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A HIGH- THROUGHPUT VLSI ARCHITECTURE FOR LTE USING QR DECOMPOSITION

A.Arockia Faustine[1], M. Vasudevan[2]

[1]P.G Scholar, VLSI Design,Parisutham Institute of Technology and Science, (India)

[2]Assistant Professor Electronics and Communication Engineering,

Parisutham Institute of Technology and Science, (India)

ABSTRACT

The MIMO (Multiple-Input Multiple-Output) techniques are a key supporting technology for high-rate wireless communications. The excellent growth of telecommunication industry demands novel technologies which can powerfully meet the requirements such as spectral efficiency, compact area and robustness. OFDM (Orthogonal Frequency Division Multiplexing) techniques using more compactly packed carriers, thus succeeding higher data rates using similar channels. The main challenge faced by MIMO technology is difficulty in detection of transmitted symbol at detector. The overhead associated with detection is condensed by custom of pre-processing approaches. QR decomposition is a most important one of these. Several QR decomposition methods available,an improved implementation of QR decomposition for MIMO-OFDM detection based on the Givens rotation technique is given in this research work. The hardware of QR decomposition is made by coordinate rotation digital computer (CORDIC) operating with less gate counts and lower power consumption than triangular systolic array structures. CORDIC calculates vector rotations over shifts and additions. The channel estimation implemented with QR decomposition is to reduce hardware complexity and increase the throughput of MIMO OFDM detection.

Keywords: Multiple Input Multiple Output (MIMO) systems; OFDM; QR decomposition; Givens rotation;

I. INTRODUCTION

Multiple-Input Multiple-Output (MIMO) procedures have been broadly received to build the information transmission rate or to enhance the Quality of Services (QOS) in late remote correspondence frameworks [1]. Going with the advances in VLSI innovation, gigabit remote transmission is step by step arranged and grew, for example, IEEE 802.11ac/notice (802.11 high throughput) [2]. To manage the multi-dimensional signs, grid reversal or triangularization is regularly required. Therefore, QR decomposition is a key instrument to accomplish the objective. For instance, QR decomposition has been used in the pre-coder of the transmitter to change over one MIMO-OFDM channel into layered sub-channels. It is additionally expected to pre-process the sign to be recognized by MIMO circle decoders. Additionally, MIMO signal location can be refined just by QR decomposition. Consequently, to meet the demands of a high transmission rate, a high-throughput QR decomposition module is fundamental. Three known algorithms are generally utilized for decaying a network into a unitary grid and an upper triangular matrix.

II. LITERATURE SURVEY

In QR decomposition three known methods are widely used for decomposing a matrix into a unit matrix and an upper triangular matrix. Gram–Schmidt algorithm obtains the orthogonal base spanning the column space of the matrix by the orthogonality principle. Through a series of projection, subtraction, norm and division, the column vector of the unitary matrix containing the orthogonal basis can be acquired one by one. Meanwhile, the upper triangular matrix is also generated as a by-product.

Householder transformation attempts to zero out the maximum elements of each column vector at a stroke by reflection operations. The upper triangular matrix is derived after each transformation matrix being applied to every column vector sequentially. The unitary matrix involves the multiplications of these Householder transformation matrixes and thus the complexity is much higher.

On the other hand, Givens rotation (GR) zeros one element of the matrix at a time by two-dimensional rotation. If an identity matrix is fed as an input, we can get the unitary matrix by using the same rotation sequence when the upper triangular matrix is obtained. In [3],

In addition, with the systolic array architecture, parallelism is straightforwardly adopted for a large matrix being processed by Givens rotation. Consequently, Givens rotation is regarded as a possible solution in high-throughput design of QR decomposition. In this research work, we design and implement a QR decomposition unit for MIMO-OFDM signals. We first analyse the required QR decomposition from the system-design point of view. According to the characteristics of the channel matrix, a QR decomposition scheme that combines a complex-value Givens rotation stage and a real-value Givens rotation stage is proposed which can save hardware complexity compared to the direct triangularization.

III. MIMO SYSTEMS

In radio, different info and numerous yield, or MIMO is the utilization of various receiving wires at both the transmitter and beneficiary to enhance correspondence execution. MIMO innovation has pulled in consideration in remote interchanges, in light of the fact that it offers noteworthy increments in information throughput and connection range without extra bandwidth or expanded transmit power. It accomplishes this objective by spreading the same aggregate transmit control over the reception apparatuses to accomplish an array pick up that enhances the unearthly MIMO to be proficient and/or to accomplish an assorted qualities pick up that enhances the connection unwavering quality (decreased blurring). Due to these properties, MIMO is a critical piece of present day remote correspondence standards, for example, 3GPP Long Term Evolution,IEEE 802.11n.

