ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

Development of Compression Algorithms for Remotely Sensed SAR Data

MALLIKARJUN BANKAPUR, MANJULA N HARIHAR,
Student, Assistant Professor

Abstract*— Applications of self-illuminating remote sensing systems and Radar Imagery is growing rapidly. Unique properties of Synthetic Aperture Radar (SAR) system makes it one of the most popular and applicable methods of self illuminating remote sensing techniques for ground deformation monitoring, seismic studies, and many photogrammetric applications. The objective of this project is to develop six different algorithms for reducing onboard memory requirements and downlink link budget for down-linking high resolution SAR images. We have developed six algorithms in various domains namely Block Adaptive Quantisation (BAQ), Wavelet Transform BAQ, Wavelet Packet BAQ, Amplitude Phase Compression Algorithm (AP), Wavelet Transform AP, Wavelet Packet AP. The quality of images produced by these algorithms is compared using Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and reduction in image size for the corresponding compression ratio. This Project is implemented in MATLAB is developed with graphical user interface and a few visualization enhancement features, which facilitates processing data and producing desired output.

***Index Terms*— SAR, data compression, block adaptive quantization, amplitude phase, wavelet transform.**

I. INTRODUCTION

Environmental monitoring, earth-resource mapping, and military systems require broad-area imaging at high resolutions. Many times the imagery must be acquired in inclement weather or during night as well as day. Synthetic Aperture Radar (SAR) provides such a capability. SAR systems take advantage of the long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics to provide high-resolution imagery. Synthetic aperture radar complements photographic and other optical imaging capabilities because of the minimum constraints on time-of-day and atmospheric conditions and because of the unique responses of terrain and targets to radar frequencies. Synthetic Aperture Radar is a radar technology that is used from satellite or airplane. It produces high-resolution images of earth‘s surface by using special signal processing techniques [1]. Synthetic aperture radar has important role in gathering information about earth‘s surface because it can operate under all kinds of weather condition (whether it is cloudy, hazy or dark). However acquisition of SAR images faces certain problems**.**

In this paper we are going to compare DCT, DWT and DWP based image compression techniques using various techniques with the help of hybridised image compression [8]. Since standard performance measures assume additive and uncorrelated noise a pre processing step is necessary before calculating the MSE, SNR or PSNR. Although SAR images are mostly assessed by humans, standard quality measures do not use any known properties of the human visual system. For example, the human visual system is not as sensitive to high frequencies compared to low frequencies, but standard measures give equal importance to all frequencies. Our aim is to form the 2-D image from SAR raw data and compressing SAR images using various algorithms. The implementation of all these is shown in the proposed system. The Mat-Lab code flow is developed using GUI and the simulation results are depicted in the figures.

II. PROPOSED SYSTEM

There are two main steps in the implementation of the proposed system, extraction of SAR image from the Raw data and compression of the SAR image using six different algorithms [11].

A. SAR Image formation

SAR Image formation is done using Range Doppler Algorithm, which involves the steps as follows.

- Range Compression.
- Patch Processing
- Range Migration
- Azimuth Compression

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

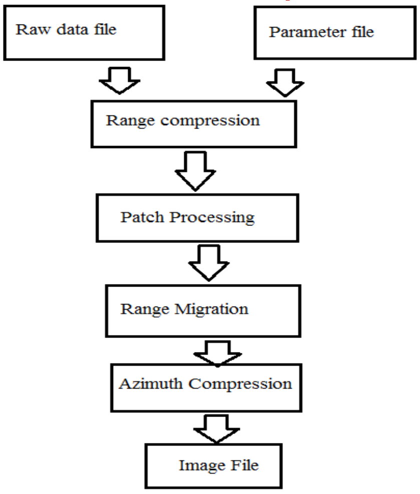

Fig 1: Image formation from SAR raw data

The flow chart of SAR Image formation is as shown in the above Figure 1. The various steps involved in formation of SAR Image is discussed below. Initially the RAW data and parameter files are input and the following processes are carried out to obtain the SAR Image.

a. Range Compression

To reduce the peak power of the radar transmitter associated with a short pulse, a long frequency-modulated chirp is emitted by the radar. This chirp propagates to the ground where it reflects from a swath typically 100 km wide. When it returns to the radar, the raw signal data consists of the complex reflectivity of the surface convolved with the chirp. Our objective is to recover the complex reflectivity by de-convolution of the chirp. This is done using Fast Fourier Transform. Target will appear as a hyperbolic shaped reflection as it moves through the synthetic aperture. In addition, there could be a pronounced linear drift due to an elliptical orbit and earth rotation. In other words, the target will migrate in range cell as a linear trend plus a hyperbola.

