Comparative Study of Different Algorithms to Implement Smart Antenna Array-A Review

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ABSTRACT

In this paper, smart antennas are antenna array use to empathize spatial signal such as DOA of the signal and used to find beamforming vectors and locate the antenna ray in the desired direction of target. Beam formed adaptive algorithms allow the antenna to steer the beam in desired direction of interest while cancelling the obtrusive signals. The prompt growth of smart antenna makes use of different algorithms to implement it. Now the comparison of different algorithms discussed in my review paper.

General Terms

Algorithms include LMS, SMI, QRD - RLS.

Keywords

Direction of arrival (DOA), Least mean square (LMS),Sample covariance matrix inversion (SMI), Quadrature Rotation Decomposition Recursive least squares(QRD-RLS).

1. INTRODUCTION

Smart antenna systems generally used in acoustic signal processing, SONAR Radio telescopes, Radio astronomy and mostly in cellular systems like WCDMA and UMTS. It has two functions: DOA estimation and Beamforming. DOA estimation is to use the particular data received by the array to estimate the direction of arrival of the signal. Beamforming is the method used to make the radiation pattern of the antenna array by adding effectively the phases of the signals in the direction of the targets and null the pattern of the mobiles that are undesired. The smart antenna systems can generally be revealed as either switched beam or adaptive array systems. In a switched beam system multiple fixed beams in predetermined directions are used to serve the users. Adaptive beam forming uses antenna arrays aided by strong signal process capability to automatically change the beam pattern in correspondence with the changing signal environment. It not only directs maximum radiation in the direction of the desired target but also introduces nulls at undesirable directions while tracking the desired mobile user at the same time [1].Fig.1 shows smart antenna system. A smart antenna technology can achieve a number benefits like increase the system capacity, greatly reduce interference, increase power efficiency.

The smart antenna electronically steer a phased array by weighting the amplitude and phase of signal at each array element in response to changes in the propagation environment. Capacity improvement is achieved by effective co-channel interference cancellation and multipath fading mitigation. Figure 2 shows the concept of smart antenna[2].

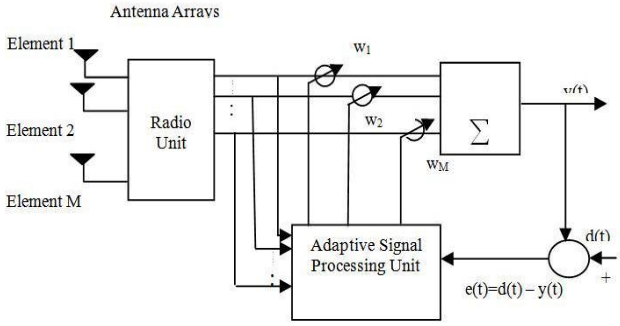

Fig.1 Smart Antenna System

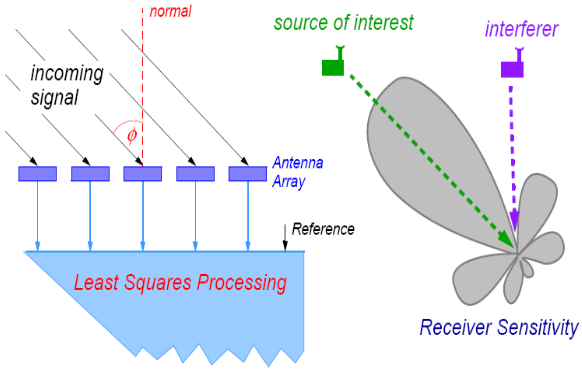

Fig.2 Concept of Smart Antenna

2. SMART ANTENNA ALGORITHMS

An LMS algorithm is used to cancel the unwanted interference. [3-6]LMS algorithm uses continuous adaptation. The weights are adjusted as the data is sampled such that the resulting weight vector sequence combines to the most favorable solution. It is an iterative beamforming algorithm that uses to find the gradient vector from the available data. This algorithm makes successive corrections to the weight vector in the direction of the negative of the gradient vector which finally wrap up to minimum MSE.Fig.3 shows adaptive beamforming network. LMS is an adaptive beamforming algorithm, defined by the following equations with input signal:

$$y(n) = w^T(n-1).u(n)$$

$$e(n) = d(n) – y(n)$$

$$w(n) = w(n-1)+\mu e(n)u^*(n)$$

where y(n) is the filter output, e(n) is the error signal between filter output and desired signal d(n) at step n . d(n) is the training sequence of known symbols (also called a pilot signal), is required to train the adaptive weights. Enough training sequence of known symbols must be present to assure convergence. w(n) update function for the LMS algorithm. Least Mean Square (LMS) algorithm, proposed by Widrow and Hoff in 1959 [9] is an adaptive algorithm, which uses a gradient-based method of steepest decent. It is used in adaptive antennas which is a is a multi-beam adaptive array with its gain pattern being adjusted dynamically [1-3]. In recent decades, it has been mostly used in different areas such as mobile communications, radar, sonar, medical imaging, radio astronomy etc. Especially with the increasing demand for improving the capacity of mobile communications, adaptive antenna is introduced into mobile systems to decrease the effect of interference and improve the spectral efficiency. SMI algorithm for adaptively adjusting the array