IV.ARCHITECTURAL DESIGN OF PROPOSED SYSTEM

The block diagram of the proposed wireless communication method is shown in Figure1.

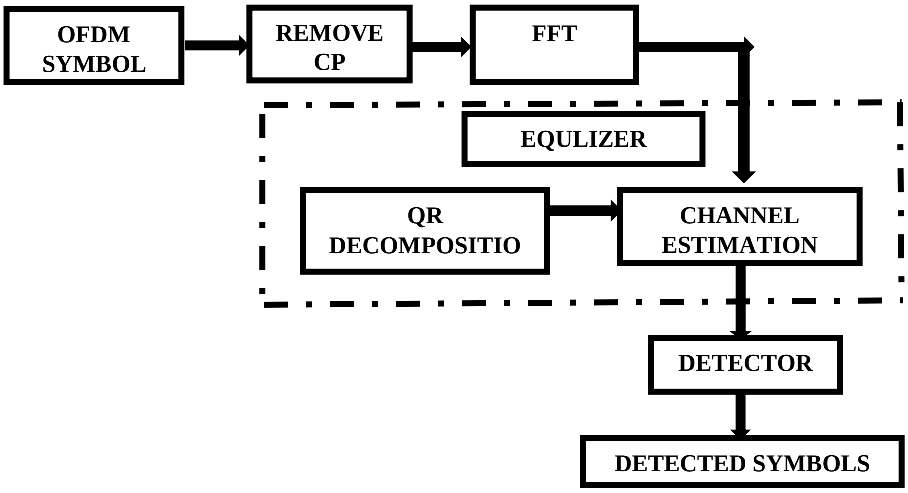

Figure 1: Architectural Design of Proposed System

In the OFDM the receiver side antenna will receive the OFDM symbols which is transmitted by the transmitter. These symbols will have the effect of the channel (i.e.) noise. After the removal of cyclic prefix the time domain of the signal is transformed to the frequency domain using FFT. In equalizer channel estimation is the important operation. In this research work this channel estimation effectively done by QR decomposition algorithm using Givens Rotation method.

V. QR DECOMPOSITION

QR decomposition (QRD) is one of the key calculations utilized in MIMO frameworks [4]. Since various MIMO recognition techniques require QR decomposition of the channel lattice as beginning stage, the QR decomposition of the grid H is a scientific operation that creates two frameworks Q and R which have the accompanying properties:

- The columns of Q are orthogonal. This means the inner product of any two columns of Q is zero (Qx Q^T = I), and the inner product of a column with itself is one.
- R is an upper triangular matrix. This means that any element under the main diagonal is zero.
- The product of Q and R must be A i.e. A=QR.

Thus, QR decomposition of a channel matrix is given by the equation

$$A = Q\,R \qquad (2)$$

After multiplying y with, the signal model can be rewritten as;

$$y = QRX + n$$

$$QTy = QTQRX + QTn$$

$$y = RX + n(3)$$

Advantage of using upper triangular matrix R is that the transmitted data can be detected without inversion computations but with a back substitution only.

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VI. GIVENS ROTATION BASED QR DECOMPOSITION.

Most of the famous routines for QR decomposition, for example, householder change, Gram-Schmidt procedure and Givens rotation, Givens rotation is generally supported as Householder change can't be parallelized and Gram-Schmidt algorithm is numerically shaky [5]. Then again, the Givens rotation permits a parallel computational structure. QR decompositions can likewise be figured with a progression of Givens rotations. Every rotation zeros a component in the sub diagonal of the lattice, framing the R grid. The connection of the considerable number of Givens rotations shapes the orthogonal Q framework. The Givens rotation strategy is valuable in circumstances where just a generally few off diagonal components should be focused, and is more effectively parallelized than Householder transformations.

