# Design and Implementation of a Smart Antenna Array with QRD-RLS Adaptive Algorithm

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***Abstract*— Smart Antenna technology offers a notably improved solution to reduce interference levels and improve the system capacity. This paper presents an application of QRD based RLS algorithm using Coordinate Rotation by Digital Computer (CORDIC) operator due to its ability to reduce area utilization for implementing smart antenna. The QR decomposition method is used to decompose the co-variance matrix of the RLS algorithm into canonical form to improve the overall beam forming of the smart antenna array. The purpose of matrix decomposition is computational convenience. The designed antenna system has been simulated by using MATLAB and code is generated by using Xilinx (Accel DSP) tool.**

***Index Terms*— Quadrature rotation decomposition, Recursive Least Squares, Coordinate rotation by digital computer, co-variance matrix.**

## I. 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 beam forming. DOA estimation is to use the specific data received by the array to estimate the direction of arrival of the signal. Beam forming is the method used to generate 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. Spatially propagating signals conflict the presence of interfering signals and noise signals. If the desired signal and the interferers take up the same temporal frequency band, then temporal filtering cannot be used to isolate the signal from the interferers [1]. However the desired and the interfering signals generally drive from different spatial locations. At the same time, some destructive effects in randomly varying mobile communication environment like multipath fading, co-channel interference and Doppler effects need to be consigned. Smart antenna is a recent design technology that known to provide the solution for these problems. It not only directs maximum radiation in the direction of the desired target but also proposes nulls at undesirable directions while tracking the desired mobile user at the same time [2]. Fig.1 shows concept of a smart antenna system. A smart antenna technology can acquire a number of benefits like rise the system capacity, greatly reduce interference and increase power efficiency.

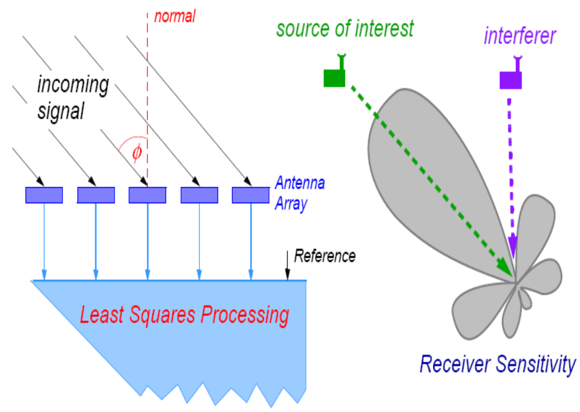


Fig.1 Concept of smart antenna

The smart antenna electronically governs a phased array by weighting the amplitude and phase of signal at each array element in respond to changes in the propagation environment. Capacity improvement is carry out by effective co-channel interference cancellation and multipath fading mitigation. The LMS has been generally used for more than 40years. Its convergence and simple implementation have made it the algorithm of choice for applications such as echo control and wire line channel equalisation. In these applications sufficient time to train the adaptive channel. Once adapted the channel is static and does not change. However for wireless applications includes equalisation, and smart antenna beam formers, MIMO systems etc. The time free for training the system is very limited, and further the channel will change and a complete re-training of the system is necessary. Now, the faster the channel changes, the shorter the time available for training. Hence faster adaptive algorithms are required [2].This is the simple encouragement and drive for the move real time LMS to real time LMS algorithms. In its direct form, the RLS algorithm would require floating point fidelity, 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. Hence the consequences of overflow and underflow can create severe problems such as Divide-by-zero errors, etc. Hence for FPGA fixed point implementation, RLS must be deliberately implemented. Therefore long fixed point word length is likely to provide the dynamic range demanded by the RLS algorithm. This encourages the QR-RLS algorithm method which is the most numerically robust method of RLS implementation. QRD-RLS algorithm is used to solve least square problems [3]. The decomposition is the basis for QR algorithm. Algorithm is used to generate the Eigen values of matrix.

QR decomposition is one of the prime numerical procedures for solving the recursive least squares estimation problem. It comprise the use of numerically well behaved unitary rotations and act on input only.The RLS algorithm would feel necessity for 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. The implementation of RLS algorithm requires large number of FPGA resources, so to decrease the large number of FPGA resources, we use QR decomposition.

