ISTANBUL UNIVERSITY –
JOURNAL OF ELECTRICAL & ELECTRONICS ENGINEERING

YEAR : 2007 (257 - 276)
VOLUME : 7
NUMBER : 1

ADAPTIVE WIENER-TURBO SYSTEM AND ADAPTIVE WIENER-TURBO SYSTEMS WITH JPEG & BIT PLANE COMPRESSIONS

Kenan BUYUKATAK[1] Osman N. UCAN[2] Ersin GOSE[3]
Onur Osman[4] Sedef KENT[5]

[1,3]Turkish Air Force Academy, Yesilkoy, Istanbul, Turkey
[2]Istanbul University, Engineering Faculty, Electrical-Electronics Engineering, Istanbul, Turkey
[4]Istanbul Commerce University, Uskudar, Istanbul, Turkey
[5]Istanbul Technical University, Engineering Faculty, Electrical-Electronics Engineering, Istanbul, Turkey

ABSTRACT

In order to improve unequal error protection and compression ratio of 2-D colored images over wireless environment, we propose two new schemes denoted as "Adaptive Wiener-Turbo System (AW-TS) and Adaptive Wiener-Turbo Systems with JPEG & Bit Plane Compressions (AW-TSwJBC)". In AW-TS, there is a feedback link between Wiener filtering and Turbo decoder and process iteratively. The scheme employs a pixel-wise adaptive Wiener-based Turbo decoder and uses statistics (mean and standard deviation of local image) of estimated values of local neighborhood of each pixel. It has extra-ordinary satisfactory results of both bit error rate (BER) and image enhancement performance for less than 2 dB Signal-to-Noise Ratio (SNR) values, compared to separately application of traditional turbo coding scheme and 2-D filtering.

In AW-TSwJBC scheme, 2-D colored image is passed through a color & bit planes' slicer block. In this block, each pixel of the input image is partitioned up to three main color planes as R,G,B and each pixel of the color planes is sliced up to N binary bit planes, which corresponds to binary representation of pixels. Thus depending on importance of information knowledge of the input image, pixels of each color plane can be represented by fewer number of bit planes. Then they are compressed by JPEG prior to turbo encoder. Hence, two consecutive compressions are achieved regarding the input image. In 2-D images, information is mainly carried by neighbors of pixels. Here, we benefit of neighborhood relation of pixels for each color plane by using a new iterative block, named as "Adaptive Wiener–Turbo" scheme, which employs Turbo decoder, JPEG encoder/decoders and Adaptive Wiener Filtering.

***Keywords**: Image transmission, Image Compression, Turbo Coding, Color and Bit Plane Slicing, JPEG.*

1. INTRODUCTION

Image compression and transmission is one of the main approaches in nowadays [1]-[23]. The performance of AW-TS is investigated over Additive White Gaussian Noise (AWGN) channel. It is a combination of turbo codes and the 2D adaptive noise removal filtering. In AW-TS, each binary correspondence of the amplitude values of each pixel is grouped in bit-planes. Then each bit of bit planes are transmitted and at the receiver side, a combined structure, denoted

Received Date : 08.05.2006
Accepted Date: 01.02.2007

as Wiener-Turbo decoder is employed. Wiener-Turbo decoder is an iterative structure with a feedback link from the second Turbo decoder and Wiener filtering. The decoding process continues iteratively till the desired output is obtained. At the receiver, after each bit slice is decoded and hard decision outputs are formed, then all bit slice plane outputs are reassembled as first bit from the first bit slice, second bit from the second bit plane,.. , the most significant bit from the last bit slice. Then these binary sequences are mapped to corresponding amplitude value of the pixel.

Here, the compression and transmission performance of Adaptive Wiener-Turbo Systems with JPEG & Bit Plane Compressions (AW-TSwJBC), which is investigated over Additive White Gaussian Noise (AWGN) channel. In the transmitter side, AW-TSwJBC scheme uses Bit Plane Slicing (BPS) [7], JPEG [8],[9] and Turbo Codes [10], for compression and transmission improvement, respectively. The compression scenario reduces the significant amount of data required to reproduce the image at the receiver. In AWGN environment, 2D adaptive noise removal filtering is used at the receiver side to achieve a better error performance. In AW-TSwJBC scheme, each binary correspondence of the amplitude values of each pixel is grouped in bit-planes. A combined structure, denoted as Adaptive Wiener-Turbo decoder is employed. Adaptive Wiener-Turbo decoder is an iterative structure with a feedback link between Turbo decoder and Wiener filter. The decoding process works iteratively till the desired output is obtained. The advantage of neighborhood relation of pixels is taken into account in AW-TSwJBC scheme to get improvement on image enhancement. Instead of classical binary serial communication and decoding, in our scheme, the coordinates of the pixels are kept as in their original input data matrix and each bit of the pixel is mapped to corresponding slice matrix.

