FPGA Implementation of Multispectral Image Compression for Satellite Images

S Saranya, M Thamarai, M Subbarao

Abstract: Multispectral image compression plays a vital role in remote sensing through satellites. Satellite images are more powerful approach to study the space information and research the geographical nature of the earth. Satellite images contains the huge amount of data and it requires more bandwidth for transmission and more memory for storage. Multispectral image compression reduces the size of the multispectral data and makes it easy for storage and transmission to the earth station form the satellite. The image is compressed by reducing the irrelevant and redundant part of data. This paper presents FPGA implementation of multispectral image compression using Dual Tree Complex Wavelet Transform (DTCWT) and Arithmetic Coding. This compression algorithm is implemented and simulated using MATLAB and XILINX ISE14.5 simulator. The FPGA Spartan -6 architecture is used to implement the algorithm. The proposed method gives better result in PSNR and MSE ratio as compared to DWT.

Keyword: Multispectral image, DTCWT, VLSI, Arithmetic coding, compression ratio

I. INTRODUCTION

Image compression is performed a major role of satellite images, telecommunications, video conferencing, remote sensing [1], medical imaging. Most satellites today measure energy at many wavelengths is called multispectral imaging. Multispectral image is a collection of several images of the same scene, each of them taken with a different sensors. Each image is referred to as one band and it is a 3D image, third dimension is spectral component. Multispectral image can capture the light from the frequency beyond the visible light range, such as infrared. Multispectral image sensors can allow extraction of additional information that the human eyes fails to capture with its Green, Red and Blue receptors.

Remote Sensing Multispectral image compression Encoder requires the low complexity, High performance, High Robust because the encoders usually works on remote sensing satellite where the resources such as Memory, Power, and processing capacity, are limited. Multispectral image compression techniques are developed to reduce the data size and it is must for data transmission and storage and also reduce the cost.

A high efficient technique in digital image processing wavelet Transform which finds its applications in motion estimation, de-noising, data compression, segmentation and classifies the areas. In spite of its limitations such as lack of directional Selectivity, shift Limitations, Lack of Phase Information. It was not employed in many fields. Dual tree Complex Wavelet transform over comes the limitations. The proposed work will be implemented using Dual tree Complex Wavelet transform [2]. The FS Farres and Dual tree Wavelet filters are used in this work .The algorithm is implemented in VHDL and MATLAB. In this Dual tree Complex Wavelet transform used in 2discrete wavelet transforms. To obtain the higher compression ratio of an image or data by using Dual tree Complex Wavelet transform Technique. It is a one of the Lossy image compression technique, it is widely implemented which reduce the memory space, and increase the quality of image.

II. LITERATURE SURVEY

The image compression is normally obtained by reducing the irrelevant and redundant part of data. Basically image compression Broadly Classified into 2 categories. There are LOSSY image compression and LOSSLESS image compression. In the previous works, the multispectral image compression is done by using DWT and CCSDC technique. In DWT used in lifting based technique is mainly derived into 3 categories. There are: (1) Decomposition (2) Predict (3) update. The lifting based DWT is a more powerful and high powerful tool, But it has some limitations like shift invariance, poor directional selectivity and absence of phase information. [3]

Lucana Santos was developed A Low Complexity of implementation of the CCSDS123 standard for space applications was proposed [4]. A hardware architecture is designed with the aim of achieving low hardware occupancy and it implemented on board space qualified FPGA from Microsemi RTAX Family. This method have complex mathematical calculations and the construction is derived in very difficult in VHDL. This forced locked for a better implementation computing compression technique for satellite images. In this one implementing the multispectral image compression will be implemented by Dual tree Discrete Wavelet transform (DTCWT) [2].Giriprasad.M.N et al [5] were implemented FPGA implementation of Combined Compression & Denoising for remote sensing images. The Compression process is carried out using lifting based DWT and denoising is carried out using Kernal based bilateral filtering scheme. The DWT technique implemented in XILINX ISE.Y.B Gandole [6], was developed an image compression technique using 2D dual tree complex wavelet transform and