The Givens Method accomplishes a QR factorization through unitary transformations, called Givens Rotations, which specifically permit the presenting of a zero component [6]. Givens rotation lattice has rank-two redresses about character framework, where the rank (i; j) is supplanted by orthogonal qualities in light of sines and cosines.

$$\begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix} x \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} a'_1 \\ 0 \end{bmatrix} \quad (4)$$

As a sample, a Givens rotation is spoken to in Eq. 4 for a 2 x 1 network, where the resultant lattice has another embedded zero; this can be extrapolated to some other grid size. The rotation point ϴ must be figured previously by the recipe bend tan (a2/a1). On the other hand, these qualities can likewise be figured by Eq. 5 and Eq.6.

$$c_1 = \frac{a_{11}}{\sqrt{a_{11}^2 + r_i^2}} \; s_1 = \frac{r_i}{\sqrt{a_{11}^2 + r_i^2}} \quad (5) \; \&(6)$$

As needs be, Givens Method algorithm begins focusing the lower components, from the first segment to the keep going one, and, on every section, beginning from the base most component to the diagonal component. The upper triangular grid R is accomplished by aggregating the Givens Rotations on the introductory framework. So also, Q is gotten when the same rotations are connected to the personality lattice.

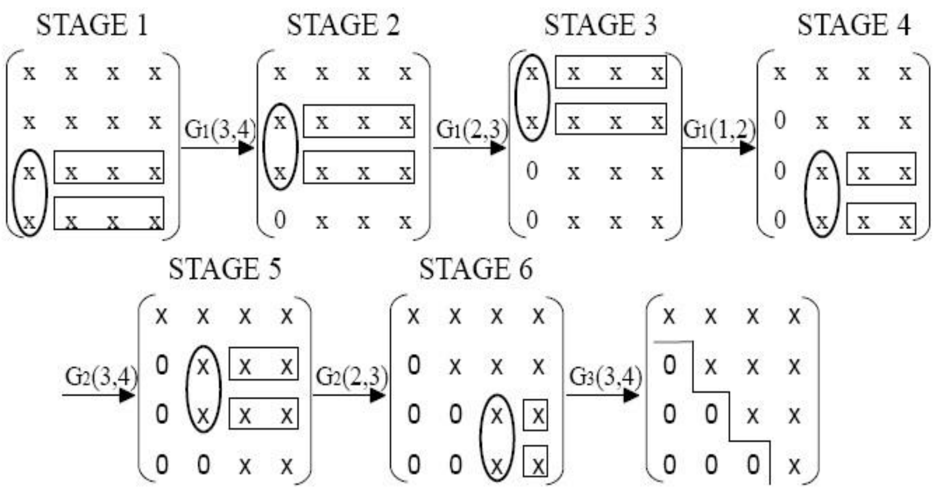

Figure 2: Usual Givens Rotation Schedule for 4X4 Matrices

*Gk (i,j)= Givens rotation of line i and j, k is the segment where a zero is inserted.As a sample, Fig. 2 represents the use of the Givens Method on a 4 x 4 network to accomplish an upper triangular lattice R in 6 stages. Every

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bolt speaks to a Givens Rotation, where Gk (i ; j) indicates the included lines (i; j) and the segment k where a zero will be embedded. The roundabout ranges demonstrate the components chose to compute the rotation point, while the squared zones delimit those components that will be turned utilizing said edge.

It is unmistakably seen that this algorithm has diverse levels of parallelism that could be abused relying upon the chose structural planning. A few works, for example, in [7], have proposed a 2D systolic array like the one appeared in Fig. 2. In this structural engineering, every PE dependably works over components on the same section.On every line of the construction modelling, the Givens rotations may be performed in parallel utilizing the same number of PEs as non-zero components are inside of the column of the network.

Other than this parallel calculation, this setup has the benefit of the two unique sorts of PEs utilized, one (V) to process the rotation edge which, at to begin with, requires substantially more confused operations, and another (R) to perform the viable rotations, which is much easier. Every line of PEs just needs one PE sort V and the rest as sort R. Along these lines, in spite of the fact that they require more PEs, the quantity of PEs sort V (a great deal more mind boggling) are decreased and, then, the general range may be additionally lessened.This structural engineering is utilized as a part of [7], where standard math operations are used to execute the PEs. In [8], iterative CORDIC circuits are utilized rather, which lessens region utilization.

Be that as it may, in these methodologies, because of information conditions between sequential rotations, the PEs of the last lines are sit without moving more often than not, which implies an essential misuse of assets. Other than this, the same information reliance keeps the utilization of pipelining inside in the PEs, which constrains the achievable throughput. An alternate and more seasoned methodology is the one utilized as a part of [9] which is appeared in Fig. 3.