In AW-TSwJBC, data rate can be increased up to (N) times, by only transmitting most important significant BPS. Then the other BPSs can be transmitted to obtain more accurate 2D images. Maximum resolution is obtained if all BPSs from most significant to least significant planes are decoded at the receiver side without sacrificing bandwidth efficiency. Thus, our bit slicing approach can also be an efficient way of compression technique.

2. SYSTEM MODEL

AWTS The system consists of image slicer, turbo encoder (transmitter), iterative 2D adaptive filter, turbo decoder (receiver), and image combiner sections as shown in Figure 1. The decoder employs two identical systematic recursive convolutional encoders (RSC) connected in parallel with an interleaver preceding the second recursive convolutional encoder. Both RSC encoders encode the information bits of the bit slices. The first encoder operates on the input bits in their original order, while the second one operates on the input bits as permuted by the interleaver. The decoding algorithm involves the joint Estimation of two Markov processes one for each constituent code. The output of one decoder can be used as a priori information by the other decoder. The iteration process is done until the outputs of the individual decoders are in the form of hard bit decisions.

AW-TSwJBC scheme consists of color & bit planes' slicer, JPEG encoder, turbo encoder in the transmitter side; Adaptive Wiener–Turbo System employing turbo decoder, JPEG decoder, Adaptive Wiener filtering and color & bit planes' combiners in the receiver side as shown in Figure 1. In order to increase the performance of the scheme, at the receiver, JPEG encoders are applied as a feedback link between adaptive Wiener filtering and turbo decoder. In the transmitter side of the proposed scheme, the colored image is sliced into RGB planes and each of RGB planes is separated to various bit planes. As an example, we consider 8 bit for each color plane, thus totally 24 bit planes are encoded with JPEG encoders prior to Turbo encoder. Turbo encoder employs two identical systematic recursive convolutional encoders (RSC) connected in parallel with an interleaver preceding the second recursive convolutional encoder. Both RSC encoders encode the information bits of the bit slices. The first encoder operates on the input bits in their original order, while the second one operates on the input bits as permuted by the interleaver. These bit planes are transmitted over AWGN channel by Turbo encoder block.

2.1 Wiener Filtering Applied to Bit Planes

The goal of Wiener filtering is to obtain an estimate of the original bit plane from the degraded version. The degraded plane $g(n_1,n_2)$ can be represented by

$$g(n_1,n_2) = f(n_1,n_2) + v(n_1,n_2) \tag{5}$$

where, $f(n_1,n_2)$ is the nice, under graded plane and $v(n_1,n_2)$ is the noise. Given the degraded plane $g(n_1,n_2)$ and some knowledge of the nature of $f(n_1,n_2)$ and $v(n_1,n_2)$ and some knowledge of the nature of $f(n_1,n_2)$ and $v(n_1,n_2)$ we want to come up with a function $h(n_1,n_2)$ that will output a good estimate of $f(n_1,n_2)$. This estimate is $p(n_1,n_2)$, and is defined by the following:

$$\begin{aligned} p(n_1,n_2) &= g(n_1,n_2) * h(n_1,n_2) \\ P(w_1,w_2) &= G(w_1,w_2)H(w_1,w_2) \end{aligned} \tag{6}$$

The Wiener filter generates $h(n_1,n_2)$ that minimizes the mean square error, which is defined by:

$$E\{e^2(n_1,n_2)\} = E\{(g(n_1,n_2) - f(n_1,n_2))^2\} \tag{7}$$

This is a linear minimum mean square error (LMMSE) estimation problem, since it is a linear estimator, and the goal is to minimize the mean squared error between $g(n_1,n_2)$ and $f(n_1,n_2)$. Using the orthogonality principle, we can solve this signal estimation problem. The principle states that error $e(n_1,n_2) = g(n_1,n_2) - f(n_1,n_2)$ is minimized by requiring that $e(n_1,n_2)$ be uncorrelated with any random variable. From the orthogonality principle,

$$E\{e(n_1,n_2)g^*(m_1,m_2)\} = 0 \quad \textit{for all } (n_1,n_2) \textit{ and } (m_1,m_2) \tag{8}$$

We have:

$$\begin{aligned} E\{f(n_1,n_2)g^*(m_1,m_2)\} &= E\{(e(n_1,n_2)+p(n_1,n_2))g^*(m_1,m_2)\} \\ &= E\{p(n_1,n_2)g^*(m_1,m_2)\} \\ &= E\{(g(n_1,n_2)*h(n_1,n_2))g^*(m_1,m_2)\} \\ &= \sum_{k_1=-\infty}^{\infty}\sum_{k_2=-\infty}^{\infty} h(k_1,k_2)E\{g(n_1-k_1,n_2-k_2)g^*(m_1,m_2)\} \end{aligned} \tag{9}$$