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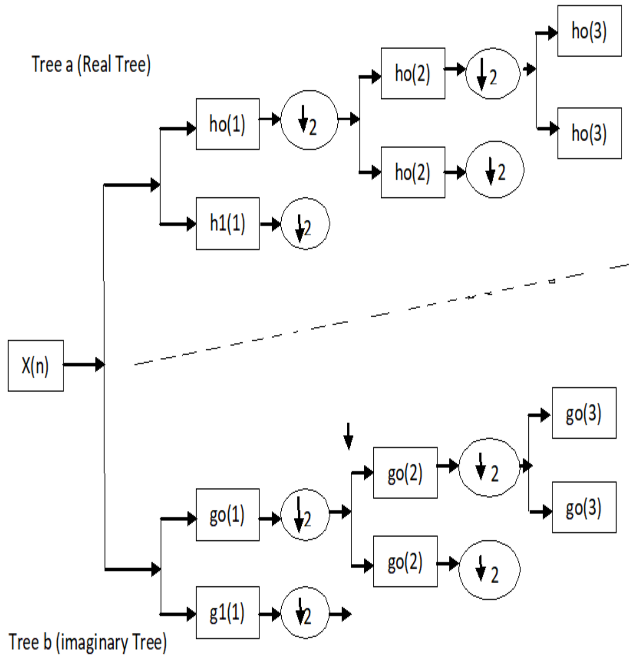
achieved a high compression ratio and lower RMS error.

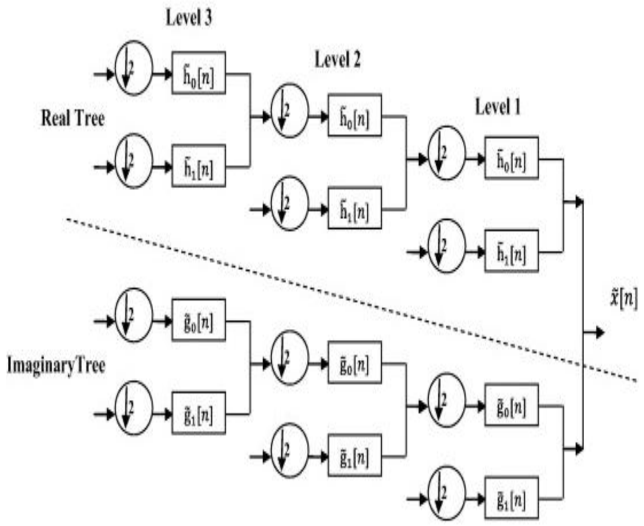
C.Senthi kumar et al [7] proposed a method for color and multispectral image compression using enhanced Block truncation coding. P.R.Burad et al [8] used dual tree wavelet transform for image compression and they applied SPIHT coding for the decomposed coefficients to improve the compression ratio. The technique is applied for normal images.Charu patil & Ravi Mishra [9] presented the implementation of Dual tree Complex wavelet transform in Verilog HDL V. Bhaya Raju et al [10] used Improved DWT with SPIHT algorithm for multi spectral image compression. They tested the technique for various multispectral image bands to improve the compression performance. Q. Du and J.E.Fowler et al [11] proposed hyper spectral image compression using JPEG 2000 and Principal component analysis.The proposed multispectral image compression technique uses Dual tree Complex Wavelet transform with Arithmetic coding. The VLSI implementation of arithmetic coding occupies less memory space when compared to the other encoding techniques. The paper is organized as follows. Section III explains the DTCWT basics and its filters and section. IV describes thresholding. Section V explains arithmetic coding and section VI explains proposed work. Section VIII describes FPGA implementation and section IX FPGA Design flow. The DTCWT Synthesis results are in section X. Section VII and section XI describe the MATLAB and Xilinx Simulation results respectively.