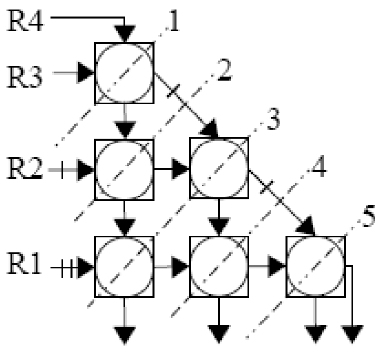


Figure 3: Row based 2D-systolic array for 4 X 4 matrices

On this plan, a PE totally performs a Givens rotation for all components of the two lines. Subsequently, the two operations included in a Givens rotation must be joined in one PE, making it more unpredictable, albeit many less PEs are required. The principle favourable position of this methodology is the way that the main information reliance, which keeps the pipelining inside of the PEs, is the one between the calculation of the rotation edge and the rotation itself.

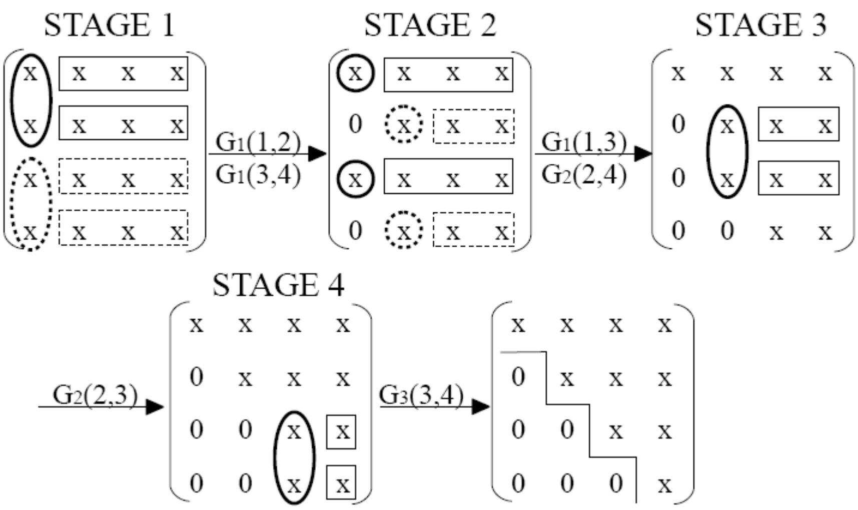
Subsequently, this structural planning accomplishes a high-throughput, yet the many-sided quality of the operations included likewise requires a high usage of asset.

VII. PROPOSED ARCHITECTURE

Correspondingly to the work in [9], we propose to utilize a 2Darray building design where every PE works with every one of the components of the same column and these PEs are pipelining, to accomplish high throughput. Yet, in the meantime, we propose distinctive associations for the PEs inside of the 2D array to decrease idleness. In addition, the PEs are composed taking into account the CORDIC algorithm to execute this pipeline in a less difficult manner, which creates a framework with lower range and higher throughput. Next, we show a few points of interest of this construction modelling.

Givens Rotations Schedule The excellent calendar to execute the Givens algorithm, as it is beforehand depicted in Fig. 2, begins focusing the base most component of the first section, and serially proceeds up in the same segment until this segment is done. At that point, the same methodology is performed throughout the following segment and so on, until the lattice is triangular. The 2D systolic array same time. Solidly, as it is shown in Fig 3, all PEs in the same diagonal work in parallel, altogether decreasing the quantity of steps required for one framework calculation.

On the other hand, this calendar can be performed with a higher level of parallelism, if however many lines as could be expected under the circumstances were pivoted all the while.Along these lines the algorithm diminishes inactivity by decreasing its measure of steps. We ought to take note of that the quantity of Givens rotations continues as before however the quantity of Givens rotations by step is expanded. To diminish the quantity of ventures however much as could be expected, on every stride every single suitable pair of lines (i.e., two unselected columns that contain the same number of zeros to one side) are chosen and they are turned in parallel. This is rehashed until an upper triangular network is accomplished.



*Gk(i,j)=Givens Rotation of rows i and j, k is the column where a zero is inserted.

Figure 4: Givens rotations scheduled for increasing parallelism

Fig. 4 illustrates how a 4 x 4 matrix is factorized by using this schedule. In this figure, two types of lines are described, dotted and continuous; each one represents a Givens rotation made simultaneously. In the first stage, two Givens rotations are performed concurrently, it takes the adjacent rows (1; 2) and (3; 4). This means inserting two zeros in rows 2 and 4 as shown on the second stage. Following, rotations G1(1; 3) and G2(2; 4) are calculated, finishing the computation on the first column. Then, the first row will not be used again, restricting the algorithm to only one rotation by stage for the two last stages. Therefore, only four stages are required using this schedule.