Rewrite (9), we have:

$$\begin{aligned} &R_{fg}(n_1-m_1,n_2-m_2) \\ &= \sum_{k_1=-\infty}^{\infty}\sum_{k_2=-\infty}^{\infty} h(k_1,k_2)R_g(n_1-k_1-m_1,n_2-m_2-m_2) \end{aligned} \tag{10}$$

So:

$$R_{fg}(n_1,n_2) = h(n_1,n_2) * R_g(n_1,n_2) \tag{11}$$

$$H(w_1,w_2) = \frac{P_{fg}(w_1,w_2)}{P_g(w_1,w_2)} \tag{12}$$

The filter in (12) is called the noncausal Wiener filter. Suppose $f(n_1,n_2)$ is uncorrelated with $v(n_1,n_2)$

$$E\{f(n_1,n_2)v^*(m_1,m_2)\} = E\{f(n_1,n_2)\}E\{v^*(m_1,m_2)\} \tag{13}$$

Noting that $f(n_1,n_2)$ and $v(n_1,n_2)$ are zero-mean process, we obtain:

$$\begin{aligned} R_{fg}(n_1,n_2) &= R_f(n_1,n_2) \\ R_g(n_1,n_2) &= R_f(n_1,n_2) + R_v(n_1,n_2) \end{aligned} \tag{14}$$

and,

$$P_{fg}(w_1,w_2) = P_f(w_1,w_2) \tag{15}$$

So,

$$H(w_1,w_2) = \frac{P_f(w_1,w_2)}{P_f(w_1,w_2) + P_v(w_1,w_2)} \tag{16}$$

If we further impose the additional constraint that $f(n_1,n_2)$ and $v(n_1,n_2)$ are samples of Gaussian random field, equation (7) becomes minimum mean square error (MMSE) estimation problem, then the Wiener filter in equation (16) becomes the optimal minimum mean square error estimator. The Wiener filter in (16) is a zero-phase filter. Since the power spectra $P(w_1, w_2)$ and $P_v(w_1, w_2)$ are real and nonnegative, $H(w_1, w_2)$ is also real and nonnegative. Therefore, the Wiener filter affects the spectral magnitude but not the phase. By observing (16), if we let $P_v(w_1, w_2)$ approach 0, $H(w_1, w_2)$ will approach 1, indicating that the filter tends to preserve the high SNR frequency components. If we let $P_v(w_1, w_2)$ approach infinity, $H(w_1, w_2)$ will approach 0, indicating that the filter tends to attenuate the low SNR frequency components. In our problem, Wiener filter is applied to all planes and the additive noise on the bit-plane $v(n_1, n_2)$ is assumed to be zero mean and white with variance of σ_v^2. Let $f^j(n_1, n_2)$ shows each planes from 0th to 3rd (i.e. $j = 0,1,2,3$). Their power spectrums $P_v^j(w_1, w_2)$ are then given by $P_v^j(w_1, w_2) = (\sigma_v^j)^2$. Consider a small local region in which the plane $f^j(n_1, n_2)$ is assumed homogeneous. Within the local region, the plane $f^j(n_1, n_2)$ is modeled by,

$$f^j(n_1, n_2) = m_f{}^j + \sigma_f{}^j w^j(n_1, n_2) \tag{17}$$

where $m_f{}^j$ and $\sigma_f{}^j$ are the local mean and standard deviation of $f^j(n_1, n_2)$ and $w^j(n_1, n_2)$ is zero-mean white noise with unit variance effecting each plane. Within the local region, then, the Wiener filter $H^j(w_1, w_2)$, $h^j(n_1, n_2)$ is given by:

$$H^j(w_1, w_2) = \frac{P_f{}^j(w_1, w_2)}{P_f{}^j(w_1, w_2) + P_v^j(w_1, w_2)} = \frac{(\sigma_f^j)^2}{(\sigma_f^j)^2 + (\sigma_v^j)^2}; \quad j = 0,1,2,3 \tag{18}$$

$$h^j(n_1, n_2) = \frac{(\sigma_f^j)^2}{(\sigma_f^j)^2 + (\sigma_v^j)^2}\delta(n_1, n_2); \quad j = 0,1,2,3$$

19)

Then, the restored planes $p^j(n_1, n_2)$ within the local region can be expressed as

$$p^j(n_1, n_2) = m_f{}^j + (g^j(n_1, n_2) - m_f{}^j) * \frac{(\sigma_f^j)^2}{(\sigma_f^j)^2 + (\sigma_v^j)^2}\delta(n_1, n_2)$$

$$= m_f{}^j + \frac{(\sigma_f^j)^2}{(\sigma_f^j)^2 + (\sigma_v^j)^2}(g^j(n_1, n_2) - m_f{}^j); \quad j = 0,1,2,3 \tag{20}$$

