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Base Transceiver Station (BTS) Receiver for Smart Antenna System

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Abstract: Use of Smart antenna systems enables the network operators to increase the wireless network capacity. Networks are expected to experience an enormous increase in the traffic due to the increased number of users as well as high data rate services and applications. In this article we present simulation results of a smart base transceiver station (BTS) uplink receiver assuming four element linear array and two interference signals. A 10 bit authenticating bits are transmitted and regenerated in presence of white Gaussian noise of 30 dB. Operation is subdivided into direction of arrival (DOA) estimation of two interference signals with an MUSIC algorithm, adaptive beamforming with a null beamformer and regeneration of digital data with comparator. The spatial spectrum for MUSIC algorithm, output radiation patterns and output valid digital data of the Null beamformer are plotted. Results of numerical simulation are useful for the design of smart antenna BTS receiver system.

Keywords: Smart antennas, MUSIC, Null beamformer, Simulation, BTS receiver.

1. INTRODUCTION

The adoption of smart antenna techniques in future wireless systems is expected to have a significant impact on the efficient use of the spectrum, the minimization of the cost of establishing new wireless networks [1]. Most intelligent transceiving system employs some kind of DOA at the receiver to resolve the DOAs of all impinging signals on the array. The receiver then applies the adaptive algorithm to calculate complex weight factors which multiply the analytic signal at each element of the associated array [2]. These signals are then combined to produce a resulting signal with improved overall signal to interference ratio (SINR) . This signal is passed to a demodulator where bit error rate (BER) performance is improved. Figure 1 shows the generalized smart antenna receiver architecture.

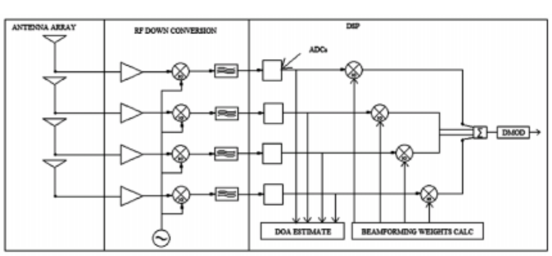


Figure 1: Generalized Smart Antenna Receiver Architecture

In this system a linear element array consisting of omni-directional antenna elements receives the high frequency radio frequency (RF) signal. This high frequency signal is down converted to an intermediate frequency (IF) suitable for sampling. The analog IF signals at each element of the array are then converted to digital format by high speed ADCs, these samples are then passed to the DOA estimation. Once estimates for the DOAs of the impinging signals have been found beamforming weights can be calculated and applied to each element of the array. It is the application of thses complex weights that effectively forms the antenna pattern of the receiver that enables optimized reception of RF signals. Finally the weighted signals are summed and passed to a demodulator [3].

2. SMART ANTENNA BTS UPLINK RECEIVER

Smart antenna BTS receiver (uplink) is based on the direction of arrival (DOA) estimate, adaptive beamforming and signal regeneration.

2.1. A DOA estimation

From the received input data in uplink, the number of incoming wavefronts and their DOAs are estimated. The family of DOA estimation algorithms that depend on an Eigen decomposition of the array covariance matrix are so named the Eigen structure methods. Two of the most popular methods are the ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques) and MUSIC (Multiple Signal Classification) algorithms. Here MUSIC algorithm is used to estimate the direction of arrivals of interfering signals.

2.1.1. DOA Estimation Using MUSIC Algorithm

MUSIC is an acronym which stands for MUltiple SIgnal Classification. This approach was first posed by Schmidt. It is a simple, popular high resolution and efficient Eigen structure method. It promises to provide unbiased estimates of the number of signals, the angles of arrival and the strengths of the waveforms.

From array correlation matrix R obtained, we can find M eigen vectors associated with the signals and (N-M) eigenvectors associated with the noise. Then choose the eigen vectors associated with the smallest eigen values. Noise eigen vectors subspace of order N x (N-M) is constructed and is given as

$$E_N = [\bar{e}_1 \quad \bar{e}_2 \quad .... \quad \bar{e}_{N=M}] \tag{1}$$

The noise subspace eigen vectors are orthogonal to the array steering vectors at the angle of arrivals θ_1, θ_2,…….. θ_M. The Pseudo-spectrum, a function that gives an indication of the angle of arrival based upon maximum versus angle for MUSIC is given as

$$P_{MU}(\theta) = \frac{1}{|\ \bar{a}(\theta)\ \ \bar{E}_N\ \ \bar{E}_N^H\ \ \bar{a}(\theta)\ |} \tag{2}$$

2.2. Adaptive Beamforming

It is a commonly employed technique that enables system operation in an interfering environment by adaptively modifying the system's antenna pattern so that nulls are generated in the angular locations of the interference sources.

2.2.1. Null Beamformer

The null steering beamformer adapts the antenna pattern to steer the main beam towards the desired users and places nulls in the direction of interfering users. In particular, null steering is a method of beamforming for narrow band signals where we want to have a simple way of compensating delays of receiving signals from specific source at different elements of the antenna array. To reach this goal, we may only add the weighted version of the signals with appropriate weighted values. We do this in such a way that the frequency domain output of this weighted sum produces a zero result. This method is called null steering.

If S_o is the steering vector associated with the desired signal of interest and vectors S_1,....S_k are the k steering vectors associated with k interfering signals on an M element array, then the desired weight vector W is the solution of following set of simultaneous equations

$$w^H S_o = 1,\ w^H S_i = 0,\ i = 1,............k \tag{3}$$

therefore the weights can be calculated as the first column of the pseudo inverse of the matrix whose i th column is the i th steering vector, multiplied by M [5].