b. Patch processing

This process it is done to focus the image. The image must be focused in the azimuth direction using Fast Fourier transform The amount of data to process is quite high.

c. Range Migration

The shape of the migration path is calculated from the precise orbital information. Prior to focusing the image along a single column, these signals must be migrated back to a constant range cell, this is called *range migration.* And the fastest way to achieve this is by using Fourier transforming the columns first. Each Fourier component corresponds to a unique doppler shift and also a unique value of range migration. For ideal radar, the first component will have zero doppler and will correspond to the point on the earth that is perpendicular to the spacecraft velocity vector. The second component will have a small positive doppler shift and a small migration of the range cells will be needed all the way through the positive and negative doppler spectrum.

d. Azimuth Compression

Azimuth compression or azimuth focusing involves generation of a frequency-modulated chirp in azimuth based on the knowledge of the spacecraft orbit. The geometry of the strip-mode acquisition is shown below in Figure 2.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

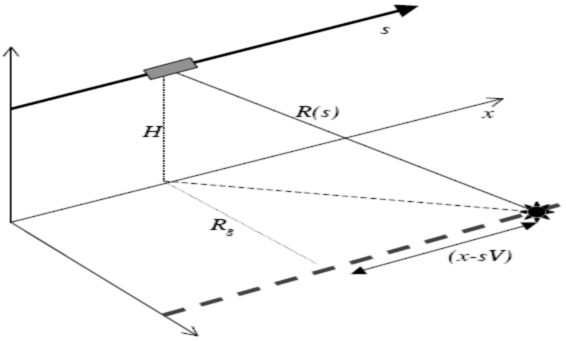

Fig 2: Geometry of strip mode acquisition.

Where, *s* – Slow time along the satellite track
x – ground-track position
V – Ground track velocity
so– time when the target is in center of the radar illumination pattern
H – Spacecraft height
Rg– ground range
R(s) – range from spacecraft to target
$Ro = \sqrt{(H^2 + Rg^2)} = Rnear + n * (C/fs)$ minimum Range from the spacecraft to the target.

As depicted in the below Figure, the first procedure in this project is to extract the Image from the SAR raw data, which involves Doppler center estimation, Range compression and Azimuth Compression. And thereafter using Matched Filtering concept the final image is extracted. The data flow diagram of SAR image formation is shown in below Figure 3.

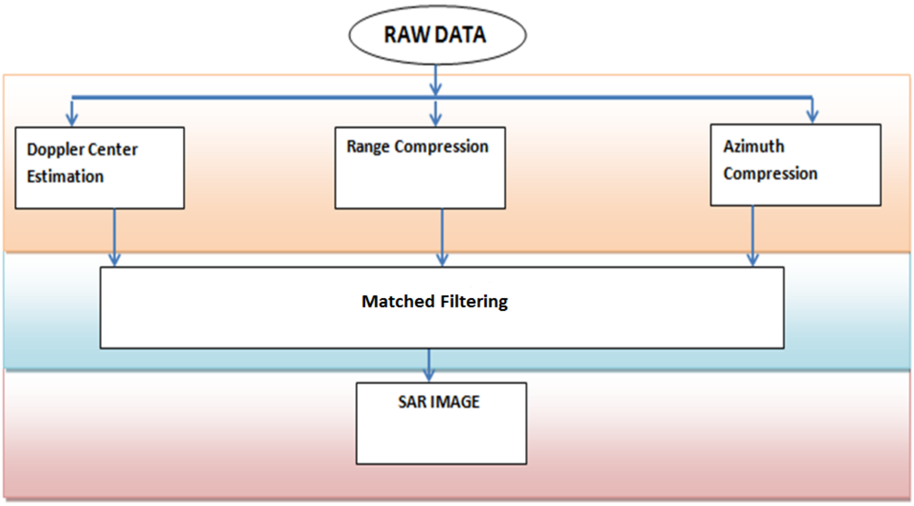

Fig 3: Data Flow Diagram of SAR Image Formation.

B. SAR Image Compression

There are totally six algorithms implemented in this paper using Matlab.

- Block Adaptive Quantization (BAQ)
- Wavelet Transform Block Adaptive Quantization (WT-BAQ)
- Wavelet Packet Block Adaptive Quantization (WP-BAQ)
- Amplitude Phase Compression (AP)
- Wavelet Transform Amplitude Phase Compression (WT-AP)
- Wavelet Packet Amplitude Phase Compression (WP-AP)

The Figure 4 shows the complete SAR image compression based on various algorithms in single process.

