International Journal for Modern Trends in Science and Technology
Volume 9, Issue 11, pages 58-62.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol9issue11.html
DOI: https://doi.org/10.46501/IJMTST0911012

Design and analysis of Intelligent Antenna assemblage with QRD-RLS Adaptive Algorithm

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To Cite this Article
P. Maheswari and Y. Asha Chandra. Design and analysis of Intelligent Antenna assemblage with QRD-RLS Adaptive Algorithm, International Journal for Modern Trends in Science and Technology, 2023, 9(11), pages. 58-62.https://doi.org/10.46501/IJMTST0911012

Article Info
Received: 28 October 2023; Accepted: 18 November 2023; Published: 22 November 2023.

ABSTRACT

The use of smart antenna technology provides a noticeably better means of lowering interference levels and boosting system capacity. The ability of the Coordinate Rotation by Digital Computer (CORDIC) operator to create smart antennas with less area consumption is the reason and this study provides an implementation of the QRD based RLS method. To enhance the overall beam shaping of the smart antenna array, the co-variance matrix of the RLS algorithm is broken down into canonical form using the QR decomposition approach. Matrix decomposition is used for computational convenience. The Xilinx (Accel DSP) tool is used to produce code, and MATLAB has been used to simulate the planned antenna system.

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

1. INTRODUCTION

Smart antenna systems are mostly utilized in cellular systems like WCDMA and UMTS, radio astronomy, SONAR radio telescopes, and acoustic signal processing. It does beam shaping in addition to DOA estimation. The process of estimating the direction of arrival of a signal involves using the specific data that the array has received. The technique known as beam shaping is utilized to create the antenna array's radiation pattern by strategically adding signal phases in the direction of the targets and canceling out the unwanted mobile patterns. The existence of noise and conflicting signals clashes with spatially propagating 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]. Nonetheless, the intended and disruptive signals typically originate from distinct spatial places. In addition, certain detrimental effects such as multipath fading, co-channel interference, and Doppler effects must be tolerated in a randomly changing mobile communication environment. A more modern design technique called smart antenna is thought to offer an answer to these issues. It tracks the intended mobile user while simultaneously proposing nulls at unwanted directions and directing maximal radiation toward the desired target[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.

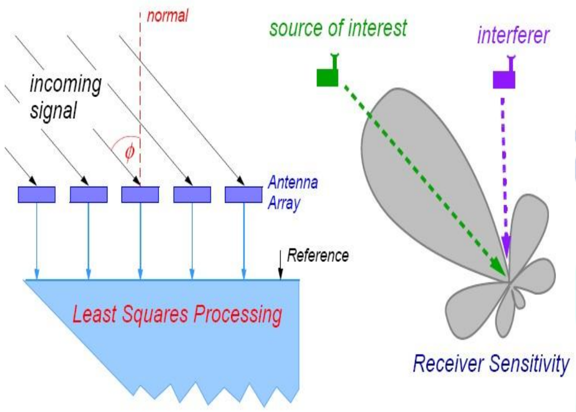

Fig.1 Concept of smart antenna The smart antenna electronically governs a phased array by weighting the amplitude and phase of signal at each array element in respond to changes in the propagation environment. Capacity improvement is carry out by effective co-channel interference cancellation and multipath 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 illconditioning. 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 [4-9].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 [10-11]. The implementation of RLS algorithm requires large number of FPGA resources, so to decrease the large number of FPGA resources, we use QR decomposition.

2. QRD-RLS ADAPTIVE ALGORITHM

Matrix decomposition has very relevant applications in scientific computing because of its scientific and engineering significance [4]. 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:

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

$$C_i = \frac{1}{R_{ii}}\left(u_i - \sum_{j=i+1}^{N} R_{ij} C_j\right) \text{for } i=N-1,\ldots\ldots1 \qquad (2)$$

The QRD-RLS algorithm flow is shown as below:

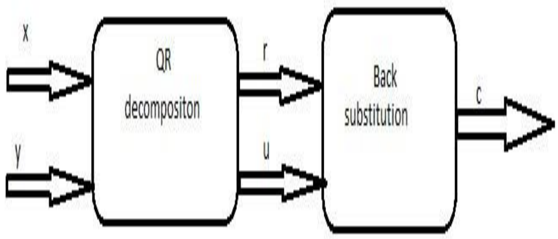

Fig.2: QR Decomposition Based Least Square

3. 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.