III. DTCWT IMPLEMENTATION

Image compression using DTCWT technique is introduced by Kingsbury in 1998[2]. DTCWT exhibits shift-invariant property and improves directional resolution when compared with that of the decimated DWT. The Dual-tree Complex Wavelet transform consists of two parallel filter bank trees. These are analysis and synthesis filters. The filter banks are employs 2 real DWTs: The first real DWT gives the real part of the transform and the second real DWT gives the imaginary part of the transform (Tree a, Tree b) with low pass and high pass sub bands filters to calculate the complex signal transform as shown in figure 1. The Dual tree Complex Wavelet transform is not a critically sampled transform. First, Transform of an input image is done by the 2 branches. Which are ‘a’ and ‘b’. The two real DWTs can produce real and imaginary coefficient separately. The analysis and synthesis filter banks used in the proposed DTCWT framework are length-10 filter based on FSFarras wavelet transform. A separate set of analysis and synthesis filter banks are used for first stage and higher stages of transformation. There are used in Length-10 filter based on Dual tree Complex Wavelet filter implemented.



(a)



(b)

Fig-1 Dual tree Complex Wavelet transform Trees; (a) Decomposition Tree and,(b) Reconstructed Tree

IV. THRESHOLDING

Thresholding is used to minimize the number of wavelet coefficients. Thresholding are classified into hard thresholding and soft thresholding. The threshold value λ is set to a fixed value and the input image DTCWT coefficients value below the threshold is set to zero. The thresholding generates the more zeros it is called as a hard thresholding. In hard thresholding occupies the less space. Thersholding which generates the less number of zeros is called a soft thresholding, in soft thresholding occupies more space compare to hard thresholding. The hard and soft thresholding process are shown in figure 2.

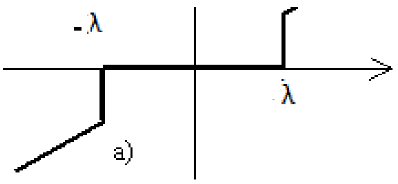
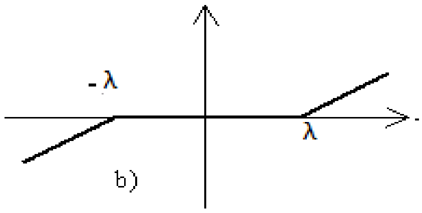


Fig 2. (a) Hard thresholding



(b)

Fig 2. (b) Soft Thresholding

V. ARITHMETIC CODING

Encoder is one of the essential part of the image compression. Arithmetic coder is an entropy encoder technique. Arithmetic coding is common algorithm used in lossless and lossy image compression. The arithmetic encoder replaces the symbols by specific coding.

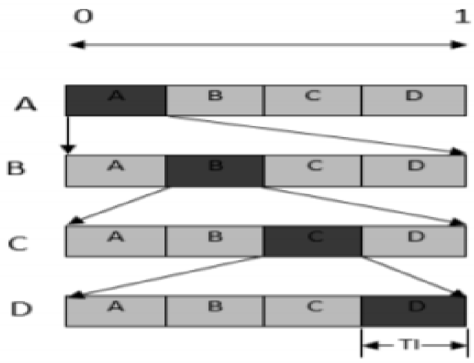
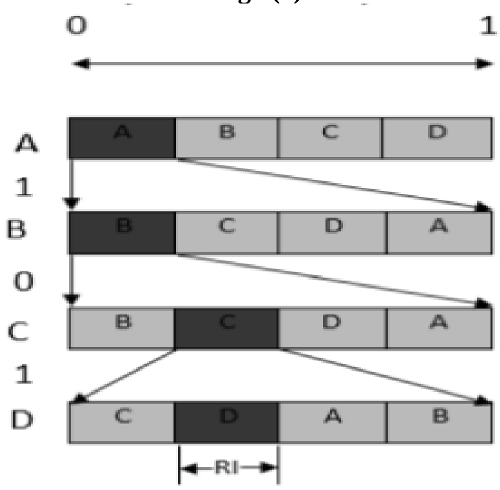


Fig.3(a)



(b)

Fig 3 (a) Conventional Arithmetic Coding example-1
(b) Conventional Arithmetic Coding example-2

For carry out the future discussion for the source with symbols. There are A, B, C, and D. According to the symbols probabilities between the [0, 1] is partitioned. In this one rotating arithmetic coding rotates encoding intervals based on a rotational key. The total length of the rotation key is lesser than the total no of symbols to be encoded by one bit.