If we assume that $m_f{}^j$ and $\sigma_f{}^j$ are updated at each symbol [2],

$$p^j(n_1,n_2) = m_f^j(n_1,n_2) + \frac{(\sigma_f^j)^2(n_1,n_2)}{(\sigma_f^j)^2(n_1,n_2) + (\sigma_v^j)^2(n_1,n_2)}(g^j(n_1,n_2) - m_f^j(n_1,n_2)) \tag{21}$$

Experiments are performed with known all the degraded bit planes, which are degraded by adding from 2dB to -3dB SNR, zero-mean white Gaussian noise. The resulting reconstructed images (by recombining the four planes) are shown in the figures from 6(c) to 11(c). The window size used for estimate the local mean and local variance is 5 by 5. From degraded planes, we can estimate $(\sigma_g^j)^2(n_1, n_2)$ only, and since

$$(\sigma_g^j)^2(n_1, n_2) = (\sigma_f^j)^2(n_1, n_2) + (\sigma_v^j)^2(n_1, n_2)$$

, Equation (21) changes to

$$p^j(n_1,n_2) = m_g^j(n_1,n_2) + \frac{(\sigma_g^j)^2(n_1,n_2) - (\sigma_v^j)^2(n_1,n_2)}{(\sigma_g^j)^2(n_1,n_2)}(g^j(n_1,n_2) - m_g(n_1,n_2)). \quad j = 1,2,3,4 \tag{22}$$

In our scheme, we modify the generalized Wiener Equation (22) as follows,

$$p_{i+1}^{(j)}(n_1,n_2) = m_{g_i}^{(j)}(n_1,n_2) + \frac{(\sigma_{g_i}^{(j)})^2(n_1,n_2) - (\sigma_v^{(j)})^2(n_1,n_2)}{(\sigma_{g_i}^{(j)})^2(n_1,n_2)}(p_i^{(j)}(n_1,n_2) - m_{g_i}^{(j)}(n_1,n_2)), \quad j = 1,2,3,4 \tag{23}$$

As seen from Figures 6(c) to 11(c), the performance of classical Wiener filtering, according to Equation (22), is only satisfying at higher SNR's. The objective in our study is to obtain better results at much lower SNR's. So, MAP based turbo-decoding algorithm is considered after filtering process. So, in equation (22), $p^j(n_1, n_2)$ (j=0, 1, 2, 3) are taken the degraded planes as the new inputs in the turbo decoders. The resulting output planes can be expressed as:

$$p_{i+1}^{(0)}(n_1,n_2)=m_{g_i}^{(0)}(n_1,n_2)+\frac{(\sigma_{g_i}^{(0)})^2(n_1,n_2)-(\sigma_v^{(0)})^2(n_1,n_2)}{(\sigma_{g_i}^{(0)})^2(n_1,n_2)}(p_i^{(0)}(n_1,n_2)-m_{g_i}^{(0)}(n_1,n_2))$$

$$p_{i+1}^{(1)}(n_1,n_2)=m_{g_i}^{(1)}(n_1,n_2)+\frac{(\sigma_{g_i}^{(1)})^2(n_1,n_2)-(\sigma_v^{(1)})^2(n_1,n_2)}{(\sigma_{g_i}^{(1)})^2(n_1,n_2)}(p_i^{(1)}(n_1,n_2)-m_{g_i}^{(1)}(n_1,n_2))$$

$$p_{i+1}^{(2)}(n_1,n_2)=m_{g_i}^{(2)}(n_1,n_2)+\frac{(\sigma_{g_i}^{(2)})^2(n_1,n_2)-(\sigma_v^{(2)})^2(n_1,n_2)}{(\sigma_{g_i}^{(2)})^2(n_1,n_2)}(p_i^{(2)}(n_1,n_2)-m_{g_i}^{(2)}(n_1,n_2))$$

$$p_{i+1}^{(3)}(n_1,n_2)=m_{g_i}^{(3)}(n_1,n_2)+\frac{(\sigma_{g_i}^{(3)})^2(n_1,n_2)-(\sigma_v^{(3)})^2(n_1,n_2)}{(\sigma_{g_i}^{(3)})^2(n_1,n_2)}(p_i^{(3)}(n_1,n_2)-m_{g_i}^{(3)}(n_1,n_2)) \tag{24}$$

where, i is the iteration index for each plane, between the wiener process and turbo decoder (called WT iteration index). i can be taken from one to the desired number. If it is taken one, the MAP processed plane (at the output of the decoder) enters to the wiener filter only one time. In this case, we have $P_1^j(n_1,n_2)$, $P_2^j(n_1,n_2)$ for each plane and the last iterated planes i.e. $P_2^j(n_1,n_2)$ are taken into consideration for reconstruction.

