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Development of Low Cost Smart Antenna System and its FPGA Implementation

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Abstract: ***Recently, smart antennas have been proposed as a promising solution that can significantly improve the quality of wireless transmission, which is limited by interference, local scattering, and multipath propagation. The antenna array is combined with digital signal processing to give a narrow beam pattern in response to the received signal by the smart antenna. The weights of the beam-former is calculated by using the adaptive approach which uses reference signal and the direction of the user based on the received signal. The main beam is then directed towards the specific user, while the nulls are adjusted toward the interferers [1].This paper presents the development of a smart antenna using QD (Quadratic Decomposition) RLS algorithm and its FPGA implementation. FPGA resource estimates and the implementation results have been presented in this paper.***

Keywords: Beamforming, Smart Antennas, FPGA, Quadratic Decomposition

1. Introduction

Smart antennas are considerably important because of their potential for decreasing interference and improving quality of service. In an adaptive antenna system, the weight of antenna arrays can be adjusted to form certain amount of adaptive beam to track corresponding users automatically and at the same time to minimize interference arising from other users by introducing nulls in their directions [2]. Beamforming is a method to create the radiation pattern in the desired direction. Radiation pattern is controlled by adaptive filters. The adaptive algorithms like LMS and RLS can be used for beamforming in smart antennas. The concept of smart antenna is explained in Fig 1.

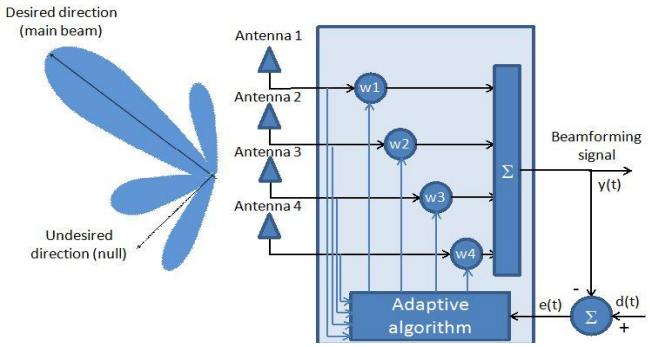


Figure 1: Concept of Smart Antenna

J. Litva, K.Y. Lo [3] discussed the fundamental concepts of adaptive beamforming and the adaptive algorithms like LMS, RLS and SMI. The fundamental method in adaptive beamforming is to choose the weights of array elements in order to optimize the beam-former response to fulfill certain criterion. These criterion includes Minimum Mean Square Error, Maximum Signal to Interference Ratio and Minimum Variance was discussed. The choice of criteria is not critically

important since they are closely related to each other. The most important part is the adaptive algorithms, which determine the speed of convergence and hardware complexity required. L.C. Godara [4] contributed a thorough study on antenna array applications in mobile communication. He also compared the LMS and SMI algorithms. He concluded that LMS is simple as compared to SMI. He also found that LMS has slower convergence as compared to the SMI algorithm. But the complexity of SMI requires advance hardware for its implementation. R. S. Dhanaraj, L. Gudino, Dr. J. Rodrigues [1] developed a smart antenna using adaptive algorithms. They discussed the performance of the LMS, RLS and CMA algorithms. Z. Ahmad, M. Tahir and I. Ali [5] compared LMS and RLS algorithms with optimized-LMS algorithm. They concluded that RLS performs better than LMS and optimized-LMS in beamforming and placing nulls. A. Sergyienko and O. Maslennikov [6] discussed the QR Decomposition technique and concluded that this technique increases robustness and reduces complexity. This QRD RLS algorithm is better than RLS because of its less computational complexity.

2. QRD-RLS Algorithm

The adaptive algorithms are used for solving the following set of equations:

$$\begin{aligned} &x_1(1)c_0 + x_2(1)c_1 \ldots\ldots\ldots\ldots x_N(1)c_{N-1} = y(1) + e(1) \\ &x_1(2)c_0 + x_2(2)c_1 \ldots\ldots\ldots\ldots x_N(2)c_{N-1} = y(2) + e(2) \\ &.. \\ &.. \\ &.. \\ &x_1(m)c_0 + x_2(m)c_1 \ldots\ldots\ldots\ldots x_N(m)c_{N-1} = y(m) + e(m) \end{aligned} \quad (1)$$

Where m>N

The least squares approach is used to find the set of coefficients $c_n$that minimizes the sum of squares of the errors, i.e. $\{\min \sum e(m)^2\}$. This equation can be represented in the matrix form as given below:

XC = y+e (2)

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Where x =matrix (m>N) of noisy observations, y is a known training sequence and c is the coefficient vector. The coefficient vector c is computed to minimize the error vector e. Computation of coefficient vector c involves matrix inversion, which is time consuming and undesirable for hardware implementation. To reduce complexity and time QRD RLS algorithm is used.