For instance, if there is a sequence that has a total N symbols to be encoded. The length of the rotational key is taken as N1bits. The encoding is done symbol by symbol basis. For each symbol, the rotation key decides whether or not to make a rotation with an exception for first symbol. The working of the conventional Arithmetic coding examples are shown in figure 3.

VI. PROPOSED WORK

Multispectral image is selected for image compression. Initially the Original image is decomposed to 4 levels by applying DTCWT. The decomposed coefficient obtained are modified by applying the threshold for further compression and arithmetic encoding is applied to get the compressed image. The DTCWT image compression technique implemented in VHDL and MATLAB. The figure 4 shows the Block diagram of the proposed compression process.

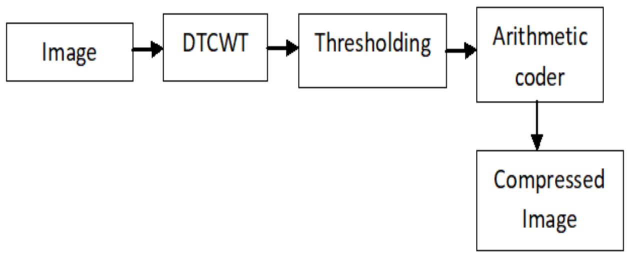


Fig 4. Block diagram using DTCWT for compression

Initially input multispectral image of size 512X512 is taken and resized to 256 X256.The input image is split into 7 sub bands using MATLAB. Then the Dual Tree Complex wavelet Transform applied for the input image and thresholding is done using the threshold value 10. The input value is below the threshold value, then the output set as a zero. Here hard thresholding is used which in turn generates more number of zeros.

Encoder is the one of the main step in compression. The arithmetic coder used for encoding. In this coding, the input symbol(Coefficient) is replaced by the specific code. The specific code is generated by using the integer value. The integer values ranges between the 0.0 to 0.1 of real numbers. The arithmetic coded coefficients results the compressed image. To get the decompressed image arithmetic decoding and inverse dual tree complex transform are applied. All the compressed sub band images are reconstructed and combined to get the multispectral reconstructed image.

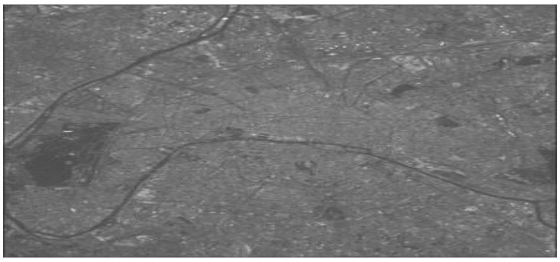
Finally after getting the multispectral image, the PSNR and MSE values are calculated using the formulas given in equation 1.

$$\text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2$$

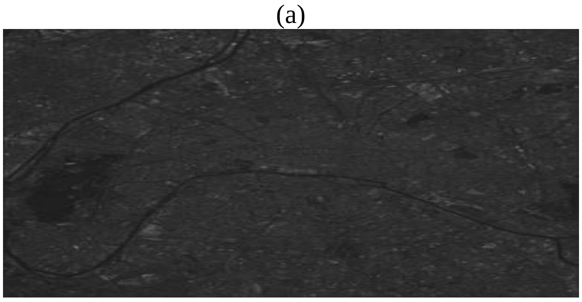
$$\text{PSNR} = 10log_{10}\left[\frac{MSE}{255^2}\right] \quad \text{-----1}$$

VII. RESULT

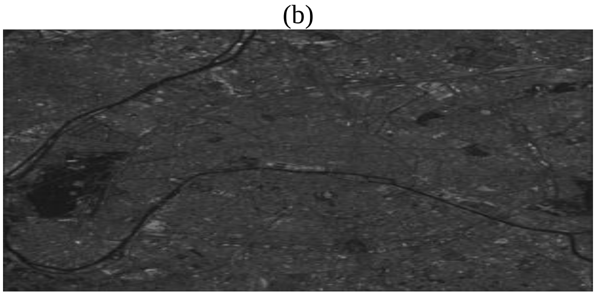
The PARIS and RIO images of size 512x512 respectively are taken for analysis. The band spilt Paris images and original are shown in figure-5.