3. SIMULATION RESULTS

In this section, we present simulation results that illustrate the performance of the proposed (AW-TS) algorithm over transmitting the image. Here the generator matrix is g = [111:101], a random interleaver is used and the frame size is chosen as N=150, iteration (between wiener filter and decoder) is taken 1. At first, the pixels of the image is converted to 16 gray levels and then sliced to four bit-planes. All planes are then coded via RSC encoder and a random interleaver. The coded planes are corrupted with SNR = 2dB, 1dB, 0dB, -1dB, -2dB and -3dB and transmitted. Figure (6-11) shows the corrupted, traditional turbo processed, well known Wiener image processed and reconstructed images via AW-TS system. The results have shown that, to recover the image corrupted at 2 dB SNR or below, the well known image-processing and conventional Turbo algorithms are not satisfying as seen from the figures 6 to 11. The proposed AW-TS algorithm gives good results from 0 dB SNR to –3 dB. This is a challenging result and we have at least 4dB and 2.5dB additional SNR improvement compared to that of classical image processing and conventional turbo coding systems, respectively.

AW-TSwJBC scheme was experimentally evaluated for the transmission of the 500x500 test image over AWGN channel. The first step of the transmission is based on partitioning the image into 3 RGB planes and then each of them is sliced to 8 BPSs. So 3x8=24 planes are coded independently carrying some important and highly protected neighborhood relations to the receiver enabling to use adaptive Wiener filter hence the whole performance of the system is improved. Figure 12-15 show the reconstructed images of system. At the receiver side, 24 bit-planes are reassembled by considering the neighborhood relationship of pixels. Each of the noisy bit-plane is evaluated iteratively by a combined block, which is composed of 2-D adaptive noise-removal filter and Turbo decoder. In AW-TSwJBC, there is an iterative feedback link between Wiener filter and Turbo decoder. Our scheme employs a plane-wise adaptive Wiener-based Turbo decoder and uses statistics (mean and standard deviation of each plane) of local neighborhood of each pixel in order to obtain the highest probability of the symbols. Figures (12-15) show the re-assembled bit-planes and the resulted image at the decoder output for SNR =1,2 and 3 dB values. In Figure 4 (a), for each R,G and B plane, we have 8 bit plane slices, 2 of them are transmitted enabling 75 % compression ratio, by BPS compression. The transmitted planes are then re-compressed using JPEG approach which is based on Discrete Cosine Transform (DCT) compression. JPEG process involves first dividing the image into 8x8 pixel blocks. Each block's information is transformed to frequency domain, every 1x1 low-frequency elements are transmitted, the others are discarded hence 87.5 % compression ratio is obtained by JPEG. In this case some high-frequency elements which contain a lot of detail can be lost. The more these high-frequency elements are discarded, the smaller the resulting file and the lower the resolution of the reconstituted image. As a result, 75 % compression ratio for BPS and 87.5 % for JPEG gives us 96.875 % total compression.

4. CONCLUSIONS

The images being transmitted over noisy channels are extremely sensitive to the bit errors, which can severely degrade the quality of the image at the receiver. This necessitates the application of error control codes in the image transmission. This study presents an efficient image transmission by means of a new proposed AW-TS (Adaptive Wiener-Turbo System) method, which takes the advantage of the superior performance of error control codes, Turbo codes. For comparison, the classical image processing (based Wiener filtering) algorithm, conventional Turbo coding, Adaptive Wiener-Turbo algorithm (AW-TS) methods are evaluated and the results are compared.

In this paper, we propose a reliable and efficient compression-transmission system for 2D images using BPS and JPEG (for compression) and TC (for error correction) named as AW-TSwJBC system. The traditional methods have been time consuming, but the proposed method promise to speed up the process enabling to get a better Bit Error Rate. In compression we use less memory storage and increase data rate up to N times by simply choosing any number of bit slices, sacrificing resolution. Hence, we conclude that AW-TSwJBC system will be a compromising approach in 2-D image transmission, recovery of noisy signals and image compression.

REFERENCES

[1] R.C.Gonzales, R.E.Woods, ”Digital Image Processing”, ISBN 0-201-50803-6, 1992.

[2] A. D. Hillery and R. T. Chin, “Iterative Wiener filters for image restoration,” *IEEE* Trans. Signal Processing, Vol. 39, No. 8, 1892-1899, August, 1991.

[3] D. Divsalar and F. Pollara Communications Systems Research Section,” Turbo Codes for Deep-Space Communications” TDA Progress Report 42-120 February 15, 1995”.

[4] K.Buyukatak, E.Gose,O.N.Uçan, S.Kent, O. Osman, “Channel Equalizatin and Noise Reduction Based Turbo Codes“, Recent Advances on Space Technology, 2003.

[5] E.Gose, K.Buyukatak, Onur Osman, Osman N. Ucan, Halit Pastaci,” Performance Of Turbo Decoding For Time-Varying Multipath Channels” Recent Advances on Space Technology, 2003.

[6] Bernard Sklar, “A Primer on Turbo Concepts”, IEEE Communications Magazine, Dec.1997.