This method involves transforming the matrix X into upper triangular matrix R (N*N) and the vector y into another vector u such that Rc = u. Back substitution procedure is then used to compute coefficient vector c .This involves solving the following equations:

$$c_N = \frac{u_N}{R_{NN}} \quad (3)$$

$$c_i = \frac{1}{R_{ii}}\left(u_i - \sum_{j=i+1}^{N} R_{ij}c_j\right) \text{ fori=N-1} \quad (4)$$

The QRD RLS algorithm flow is shown below:

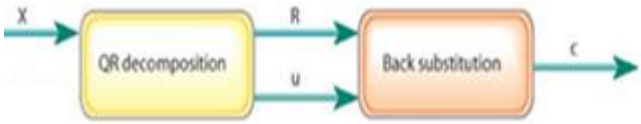


Figure 2: QR Decomposition Based Least Square

CORDIC based QR Decomposition. Using the systolic array architecture as shown in fig 3, QR Decomposition of matrix x is performed. The rows of matrix x and the corresponding elements of vector y are fed as inputs to the array from the top. The r and u are the outputs from QR Decomposition. These values then derive the coefficients using the back substitution procedure. The cells in the array are implemented as coordinate rotation digital computer (CORDIC) block. CORDIC describes a method to perform a number of functions, including logarithmic and trigonometric functions.

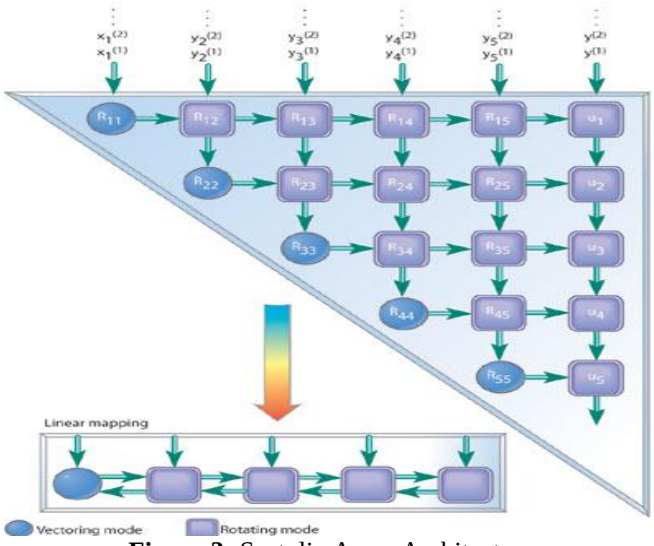


Figure 3: Systolic Array Architecture

The algorithm uses only addition, shift and subtraction method, making it attractive for hardware implementations.

3. Implementation of Beam-former

In the proposed work, adaptive beam-former is implemented on Virtex4 xc4vsx35FPGA using AccelDSP tool of Xilinx. This device has been used to compare the results with implementation of the same adaptive beam-former by [7] in which system generator tool of Xilinx was used. The performance of the proposed beam-former has been compared with the earlier work [7].

The simulation results by [7] and our work have been shown in figures 4 to 6. The broadside array output without beamforming is shown in figure 4. Figure 5 shows the beam-former output proposed by [7] and figure 6 shows the performance of our design.