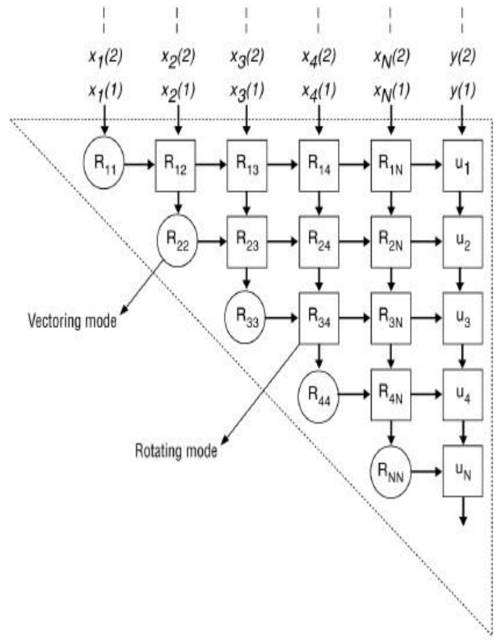

Fig.3 Systolic array architecture for QR decomposition

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

4. ANALYSIS OF PROPOSED INTELLIGENT 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.

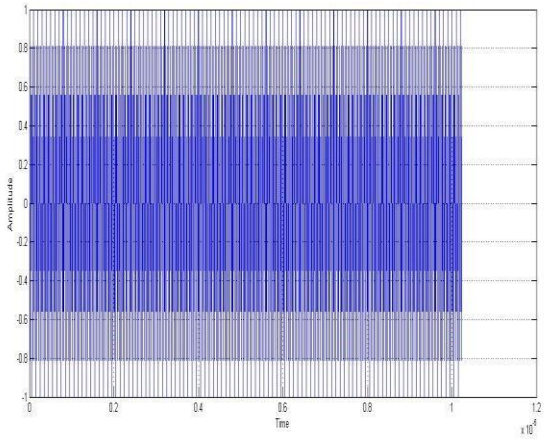

Fig.4 Input Signal

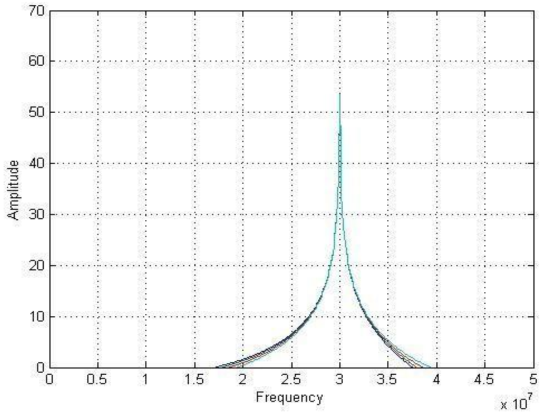

Fig.5 Frequency Spectrum of Input Signal

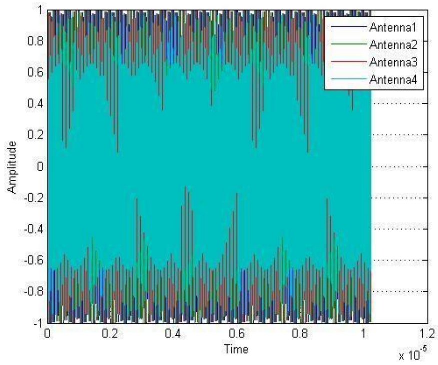

Fig.6 Interference Signal

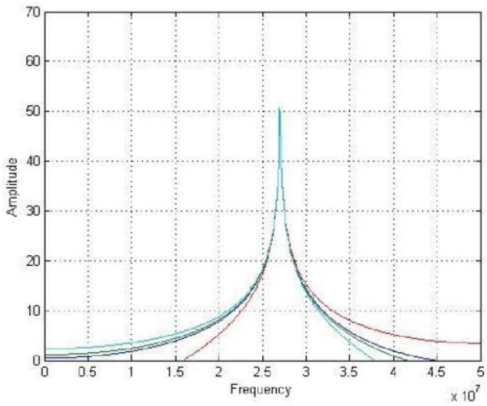

Fig.7 Frequency spectrum of interference signal

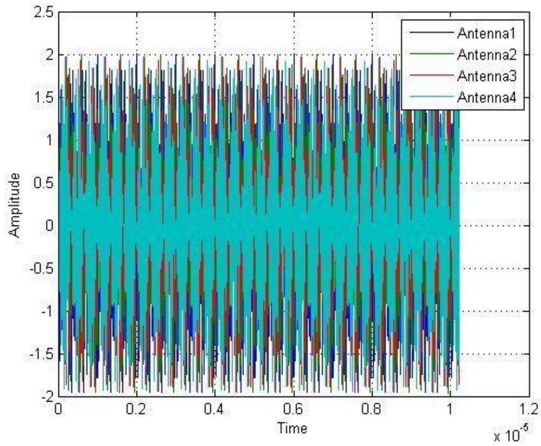

Fig.8 Input Signal corrupted with interfering signal

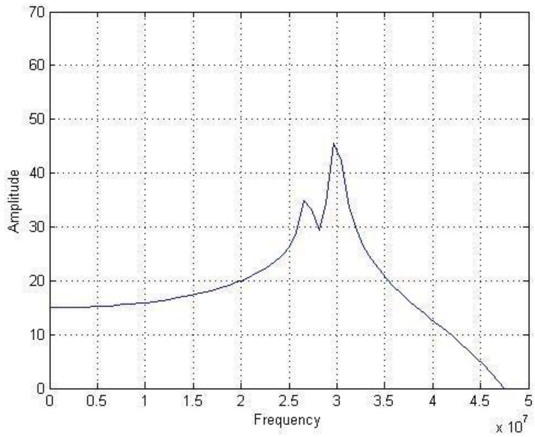

Fig.9 Frequency spectrum of input signal corrupted with interference signal