(a)



(b)



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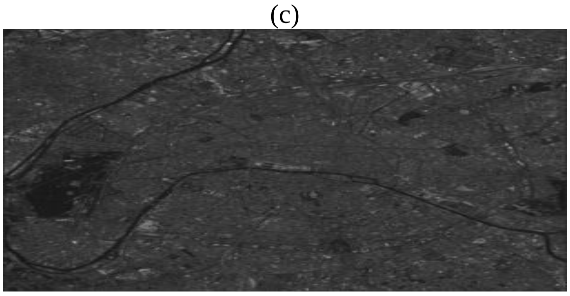

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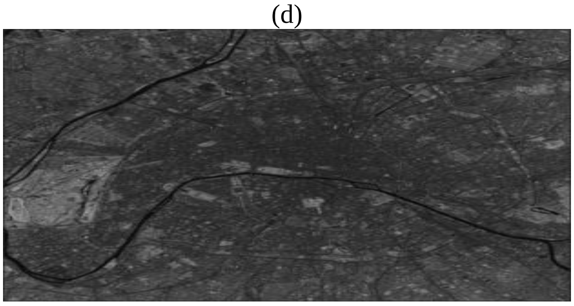

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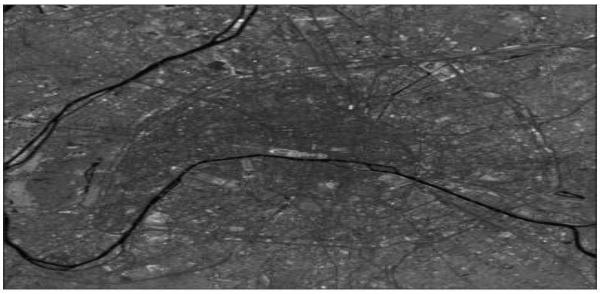
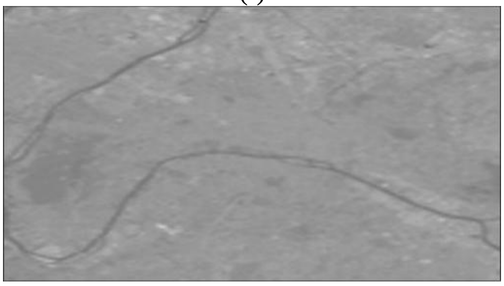
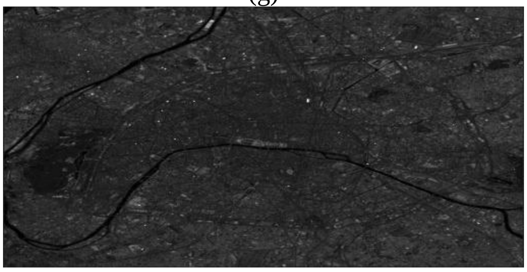


(f)



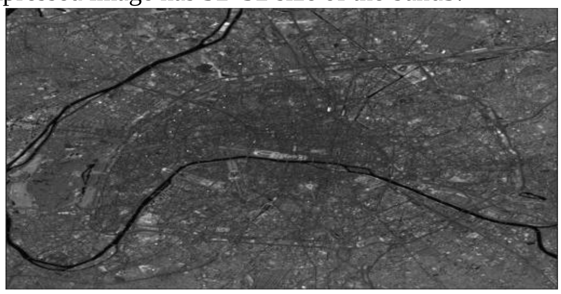
(g)



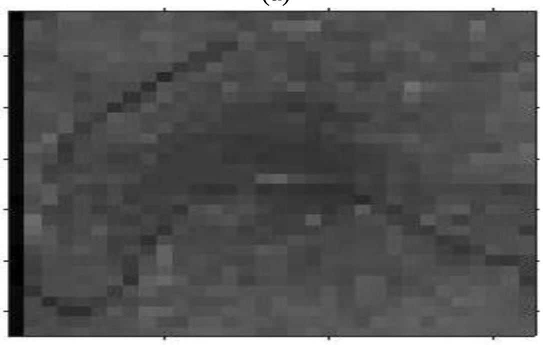
(h)

Fig-5 (a) Band1 (b) Band2 (c) Band3 (d) Band4 (e) Band5 (f) Band6 (g) band7

The compression algorithm is applied and the compressed image and reconstructed image of Band5 is shown in figure 6.The original image has 256*256 size of the band5. The compressed image has 32*32 size of the band5.