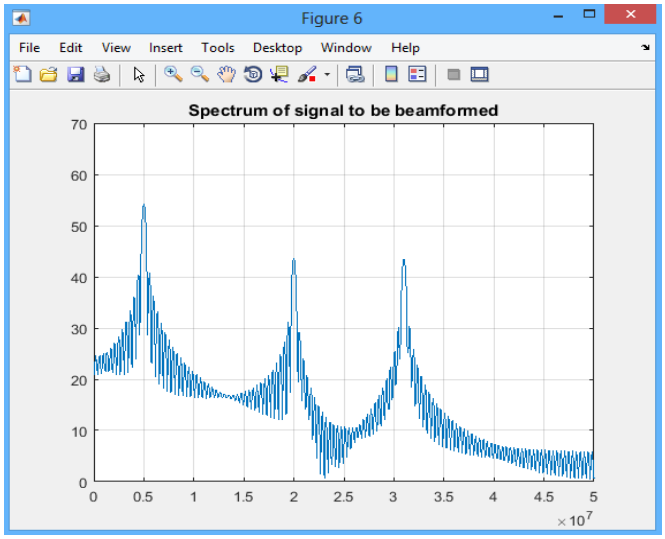


Figure 4: Broadside array output without beamforming

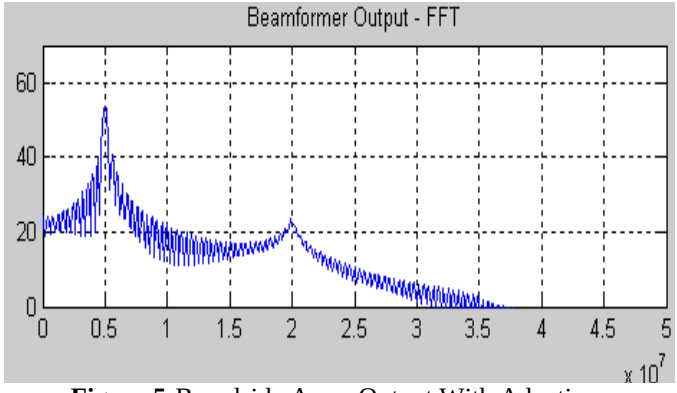


Figure 5: Broadside Array Output With Adaptive Beamforming [7]

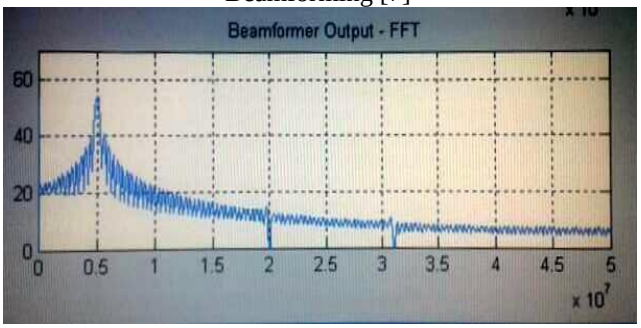


Figure 6: Broadside Array Output with Adaptive Beamforming

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From figures 5 and 6 it can be seen that the performance of the proposed beam-former is better than the beam-former proposed by previous work [7], in terms of side lobe cancelation. Table 1 shows the comparison of resources utilized by the present and the previous work.

Table 1: Resource utilization for the virtex4 xc4vsx35-ff68 FPGA Device

Resources	*Present Work*	*Previous Work*
Number of slice flip flops	980	5175
Number of slices	658	5052
NUMBER OF 4 I/P LUT	1821	7316
NUMBER OF BONDED IOBS	99	1304

From table 1, it can be concluded that the resources utilized by the present design are far better as compared to the deign proposed by [7]

4. Conclusion

This paper describes the development of adaptive beam-former and its FPGA implementation using QDR RLS algorithm. The results show that the performance of the beam-former implemented using the AccelDSP tool in the present work is better in side lobe cancellation and area utilization as compared to the past work .

References

[1] Ms. Rachel SelvaDhanaraj, Mrs. Lucy Gudino, Dr. Joseph Rodrigues," Development ofAdaptive Beamforming Algorithms for Wireless Communication Networks," IEEE-International Conference on Recent Trends in Information Technology, ICRTIT 2011
[2] KhyatiR.Zalawadia,Twinkle V. Doshi ,Dr U D DalalAdaptive Beam Former Design using RLS Algorithm for Smart Antenna System," 2011 IEEE DOI 10.1109/CICN.2011.20, International Conference on Computational Intelligence and Communication Systems
[3] J. Litva, T. K. Lo,"Digital beamforming in wireless communication,"artech house, norwood, first edition, 1996.
[4] L. C. Godara,"applications of antenna arrays to mobile communication," PartI: Performance Improvement, Feasibility, and System Considerations," in Proc. IEEE, pp. 1031-1060, vol. 85, July 1997.
[5] Z.Ahmad, M. Tahir, I. Ali,"Analysis of Beamforming Algorithms for Antijams," *DIPED-2013 Proceedings.*
[6] A. Sergyienko, O. Maslennikov. "Implementation of Givens QRDecomposition in FPGA". Springer Berlin / Heidelberg, (2002).
[7] DrK.R.Santha, Bharani ChakravarthyChava, K.Bragadishwaran and K.Chandru, "FPGA Implementation and Resource Utilization for QRD-RLS Systolic Array for Signal Processing Applications," in Proc. IEEE TENCON.
[8] DrK.R.Santha, Bharani ChakravarthyChava ,K.Bragadishwaran and K.Chandru, "FPGA Implementation and Resource Utilization for QRD-RLS Systolic Array for Signal Processing Applications," in Proc. IEEE TENCON, 2012.

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