## II. QRD-RLS ADAPTIVE ALGORITHM

Matrix decomposition has very relevant applications in scientific computing because of its scientific and engineering significance. The purposes of matrix decomposition are analytic simplicity and computational aid. There are several different decomposition techniques which has solutions in different methods. The choice of suitable decomposition technique depends on the problem we want to solve and the matrix to be decomposed. . A QR decomposition core which decomposes a matrix into an orthogonal and a triangular matrix using Gram-Schmidt ortho-normalization technique is construct and implemented [3]. Fig.2 shows the QR decomposition based least square. Recursive least squares algorithm a try to solve for the coefficient vector **c** from *X* and **y**. To realize this, the QR-decomposition algorithm [3] is first used to transform the matrix *X* into an upper triangular matrix such that R**c** = **u.** The coefficients vector **c** is then calculated using a procedure called back substitution, which involves solving the equations shown below:

$$C_N = \frac{u_{NN}}{R_{NN}} \quad (1)$$

$$C_i = \frac{1}{R_{ii}}\left(u_i - \sum_{j=i+1}^{N} R_{ij} C_j\right) \text{ for i=N-1,……1} \quad (2)$$

The QRD-RLS algorithm flow is shown as below:

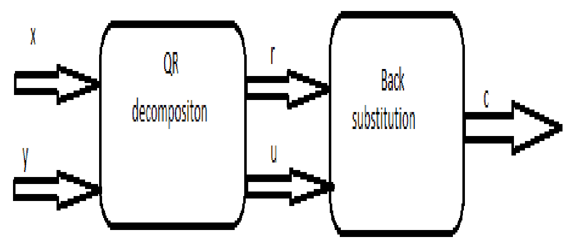


Fig.2: QR Decomposition Based Least Square

## III. CORDIC BASED QR DECOMPOSITION

The QR-decomposition of the input matrix X can be performed, as illustrated in Fig 3, using the well-known systolic array architecture [11]. The rows of matrix *X* are delivers as inputs to the array from the top along with equivalent element of the vector y. The R and u values held in each of the cells once all the inputs have been passed through the matrix are the outputs from QR-decomposition. These values are latterly used to find the coefficients using the back-substitution technique. Each of the cells in the array can be executed as a coordinate-rotation digital computer (CORDIC) block. CORDIC proposes a method to perform a number of functions, including trigonometric, hyperbolic and logarithmic functions. The algorithm is iterative, and uses only additions, subtractions and shift operations. This makes it very useful for hardware implementations. The number of iterations depends on the precision, with maximum iterations being needed for more bits.

Mixed mapping: In the mixed mapping scheme, the bottom rows in the systolic array are shifted to the end of the top rows, to possibly have the same number of cells in each row. A single CORDIC block can be used to find the operations of all the cells in a row, with the total number of CORDIC blocks required being same to the total number of rows. Since each CORDIC block has to operate in both vectors and rotating modes, the scheme is known as the mixed mapping. Discrete mapping*:* In this scheme, at least two CORDIC blocks are required. One block is used entirely for vectorize operations.

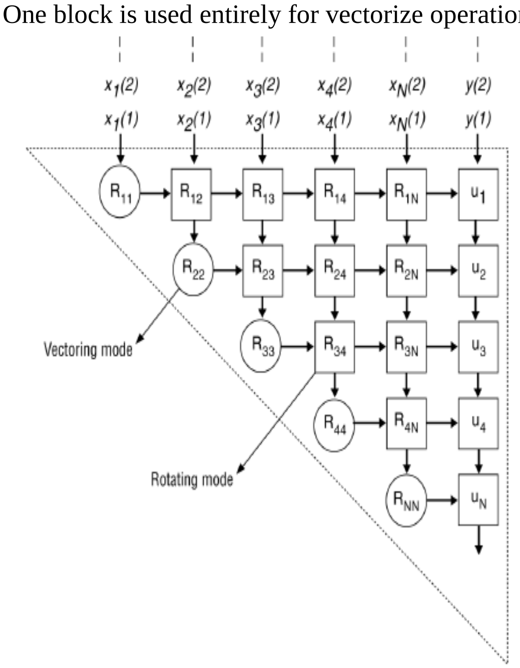


Fig.3 Systolic array architecture for QR-decomposition

Other is used for rotate operations. This single functionality of the processors allows any gains from hardware optimization to be realizable.