(a)



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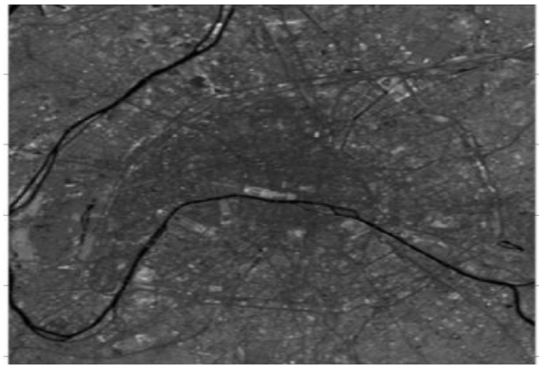

(c)

Fig-6 (a) Original Image (Paris) (b) Compressed Image (c) Reconstructed Image

Table1:- PSNR and MSE values of all bands of input images

	DTCWT			DWT	
	Band	PSNR	MSE	PSNR	MSE
Paris Image	Band1	33.98	25.98	12.76	55.23
	Band2	35.39	18.77	13.49	45.21
	Band3	36.34	15.09	13.51	42.21
	Band4	37.05	12.79	13.51	42.21
	Band5	37.70	11.03	13.59	41.23
	Band6	39.52	7.25	12.86	56.02
	Band7	39.63	7.07	13.41	42.55
	Multispectral image	34.43	13.56	13.45	42.66
Rio Image	Band1	42.43	3.71	31.23	26.05
	Band2	43.84	2.68	35.09	27.58
	Band3	44.79	2.15	31.59	30.25
	Band4	37.05	12.79	29.75	33.50
	Band5	37.70	11.03	25.60	40.52
	Band6	47.97	1.03	35.06	27.08
	Band7	48.08	1.01	30.33	35.68
	Multispectral image	32.76	26.02	29.55	40.99

The table1 shows the PSNR and MSE values of 7 bands of the two input Multispectral images for DTCWT and DWT Techniques. The PSNR and MSE values of DTCWT technique is better than and DWT compression technique.

VIII. FPGA IMPLEMENTATION

FPGA stands for field programmable gate array. FPGA is an integrated circuit designed to configure by customer. Which has the array of logic module, I/O module and routing tracks. FPGA can be configured by end user to implement specific circuitry. Speed is up to 100MHz but at present speed is in GHz. Main application are DSP, FPGA based computers, logic emulation, ASIC, FPGA can be programming technology is re-configurability. Issues in FPGA technology are complexity of logic elements, I/O support and clock support and interconnections. In this project, design of a DTCWT and IDTCWT is made using VHDL and synthesized on FPGA family of Spartan 6 through XILINX ISE 14.5 Tool.