[7] Matthew C. Valenti, , “Iterative Detection and Decoding for Wireless Communications”, A Proposal for Current and Future Work toward Doctor of Philosophy degree, September 1998.

[8] J. Hageneauer, "Iterative decoding of binary block and convolutional codes", IEEE Trans. Inform. Theory, vol. 42, pp. 429-445, Mar. 1996.

[9] Matthew C. Valenti, “An Introduction to Turbo Codes”,Virginia Polytechnic Inst.& S.U.,Blacksburg, Virginia.

[10] W.J.Gross and P.G.Gulak,”Simplified MAP Algorithm suitable for implementation of Turbo Decoders”, Electronic Letters online no:19981126,3 June 1998.

[11] J.Hageneauer, "Iterative decoding of binary block and convolutional codes", IEEE Trans. Inform. Theory, vol. 42, pp. 429-445, Mar.1996.

[12] Justin C-I Chuang. The effects of time delay spread on portable radio communication channels with digital modulation. *IEEE Trans. SAC.* 1987, **SAC-5**(5):879-889.

[13] Berrou C, Glavieux A. Near optimum error correcting coding and decoding: turbo codes. *IEEE Trans. Commun.* 1996; **44**(10):1261–1271.

[14] Ucan ON, Buyukatak K, Gose E, Osman O, Odabasioglu N. Performance of multilevel-turbo codes with blind/non-blind equalization over WSSUS multipath channels. *International Journal of Communication Systems* 2005;**19**(3):281–297.

[15] Thomos N, Boulgouris NV, Strintzis MG. Wireless Image Transmission Using Turbo Codes and Optimal Unequal Error Protection. *IEEE Transactions on Image Processing* 2005; **14**(11):1890-1901.

[16] Yang J, Lee MH, Jiang M, Park JY. Robust wireless image transmission based on Turbo-coded OFDM. *IEEE Transactions on Consumer Electronics* 2002; **48**(3):724-731.

[17] Han YH, Leou JJ. Detection and Correction of Transmission Errors in JPEG Images. IEEE *Transactions on Circuits and Systems for Video Technology* 1998; **8**(2):221-231.

[18] Gonzales RC, Woods RE. Digital Image Processing. ISBN 0-201-50803-6, 1992.

[19] Pennebaker WB, Mitchell JL. JPEG: Still Image Data Compression Standard. New York: Van Nostrand Reinhold, 1993.

[20] CCITT Recommendation T.81. Digital compression and coding of continuous-tone still images 1992.

[21] Hillery AD, Chin RT. Iterative Wiener filters for image restoration. *IEEE Trans. Signal Processing* 1991; **39**(8):1892-1899.

[23] Gross WJ, Gulak PG. Simplified MAP Algorithm suitable for implementation of Turbo Decoders. *Electronic Letters* 1998. **34**(16):1577-8.

FIGURES :