## IV IMPLEMENTATION OF PROPOSED SMART ANTENNA

Adaptive beam former has been executed using MATLAB. Accel DSP tool has been used to change MATLAB code directly to VHDL code. The performance of the proposed adaptive beam former has been figure out. The adaptive Beam former has been implemented for four antennas. For the proposed design input signal frequency has been taken as 30GHz and has been sampled at a rate of 100 GHz. The angle of incidence for desired input signal has been kept as 0 degree and amplitude has been taken as 1V. Fig 4 and 5 show the input signal and its spectrum respectively. Whereas, for the interfering signal, frequency has been taken as 27 GHz and sampled at a rate of 100 GHz. The angle of incidence for the interfering signal has been kept as pi/8 degree and amplitude has been taken as 1V.Fig 6 and 7 show the interfering t signal and its spectrum respectively.

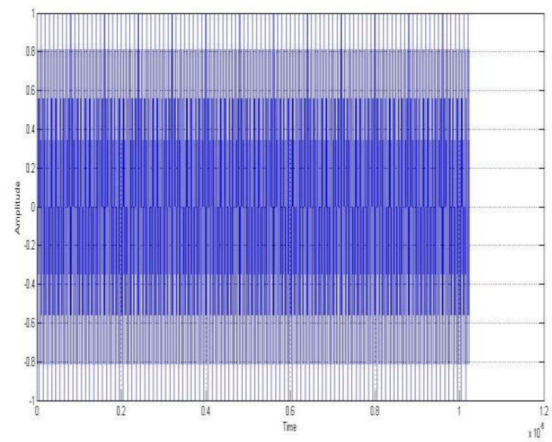

Fig.4 Input Signal

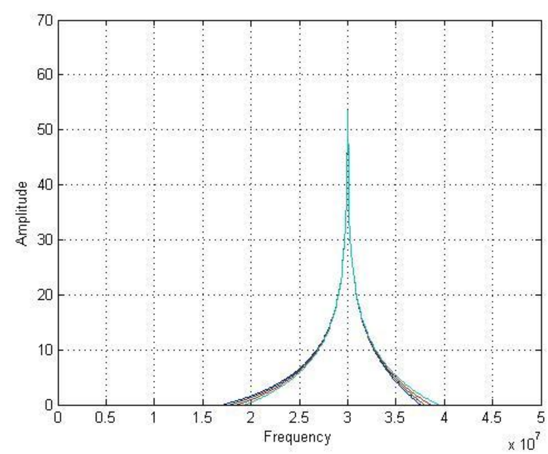


Fig.5 Frequency Spectrum of Input Signal

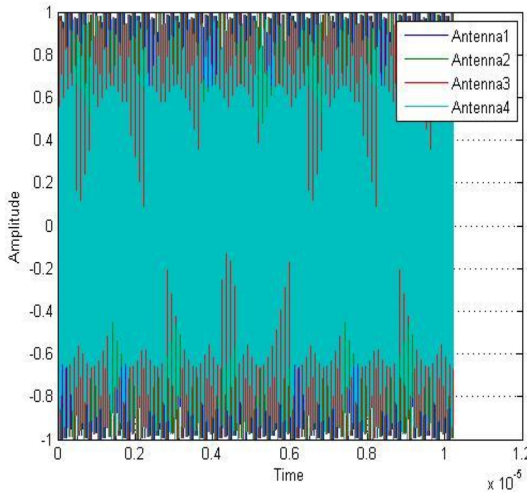


Fig.6 Interference Signal

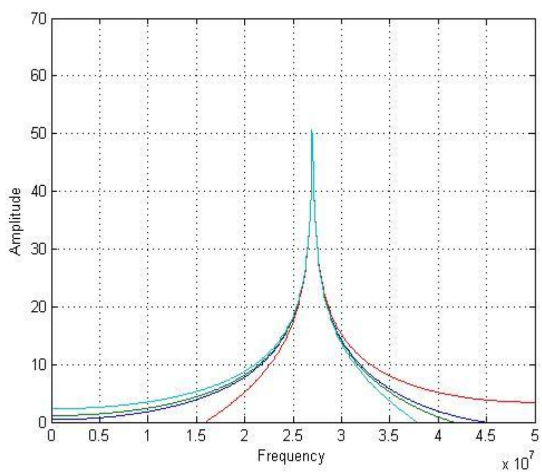


Fig.7 Frequency spectrum of interference signal