weights, uses block adaptation. The statistics are estimated from a temporal block of array data and used in an optimum weight equation. In the literature, there have been many studies about different versions of LMS and SMI algorithm Used in adaptive antennas [10]. The SMI algorithm has a faster convergence rate since it employs direct inversion of the covariance matrix. Sample Matrix Inversion (SMI) which is also known as Block adaptive approach because it involves block implementation or block processing i.e. a block of samples of the filter input and the desired output are collected and processed together to obtain a block of output samples. The process involves the parallel conversion of the input data, parallel processing of the collected data and parallel to serial conversion of the bring out output data. The computational complexity can be further decreased by the elegant parallel processing of the data samples. Thus we can say that in this type of algorithm we are adapting the weights block by block thus increasing the convergence rate of the algorithm and reducing the computational complexity further.

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k, is the no. of blocks.

Compared to SMI algorithms LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions.

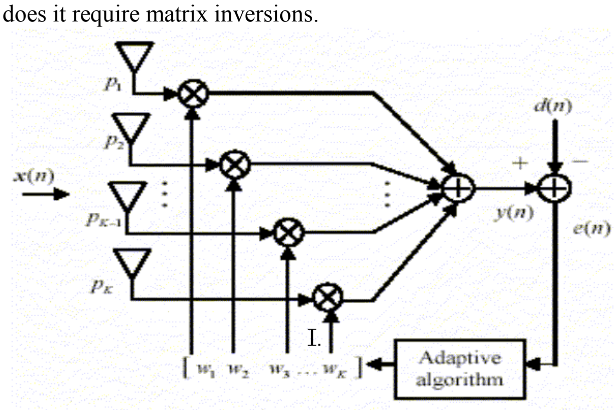

Fig.3 LMS Adaptive beamforming network

SMI employs direct matrix inversion the convergence of this algorithm is much faster compared to the LMS algorithm.

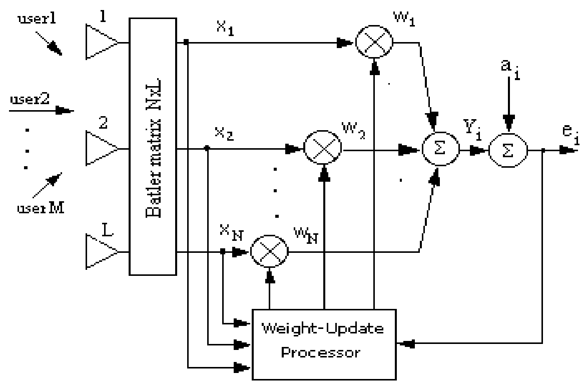

Fig.4 Adaptive RLS beamformer

QRD-RLS algorithm is used to solve least square problems. The decomposition is the basis for QR algorithm. Algorithm is used to produce the eigen values of matrix. QR decomposition is one of the best numerical procedures for solving the recursive least squares estimation problem. It involves the use of numerically well behaved unitary rotations and operates on input only.[3] Fig.4 shows the adaptive RLS beamformer.The RLS algorithm would require floating point precision, or very long fixed point word lengths, due to its numerical ill-conditioning. In addition to Multiply/Add standard RLS implementation also requires divide operations.

2.2 The QRD process is formed by a sequence of two operators. These are the unitary rotations that convert complex input data to real data and an associated angle and element combiners that decimate the selected elements of the input data set one by one. The QRD implementation was attained by using the Xilinx System Generator [12] for DSP model-based design flow. This is tool chains that lengthen the Mathworks Simulink framework with FPGA hardware generation capabilities. System Generator is a visual design environment that allows the system developer to work at a suitable level of abstraction

from the target hardware, and use the same computation graph not only for simulation and verification, but for FPGA hardware implementation. System Generator blocks are bit- and cycle-true behavioral models of FPGA subjective property components, or library elements.

The RLS algorithm provides the solution to the slow convergence of LMS and SMI with the help of QRD least square processing solution. The antenna array contains three types of processing cells including are boundary cells, internal cells and output cell. The boundary cell performing “vectoring” on complicate input samples to cancel out their imaginary part. Rotation angles are formed by using input cells. The output cells in the linear array process the elements of the upper triangular array to perform the required back substitution [2] to produce the beamformer weights.