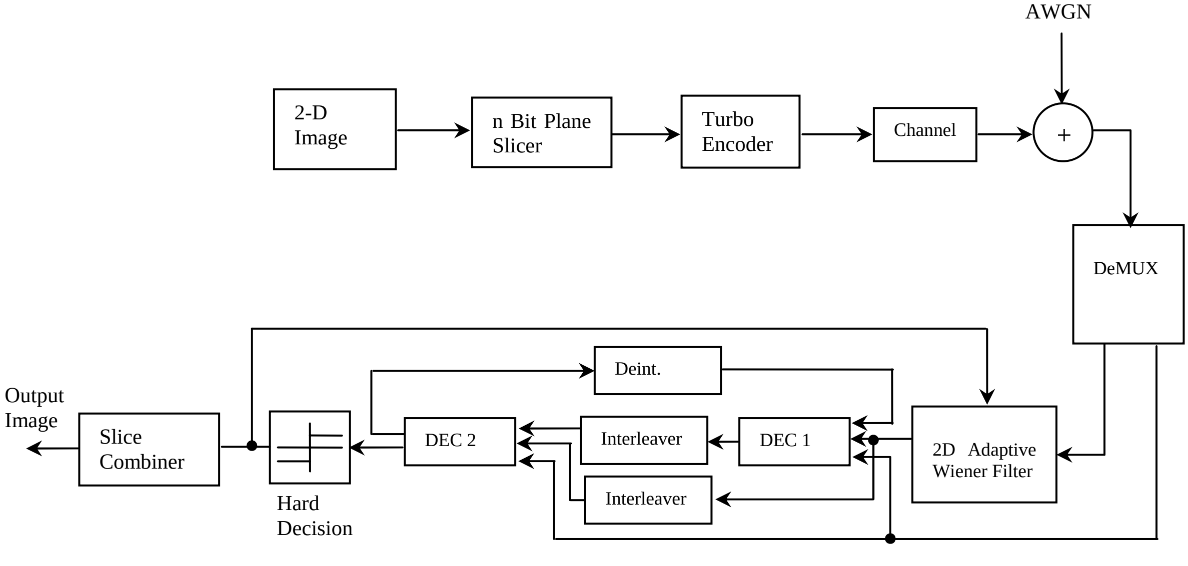


Figure 1. *AW-TS System model*

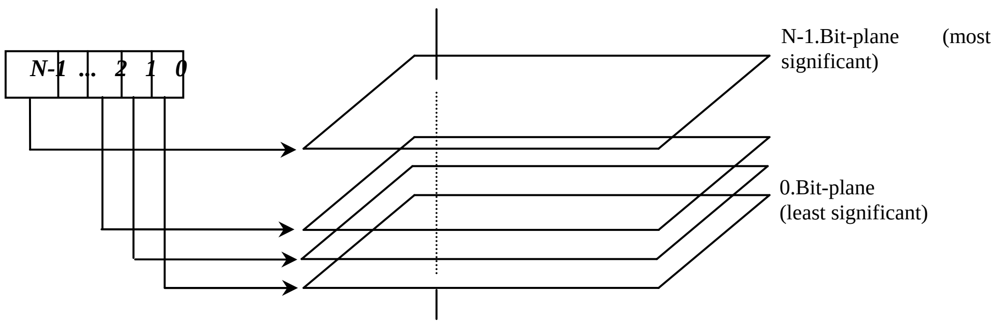
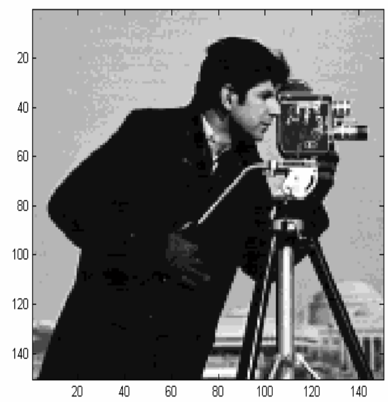
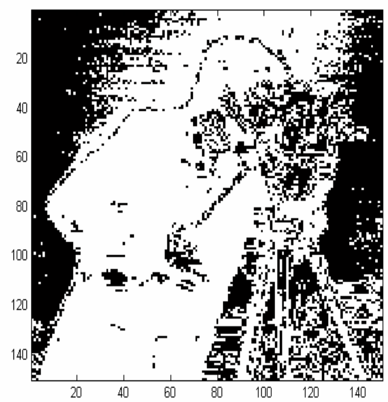


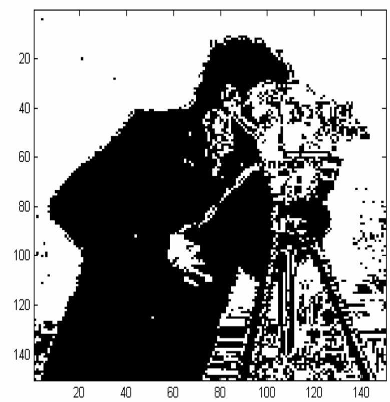
Figure 2. *N. Bit-plane decomposition of an image*



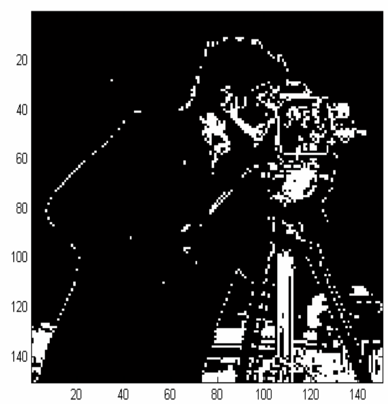
(a)



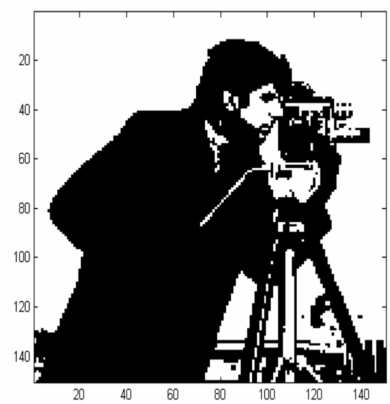
(b)



(c)



(d)



(e)

***Figure 3**. Bit plane representation of 2-D image*
(a) Original image (b) 1.Bit-plane (c) 2.Bit-plane (d) 3.Bit-Plane (e) 4.Bit-plane