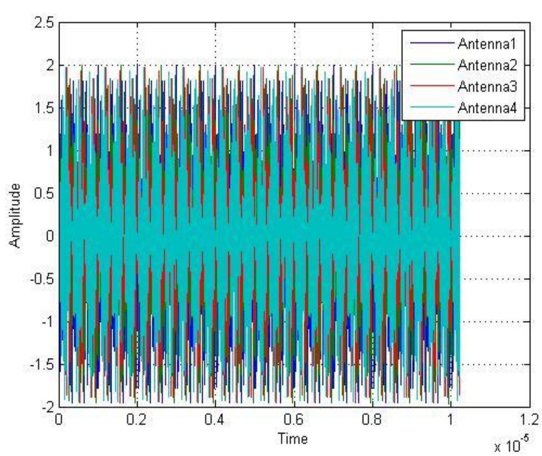


Fig.8 Input Signal corrupted with interfering signal

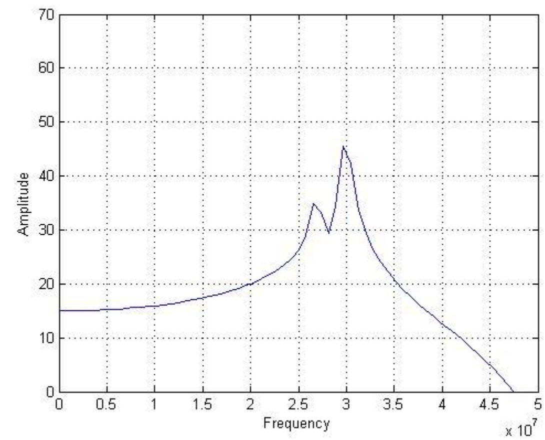


Fig.9 Frequency spectrum of input signal corrupted with interference signal

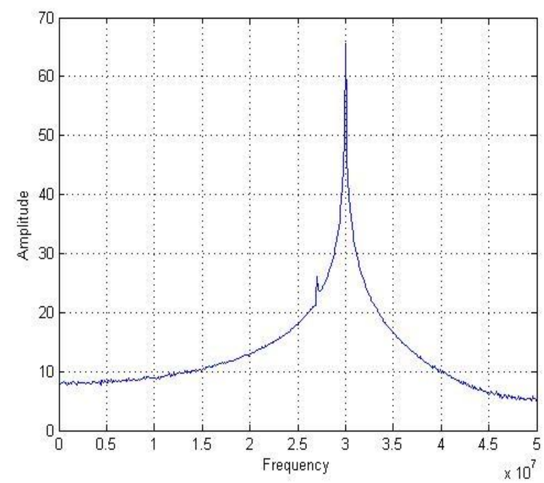


Fig.10 Smart antenna output with Adaptive Beam former

Comparing Fig 9 and 10, it has been decided that the interfering signal has resulted in an undesired peak, which is also not as smooth as input signal. It should be vanished by using adaptive beam former algorithm. Fig.10 shows the ability of QRD-RLS algorithm in suppressing the undesired peak and sharp the signal.

## V CONCLUSION

Smart Antenna with adaptive Beam forming using QR decomposition which is run on CORDIC processor has been proposed and implemented using MATLAB. It electronically governs a phased array by weighting the amplitude and phase of signal at each array element in response to changes in the propagation environment. By taking the benefit of adaptive beam forming, QRD-RLS algorithm is used to direct the Antenna beam towards the desired user while cancelling signal towards other users and suppressing the undesired peak in very effective manner.

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