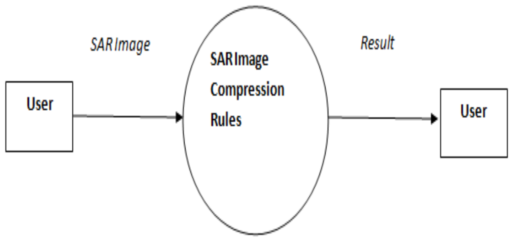

Fig 4: Overview of SAR Image Compression.

Once the image is extracted, now the compression algorithms are to be used to compress the image on-board and downlink to the earth station. In this project we have used six different algorithms to compress the image and conclude which technique provides better compression with minimal Mean Square Error (MSE) and maximal Peak Signal to Noise Ratio (PSNR). The SAR image compression data flow diagram is as shown in Figure 5.

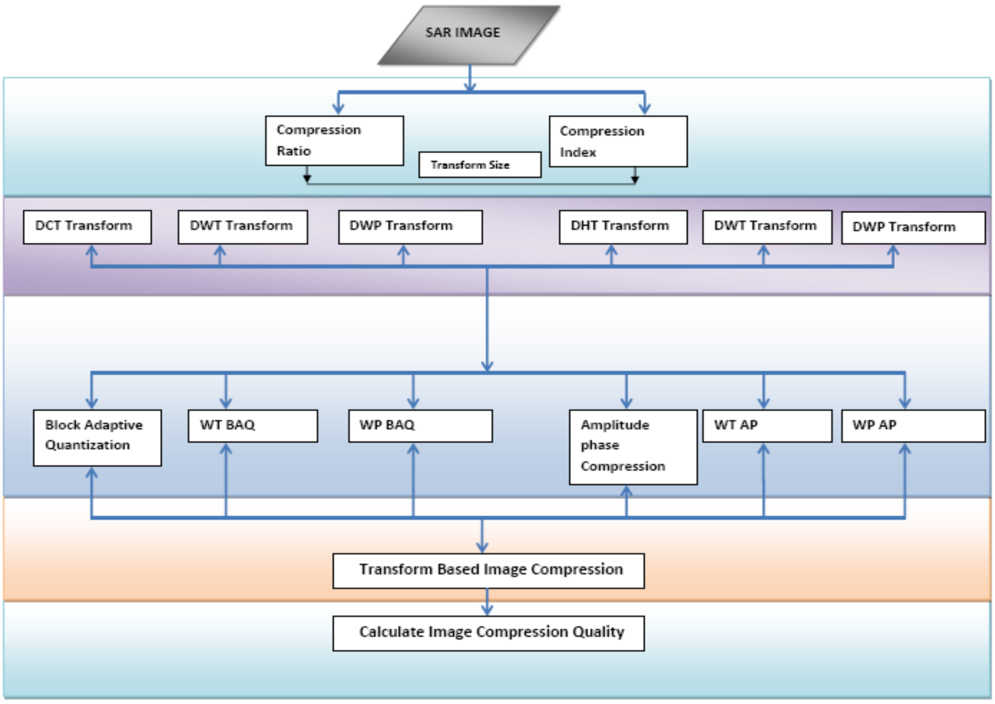

Fig 5: Data Flow Diagram of SAR image compression.