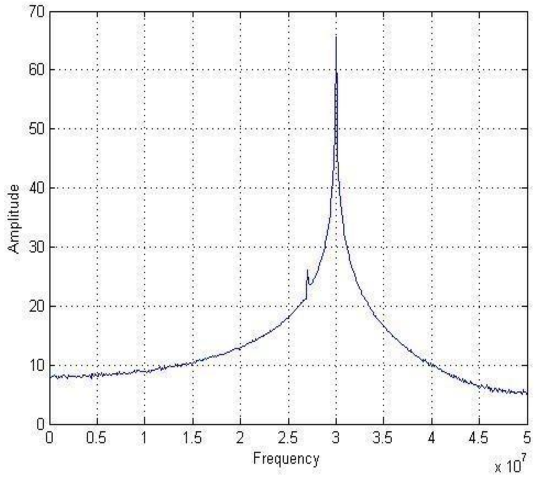

Fig.10 Smart antenna output with Adaptive Beam former

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.

5. CONCLUSIONS

MATLAB has been used to develop and implement a smart antenna with adaptive beam shaping utilizing QR decomposition that is operated on a CORDIC processor. By balancing the signal's amplitude and phase at each array member in reaction to variations in the propagation environment, it electronically controls a phased array. Utilizing adaptive beam formation, the QRD-RLS algorithm effectively suppresses the undesirable peak and cancels signals towards other users, all while directing the antenna beam towards the intended user.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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