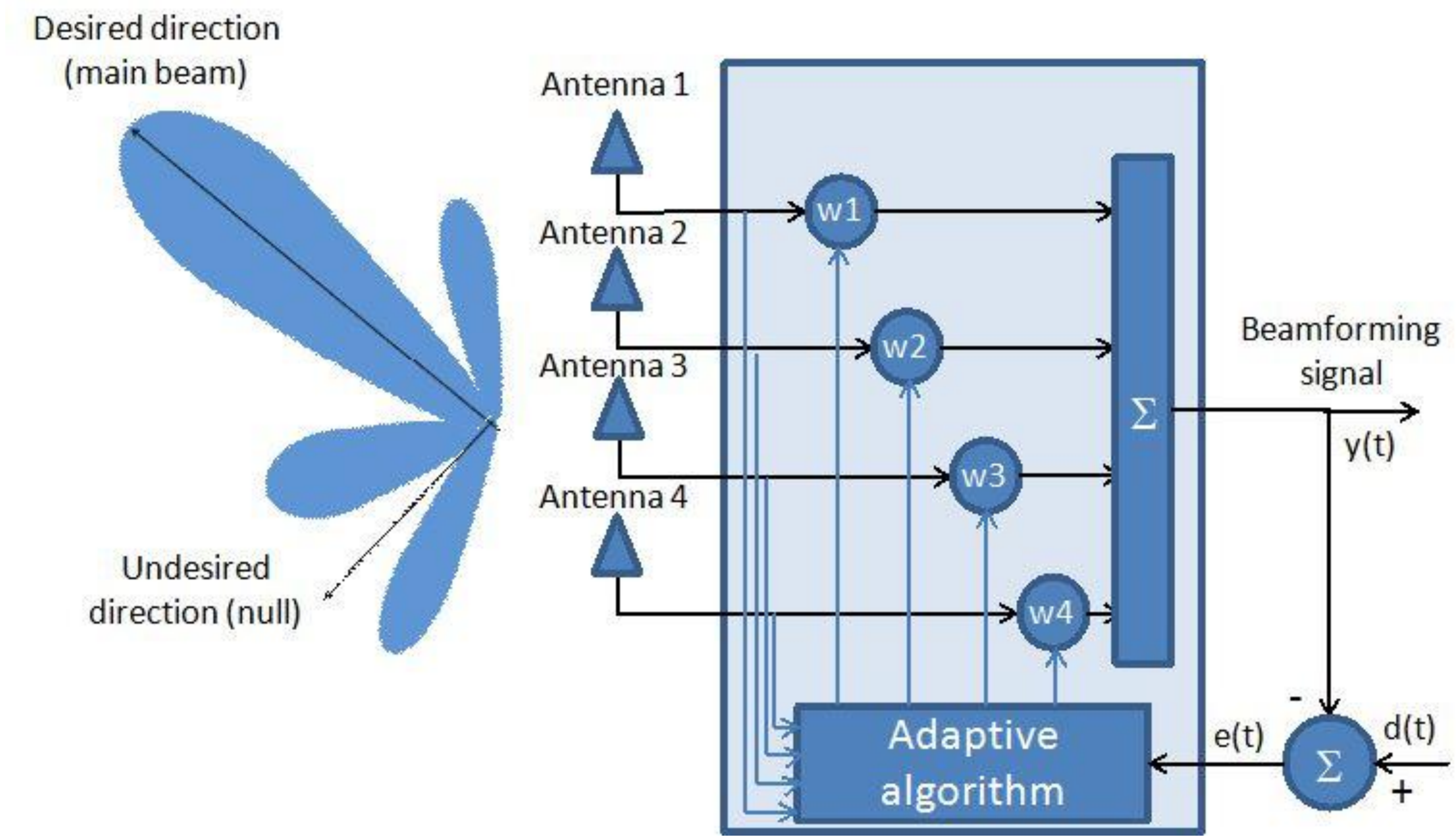


For signals 1&2



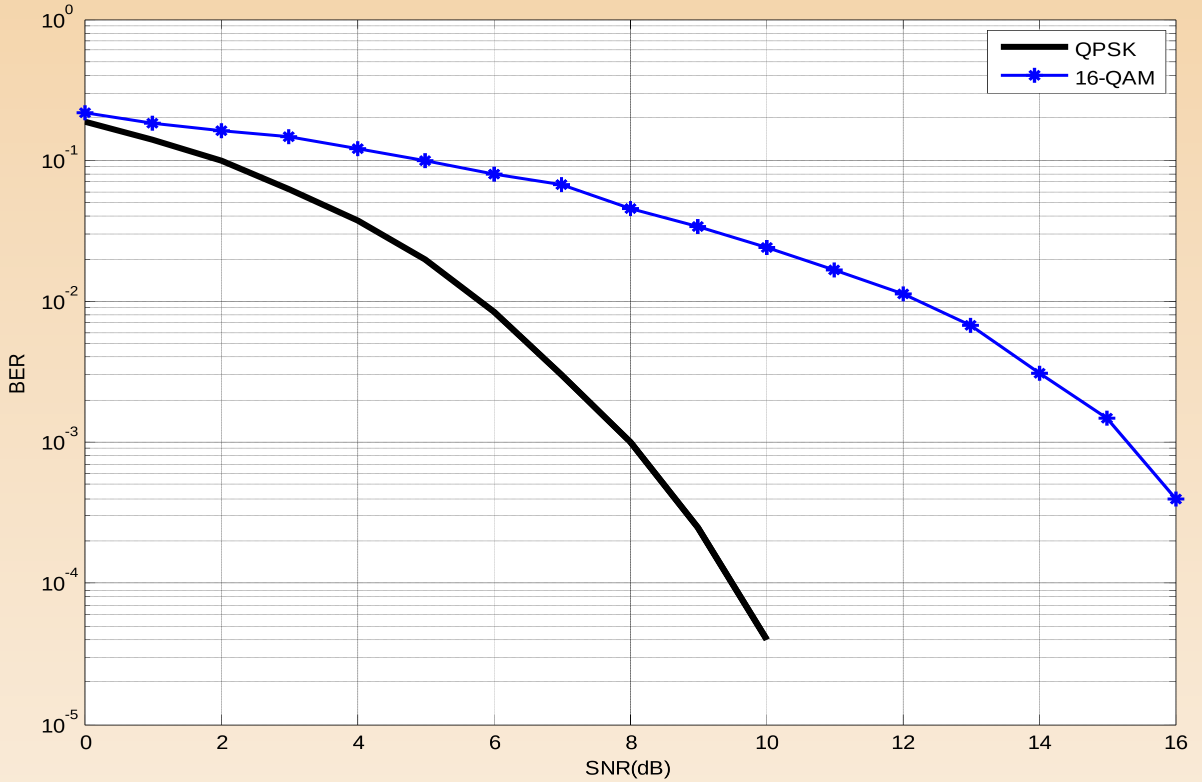
For signals 1&3

Then by using null-steering beamforming algorithm to direct the main beam towards the desired signal and give nulls in direction of the multipath interference.



Bit Error Rate (BER) calculation:

Data is detected in the desired direction:



Conclusion

- The results show that when RISR DOA algorithm is applied, the closely spaced correlated sources are completely separated as well as the number of sources is automatically determined.

- After the direct path is clearly identified the data can be correctly detected with very low BER level.

Thank you for your listening

Any Questions ?

- Presented by

Eng. Osama Gaafar