a. Mat-Lab Code Flow

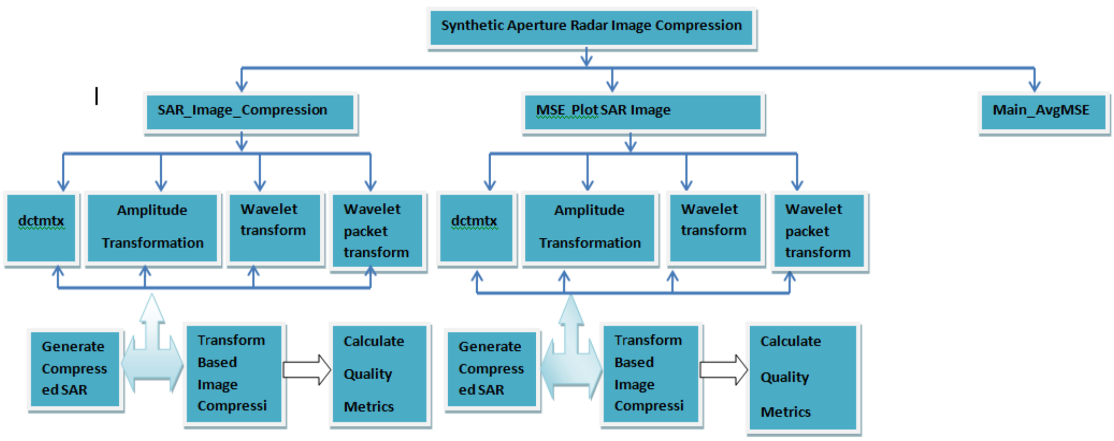

Fig 6: Mat-Lab Code Simulation.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013
The Programming for the Project is done in Mat-Lab using image processing toolbox and the user friendly Graphical User Interface (GUI). The compression algorithms are developed using Hybridised Transformation. The code flow diagram is shown in the above flow chart Figure 6.

b. Applications
Synthetic-aperture radar (SAR) has seen wide applications in remote sensing and mapping. Synthetic aperture radar technology has provided terrain structural information to geologists for mineral exploration, oil spill boundaries on water to environmentalists, sea state and ice hazard maps to navigators, and reconnaissance and targeting information to military operations. There are many other applications or potential applications. Imaging techniques now form an important part of radar use, and high-resolution images from aircraft and satellites are used for remote sensing and environmental monitoring, as well as for the military surveillance purpose.

III. SIMULATION AND RESULTS
Many different performance measures can be used to compare image compression techniques. When real time operation is crucial as in SAR image compression the computational load is one of the performance measures. Since the aim of image compression is to reduce the number of bits required to represent a image without visually destroying it, a measure of image quality for a fixed compression ratio is required.

A. *Mean Square Error (MSE)*
The mean square error is one of the most commonly used performance measures in image and signal processing. For an image of size N X M it can be defined as

$$\mathrm{MSE} = \frac{1}{NM}\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}|x[n,m]-\hat{x}[n,m]|^2$$

Where x[n,m] is the original image and x̂[n,m] is the decompressed image.

MSE Analysis

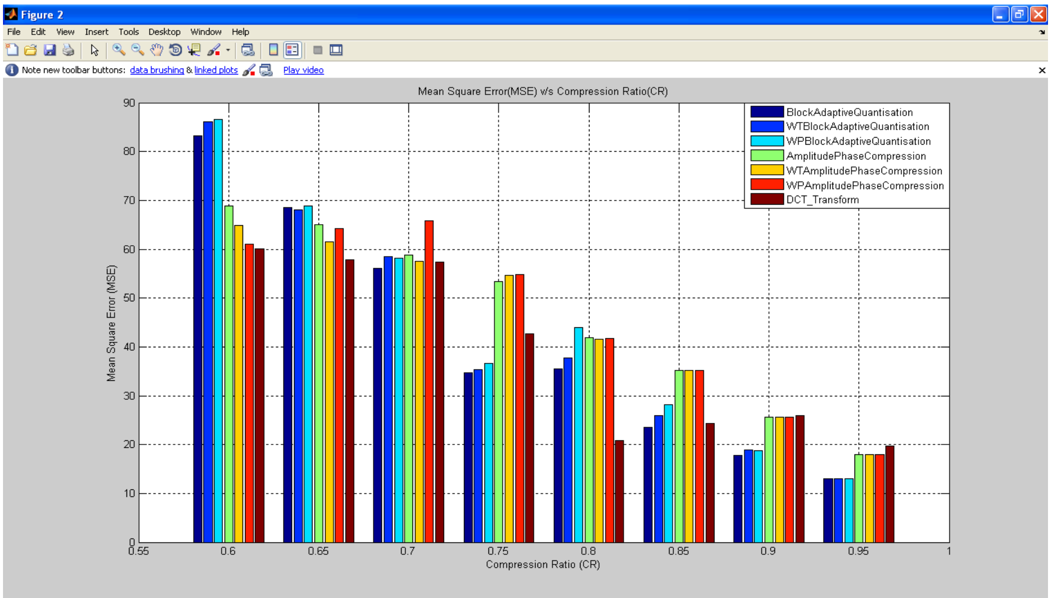

Fig 7: Graph for MSE Analysis.

From the Figure 7, it can be seen that as the compression ratio increases Mean Square Error decreases, which means for higher compression ratio the error is least and for the lower compression ratio the error is comparably more.