The proposed assigning so as to build design is determined a PE to every Givens rotation. Fig. 5 delineates the structural engineering for 4 x 4 networks. There are four stages, the two first ones with two PEs, since two Givens rotations are performed in parallel, and stand out in the two others. Info and yield transports are joined specifically starting with one stage then onto the next. Just a FIFO register is required in front of an audience 3, since one of the columns figured in stage 2 is utilized as a part of stage 4. Very little rationale is required for synchronization of this construction modelling, because of its pipelined structure.

In this way, a high throughput is accomplished (for this sample, one lattice calculation every 8 cycles).

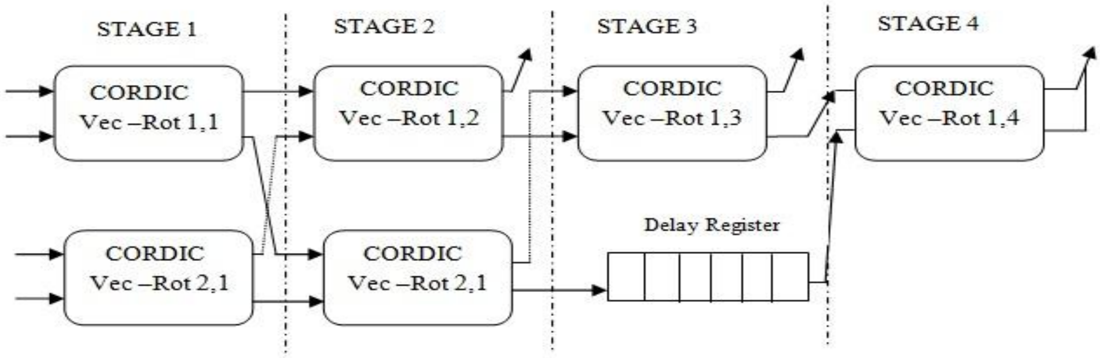


Figure 5: CORDIC Base Architecture Implemented to Factorize 4 x 4 Size Matrices

VIII.RESULT AND DISCUSSION

Utilizing the proposed building design, a VHDL settled point QR decomposition core for 4 x 4 lattices has been planned. Said core permits us to design both piece width and number of CORDIC emphases. This core has been re-enacted and combined utilizing Xilinx ISE 14.7 programming, and actualized and assessed utilizing an equipment Virtex-6 XV6VLX240T speed - 2 FPGA stage.

Table 4.1 Comparative with Other Fpga Implementation

FAMILY	VIRTEX 5		VIRTEX 6		VIRTEX 6	
	USED	AVA	USED	AVA	USED	AVA
Antenna size	4x4		4x4		4x4	
DEVICE	XC5VTX150T		XV6VLX240		XC6VLX550T	
DSP48	80	80	276	768	276	864
Modulation	16 QAM		16QAM		16QAM	
Number of BUFG	1	32	1	32	1	32
SLICE LUTs	12649	92800	516	150720	516	343680
SLICE REG	1492	92800	570	301440	570	687360

Throughput	**18.05**	**27.70**	**30.4**
W-LENGTH	**16 BITS**	**16 BITS**	**16 BITS**

Device Utilization Summary (estimated values)			
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Registers	570	687360	0%
Number of Slice LUTs	516	343680	0%
Number of fully used LUT-FF pairs	207	879	23%
Number of bonded IOBs	577	840	68%
Number of BUFG/BUFGCTRLs	1	32	3%
Number of DSP48E1s	276	864	31%

Figure 4.11 Result for Vertex 6 XC6VLX550T FPGA Hardware

IX. CONCLUSION AND FUTURE WORK

In this altered system for givens rotation based QR decomposition-section savvy givens rotation algorithm, a grid is annihilating so as to be made upper triangular all components in a segment in a solitary go. It accomplishes more parallelism than ordinary givens rotation on the grounds that the line overhauling process simultaneously works with givens era. This cover of operation as in 2D systolic array structural planning gives more proficiency in execution. It effectively lessens the overhead at beneficiary side by exchanging some portion of the calculation workload of locator to QR decomposition area. The high speed is accomplished by applying configuration improvements (multicycles or register stage insertion) on the base structural planning. Higher velocity can be effortlessly accomplished at the expense of range and throughput. Later on, we plan to research the flexibility of this and other comparable architectures to disappointments by deficiency infusion by utilizing distinctive location method as a part of beneficiary side of the remote correspondence system.

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