3. FPGA BASED QRD

The QR-decomposition(QRD)based recursive least squares (RLS) algorithm is usually used as the weight-update algorithm for its fast convergence and good numerical properties. The updated beam-former weights are then used for multiplication with the data that has been transmitted through the dedicated physical data channel (DPDCH). Maximal ratio combining (MRC) of the signals from all fingers is then performed to yield the final soft estimate of the DPDCH data.

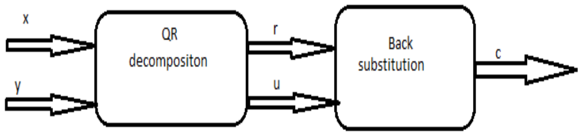

Fig.4 QR-decompositions-based least squares

The least squares algorithm attempts to solve for the coefficient vector **c** from *X* and *y*. Fig.4 shows QRD based least square process.[13]To realize this, the QR-decomposition algorithm is first used to transform the matrix *X* into an upper triangular matrix *R* (*N* x *N* matrix) and the vector **y** into another vector **u** such that *R***c**=**u**. The coefficients vector **c** is then computed using a procedure called back substitution, which involves solving these equations:

$c_N = u_{NN}/R_N$

$c_i = 1/R_{ii}(u_i - \sum RijCj)$

for i = N-1,-1

The beam-former weights vector **c** is related to the **R** and **u** outputs of the triangular array as **Rc=u**. **R** is an upper triangular matrix, **c** can be solved by a procedure called back substitution. [14]Substitution procedure works on the outputs of the QR-decomposition and involves mostly multiply and divides operations that can be accurately executed in FPGAs with embedded soft processors. The software can then complete the multiply operation in a single clock cycle. Since hardware dividers generally are not available, the divide operation can be implemented as custom logic block that generally become part of the FPGA-resident microprocessor. Between the multiply and divide accelerators, back-substitution becomes so easy and efficient. There are a number of beam-forming architectures and an adaptive algorithm that gives good performance under different scenarios, such as transmit/receive adaptive beam forming and transmit/receive switched beam forming. FPGAs with embedded processors are reliable by nature, providing options for various adaptive signal-processing algorithms. The standards for next-generation networks are generally evolving and this generates an element of risk for beam-forming ASIC implementations. Transmit beam forming, for example, utilizes the feedback from the mobile terminals.[15-16] The number of bits provided for feedback in the mobile standards can determine the beam-forming algorithm that is used at the base station. Moreover, future base stations are used to support transmit diversity, including space/time coding and multiple-input, multiple-output (MIMO) technology. Since FPGAs are remotely upgradeable, they minimize the risk of depending on evolving industry standards while providing another option for gradual deployment of additional transmit diversity schemes.

Each element of Antenna array may also be described as CORDIC block.[17] Cordic describes a method to perform a

number of functions including trigonometric, hyperbolic and logarithmic functions.

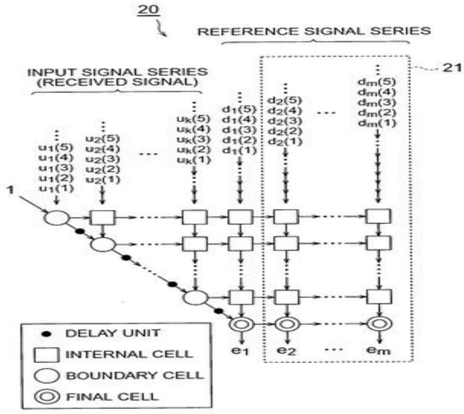

Fig.5 Configuration of Systolic cordic device.

systolic arrays are known which reduce processing time by parallel implementation of an RLS algorithm based on QR decomposition. $u_1(n)$ input signal series for first tap,$u_2(n)$input signal series for second tap, the values of tap coefficients can also be obtained as an output signal e. [18-19]Fig.5 shows the configuration of systolic cordic device. In order to perform processing of a sequential least-squares algorithm based on QR decomposition a final cell which provides the estimated error from the calculated values of boundary cells. QRD utilizes unidirectional processor array structure for smart antenna to cancel out the undesired side lobes, to increase receiver sensitivity and to eliminate all errors. It is most suitable algorithm then LMS and SMI to implement smart antenna. Therefore, one could select the systolic array structure of [7] when the polynomial order is small while preferring the unidirectional array of [9] for higher polynomial orders.

4. CONCLUSION

Algorithms for efficient direction of arrival estimation and to electronic steer the beam of smart antenna are compared. LMS algorithm is simple it does not require correlation function and matrix inversion but it has slow speed of convergence and lesser numerical stability.SMI is faster than LMS algorithm but the computational burden can cause problem. QRD-RLS is less complex than LMS and SMI and provides speed of convergence. It eliminates almost all errors and has good numerical properties. Further QRD-RLS with simulation results will be taken to implement smart antenna array.

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