B. *Peak Signal to noise ratio (PSNR)*
PSNR is the most commonly used performance measure for image processing applications. It can be defined as:

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

$$PSNR = 10\log_{10}\frac{(\text{peak-to-peak value of the original image})^2}{MSE}$$

PSNR Analysis

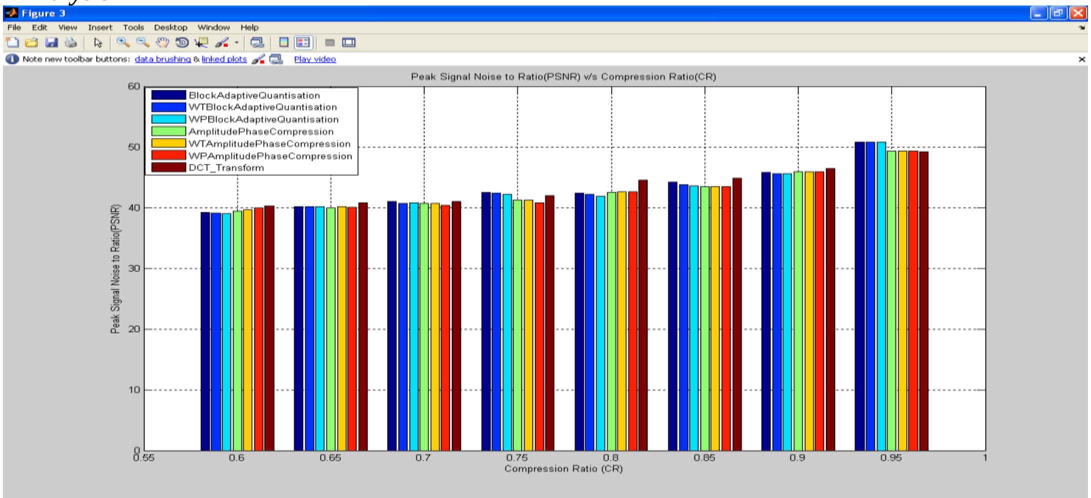

Fig 8: Graph for PSNR Analysis.

In the above Figure 8, it can be seen that, as the compression ratio increases Peak Signal to Noise Ratio (PSNR) is improved, which concludes that for lower compression ratio PSNR is comparably weak and for higher compression ratio the quality of the signal is better.

C. *Image Size*

The resulting image which is extracted from the SAR image is shown in below figure 9. This image is again considered for image compression using six different algorithms. The size of the image is compressed in accordance with the Compression Ratio provided. The Table 1 shown below is an example for quality parameters with Compression Ratio=0.5.

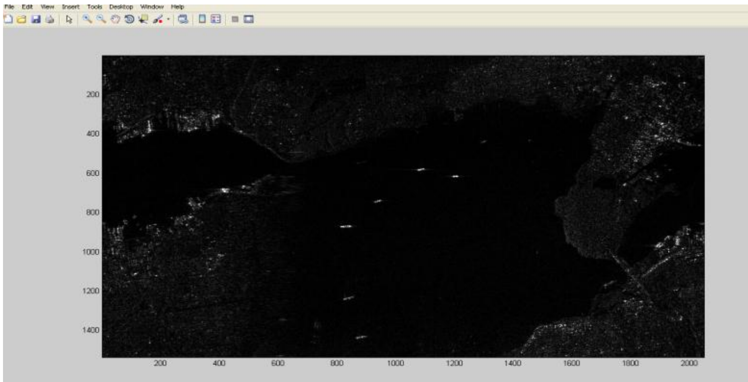

Fig 9 : Resultant image for data1.mat.

Table 1: Quality Parameters

Technique	MSE	PSNR	Original Image size	Compressed Image size
BAQ	74.45	29.41	65536 bytes	32768

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

WT-BAQ	74.40	29.42	65536 bytes	32768
WP-BAQ	81.78	29.00	65536 bytes	32768
AP	78.05	29.21	65536 bytes	32768
WT-AP	77.17	29.26	65536 bytes	32768
WP-AP	79.25	29.14	65536 bytes	32768

Comparing all the techniques implemented, it is found that, WT- BAQ algorithm and WT-AP have the least MSE and highest PSNR and found to be the better Compression Algorithms when compared to rest of the compression algorithms. And the Size of the image is reduced i.e. is compressed in accordance with the changing compression ratio.