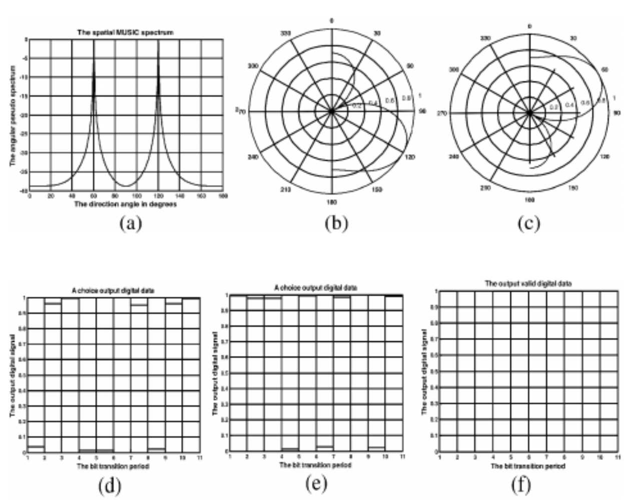
2.3. Signal Regeneration

Applied null beamformer algorithm place a main beam into the user direction and broad nulls into the directions of interfering signals. For regeneration comparator is used, which compare incoming data signal with a threshold value of 0.5 and produce valid digital output data removing distortions.

3. SIMULATIONS AND RESULTS

For simulation purpose an N = 4 element linear array and 10 digital authenticating bits in presence of white Gaussian noise with a signal to noise ratio per sample 30dB are assumed. Two interferring signals at θ_1=60° and θ_2=120° has been assumed. Simulation is carried out using MATLAB assuming narrow band signals. Operation is subdivided into three stages which are direction of arrival estimation of interfering signals with a MUSIC algorithm, adaptive beamforming with null beamformer and finally signal regeneration with comparator operation.

In the Figure 2, (a) shows the spatial MUSIC spectrum with peaks at 60° and 120°, (b) & (c) show the choice radiation patterns of a spatial beamformer with nulls at 60° and 120°, (d) & (e) show the choice output digital data 0110011011 and 1110101101 in presence of an additive white Gaussian noise as 10 bit authenticating bits, (f) & (g) shows the corresponding output valid digital data after regeneration, (h) & (i) shows the spatial MUSIC spectrum for N = 8 element array with narrow peaks at (60°, 120°) and (20°, 140°) respectively, (j) shows the MUSIC spectrum with peaks at 20° and 140°, (j) & (k) show the choice radiation patterns of a spatial beamformer with nulls at 20° and 140° respectively. It is observed that nulls of radiation patterns are pointed towards interfering signal directions and peaks of spatial MUSIC spectrum becomes sharper as number of array elements increases from 4 to 8. The weights calculated for (60°, 120°) and (20°, 140°) are (0.5000 ± 0.0015i, ± 0.0023-0.5000i, 0, 0) and (0.5000 ± 0.099i, 0,0, ± 0.3833 ± 0.3360i) respectively.



(a) (b) (c)

(d) (e) (f)

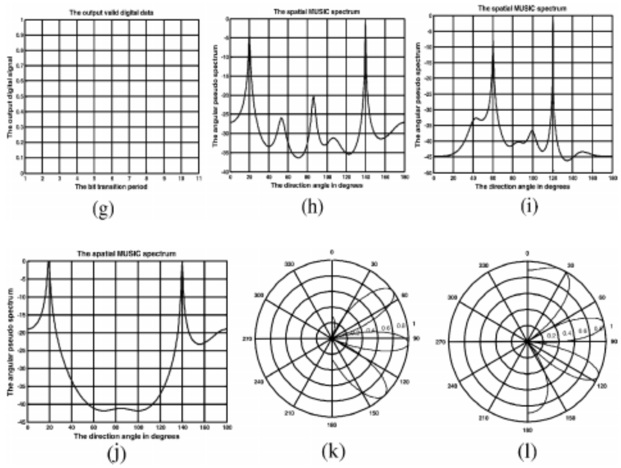


Figure 2: Simulation Results (a) Spatial MUSIC Spectrum with Peaks at 60º and 120º. (b) & (c) Radiation Patterns of a Null Beamformer with Null at 60º and 120º Respectively. (d) & (e) Choice Output Digital Data 0110011011 & 1110101101 Respectively. (f) & (g) Output Valid Corresponding Digital Data. (h) & (i) Spatial MUSIC Spectrums for Array Elements N=8 with Narrow Peaks at (60º, 120º) and (20º, 140º) Respectively. (j) Spatial MUSIC Spectrum with Peaks at 20º and 140º. (k) & (l) Radiation Patterns of a Null Beamformer with Null at 20º and 140º Respectively

4. CONCLUSION

This paper discusses the design and working of a smart antenna BTS uplink receiver. The DOAs of two narrow band interfering signals are found by MUSIC algorithm. For beamforming with nulls in those directions, the required weights are calculated using Null beamformer algorithm. It is observed that nulls of radiation patterns are pointed towards interfering signal directions. 10 authenticating bits are regenerated using comparator. It is verified that the transmitted and recovered bits are same. It is also observed that peaks of spatial MUSIC spectrum becomes sharper as number of array elements increases from 4 to 8. The results of numerical simulation are useful for study and design of a smart antenna BTS receiver.

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