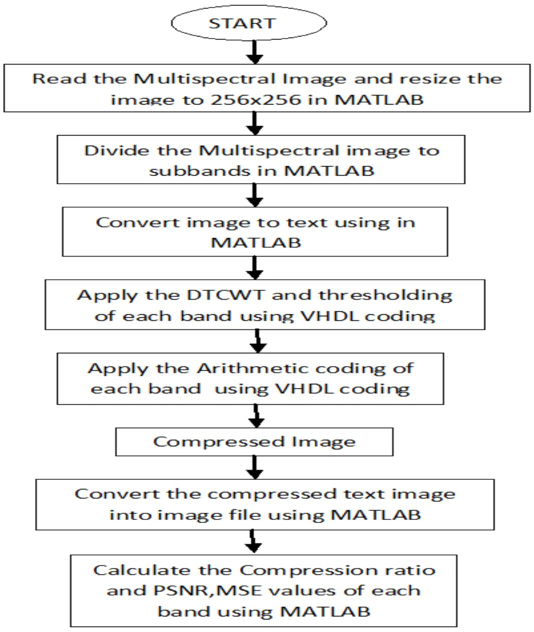

Fig-7. Compression Process Flow in VLSI

The compression process flow in VLSI is as shown in figure 7, Initially the taken Multispectral image is resizes into the image of 256x256, Next the image is split into 7 sub bands based on the their spectral bands . Then the all the sub band images are converted to a binary text file by using MATLAB. Next Dual Tree Complex Wavelet transform is applied to the sub bands. The DTCWT coefficients are subjected to thresholding to a value 10. Finally arithmetic coding of the thresolded coefficients is performed to get the compressed image. DTCWT is implemented using two wavelet, One DWT output is real and Second output is imaginary. The real and imaginary compressed coefficients are combined and results compressed image. We can visualize the compressed image in MATLAB. The MSE and PSNR are calculated using matlab for all the sub bands .The combined bands (1 -7) PSNR and MSE is the final performance value of the proposed method for the taken input image and the values are tabulated in table -1.The VLSI implementation is done using VHDL coding and the process is described in the following sections.

IX. FPGA DESIGN FLOW

The FPGA Design implementation as follow the below steps.

- Design Entry
- Technology Mapping
- Logic Operation
- Translate
- Configured FPGA
- Programming Unit
- Place & routing
- Mapping

The basic steps of FPGA implementation as shows the above. The initial design entry of may be in VHDL, schematic or Boolean expression. The

Optimization of Boolean expression will be carried out by considering area and speed. In technology mapping, the transformation of the Optimization Boolean expression to logic Blocks, that is said to be a Slices.

The DTCWT is simulated and its functionality is verified. Once the functional verification is done. The RTL model is taken to synthesis process using XILINX ISE 14.5 tool. In synthesis process, the RTL model converted into gate level net list which is mapped to a specific technology library. The design of DTCWT decomposition, thresholding and arithmetic coding are shown in. figure 8,9and 10 respectively.