IV.CONCLUSION

In this project four compression algorithms are discussed, including block adaptive quantization (BAQ) algorithm, amplitude and phase compression (AP) algorithm and wavelet BAQ (WT-BAQ) algorithm and wavelet packet BAQ (WPT-BAQ) algorithm. Considering the statistical independent property between amplitude and phase of raw data along with the growing popularity of wavelets, two additional algorithms are presented: wavelet AP (WT-AP) algorithm and wavelet packet AP (WPT-AP) algorithm. The six different algorithms are compared in image domain with several quality parameters and the simulation is given to validate analytic result. And found that comparing all the techniques implemented, it is proved that, WT- BAQ algorithm and WT-AP have the least MSE and highest PSNR and found to be the better compression algorithms when compared to rest of the compression algorithms.

REFERENCES

[1] Ronald Kwok and William T. K. Johnson, “Bandwidth compression of Synthetic Aperture Radar imagery by quantization of raw radar data”, SPIE, vol. 119, pp. 107, 114, 1977.

[2] Butman and Joo, “An adaptive quantization method for burst mode Synthetic Aperture Radar”, presented at the Int. Radar Conference, Arlington, VA, pp. 385-390, May 6-9, 1985.

[3] A. El Boustaniand, W. Kinser, "Robust Uncertainty Principles: Exact Signal Reconstruction from Highly Incomplete Frequency Information," IEEE Trans. Inf. Theory, vol. 52, 2006.

[4] Mireia Cequiel Mir and Zhishun. ”Block adaptive quantization of Magellan SAR data”, IEEE Trans. Geosci. Remote Sens., vol. 27, no. 4, pp. 375-383, Jul. 1989.

[5] Gowtham. A. Tammana and Yuan F. Zheng “A Compression of Severel Algorithms for SAR Raw Data Compression”, IEEE Trans On Geo-science and Remote Sensing, Vol 33, No 5, September 1995.

[6] D. L. Donoho, "Compressed Sensing," IEEE Trans. Inf. Theory, vol. 52, pp. 1289-1306, 2006.

[7] Sujit Bhattacharya and Thomas Blumensath “Synthetic aperture radar, systems and signal processing” Wiley Series in Remote Sensing, New York. 1991.

[8] David. T. Sandwell, “Raw SAR Data Compression Using Vector Quantization”, Int. Journal of Remote Sens., vol. 6, no. 16, 1995.

[9] Ken Cabeen and Peter Gent, "Image Compression and the Discrete Cosine Transform" Math 45,College of the Redwoods 2007.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

[10] Neim Dastgir, "Compression of Synthetic Aperture Radar Video Phase History Data Using Trellis-Coded Quantization Techniques", IEEE Trans. Geosci. Remote Sens., vol. 37, pp. 1080- 1085, 1999.

[11] N Gokhan and Necmi Serkan Tezal. "A comparison of several algorithms for SAR raw data compression" IEEE Trans. Geosci. Remote Sensing. 33(5): 1266-1276 1994.

[12] Yao Shichao, Wang Yanfei and Zhang Bingchen. "Amplitude and phase compression algorithm of SAR raw data" Journal of Electronics and Information Technology. 24(11): 1627-1633 2006.

[13] Elke Malz , Rolf Mittermayer and Paul Attema. "Block adaptive quantization of Magellan SAR data" IEEE Trans. Geosci. Remote Sensing. 27(4): 375-383. 1989.

[14] http://www.vectorsite.net/ttdcmp 2.html.

[15] Greg Ames, "Image Compression", Dec 07, 2002.

AUTHOR BIOGRAPHY

Mallikarjun Bankapur is a student in the Department of Electronics and Communication Engineering, School of Engineering, Jain University, Bangalore. He obtained his Bachelor degree in Electronics & Communication Engineering from S.C.T. Institute of Technology, Bangalore in 2011, Visvesvaraya Technological University, Belgaum and He is pursuing M.tech (SP and VLSI) in Electronics and Communication Engineering, Jain University, Bangalore. His research interest includes Image Processing, VLSI, DSP, Micro-Controller.

Manjula N Harihar is a lecturer in the Department of Electronics and Communication Engineering, Sri Bhagawan Mahaveer Jain College of Engineering, Jain University, Bangalore. She obtained her Bachelor degree in Electronics and Communication Engineering from S.T.J Institute of Technology, Ranebennur and Master degree in Communication Systems from P.D.A College of Engineering, Gulbarga, Karnataka, India. She is pursuing Ph.D in Electronics and Communication Engineering, Jain University, Bangalore. Her research interest includes Image Processing, VLSI, Neural Networks and Wireless Communication.