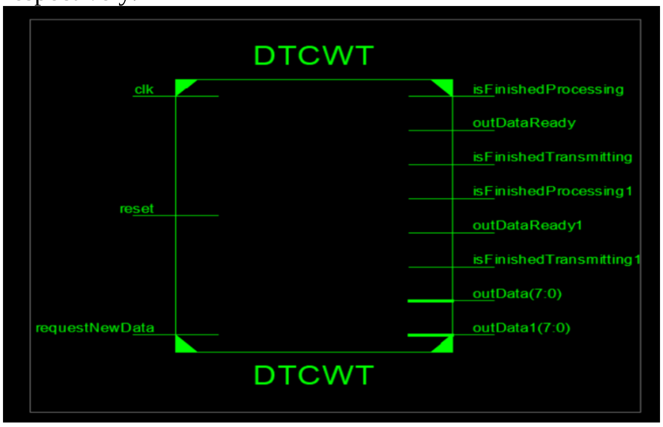

Fig-8 2D-DTCWT RTL Schematic with Basic Inputs and outputs

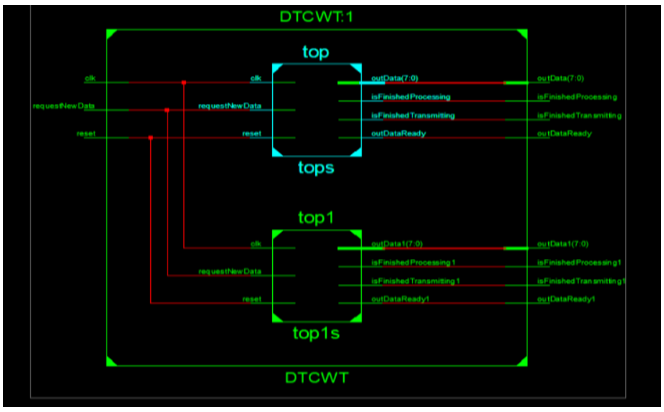

Fig-9 Block inside the Developed Top level DTCWT Design

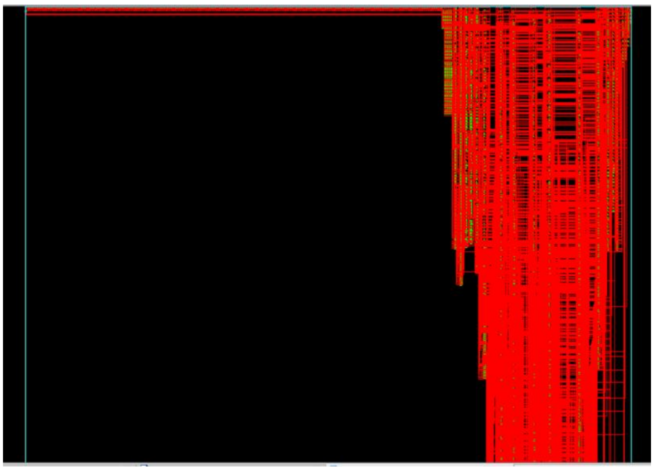

Fig-10 2D-DTCWT Schematic diagram of top level

X. DTCWT SYNTHESIS RESULT

The device utilization includes the following.

- Logic Distribution
- Logic Utilization
- Timing Constrains

The DTCWT timing constrains block is shown in figure11.

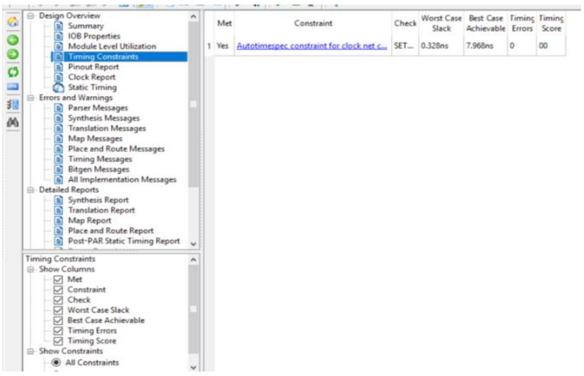

Fig-11 DTCWT Timing constrains Block

Table:-2 Logic Utilization Report:

Device Utilization Summary of DTCWT + Arithmetic coding			
Logic Utilization	Used	Available	Utilization
No of Slice Registers	910	126576	1%
No of Size Look Up Tables	1807	63288	2%
No of Fully Used LUT-FFT Pairs	692	2025	33%
No of Bounded IOB's	25	296	8%
No of Block RAM fifo	8	268	2%
Number of bufg	1	16	6%

The table-2 shows the FPGA synthesis report of band5.

The device utilization is given as number of LUTs, IOBs, Number of slice registers with their utilization percentage.

XI. DTCWT SIMULATION RESULT

Modelism simulation result for the proposed design is shown in figure 12. The input image file actually proposed for the VHDL input using MATLAB. Once if we apply the DTCWT and arithmetic coding then we can get the compressed image. The reconstructed image is obtained by the reverse process (IDCWT and Arithmetic decoding). The DTCWT LL sub band of each tree gives the real and imaginary compressed images

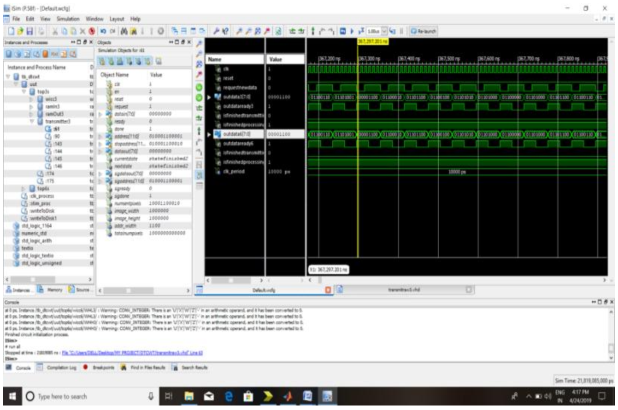

Fig-12 Simulation Result

XII. CONCLUSION

In this paper, VLSI implementation of multispectral image compression using DTCWT and Arithmetic coding is implemented. The shift invariant and directional property of DTCWT improves the performance of the method. Arithmetic coding further reduces the data size and improves the compression ratio. The performance is compared with DWT for two multispectral images in terms of PSNR .The functional and logic simulation were carried out using the XILINX ISE 14.5 and Modelsim. The proposed method gives high compression ratio and PSNR when compared to the DWT. The obtained compression ratio is 4.88.The logic utilization report shows the compact implementation of the proposed method in VLSI.

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