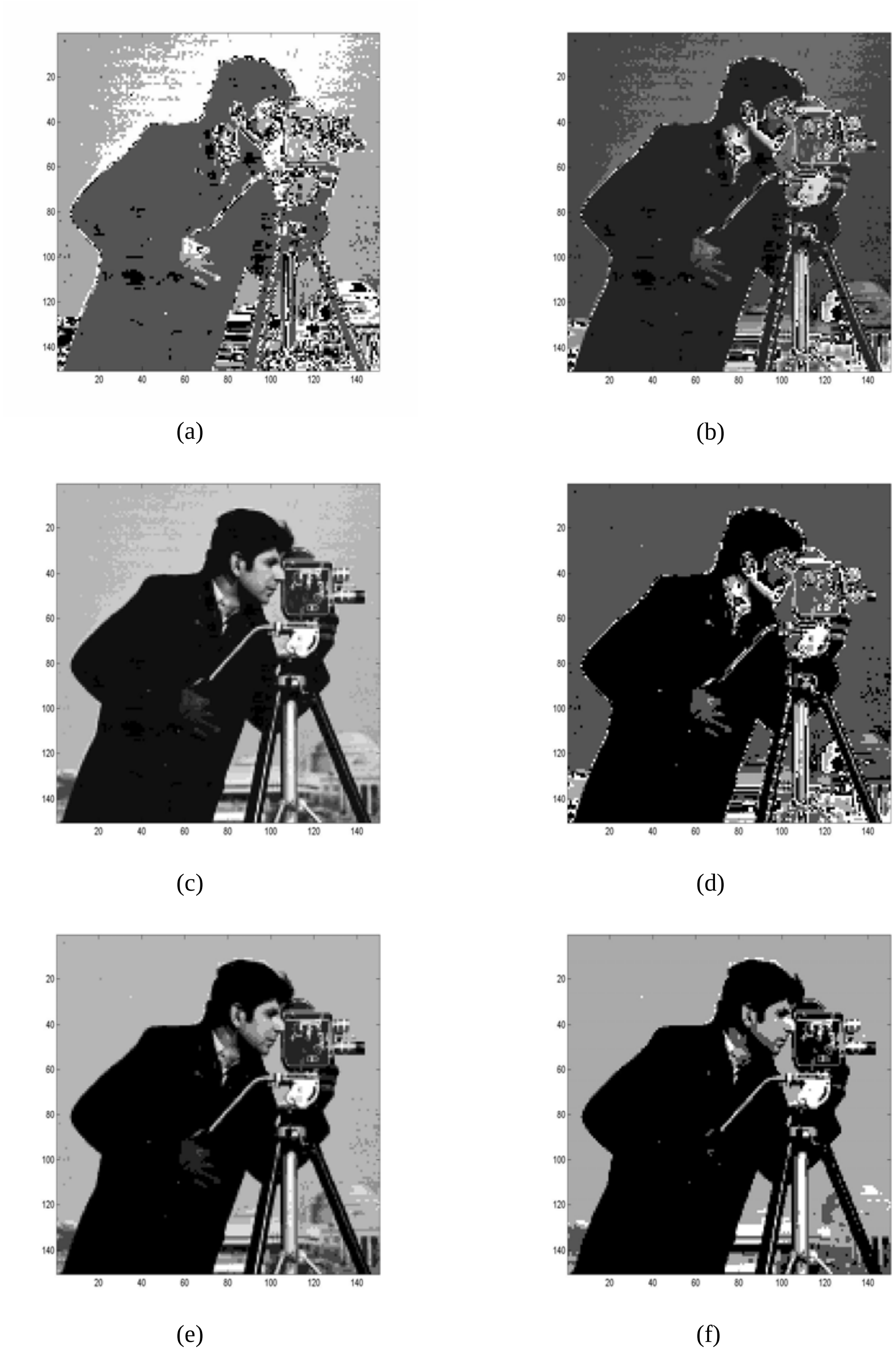
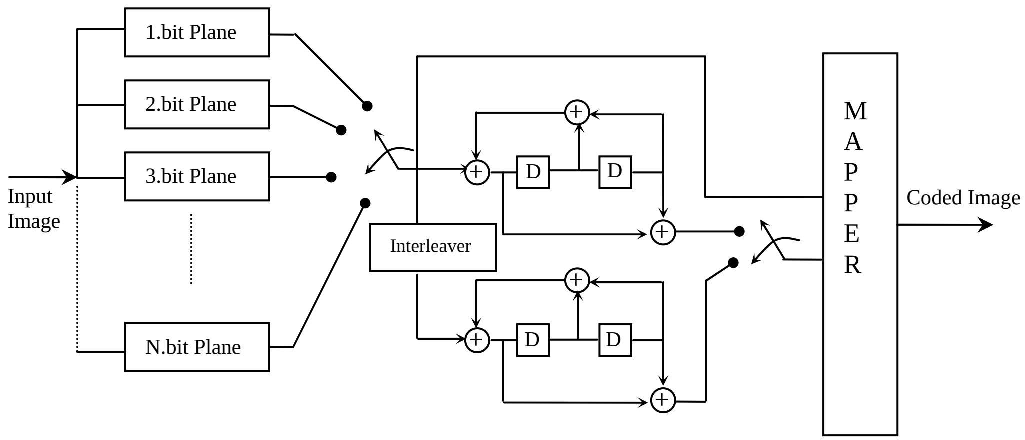
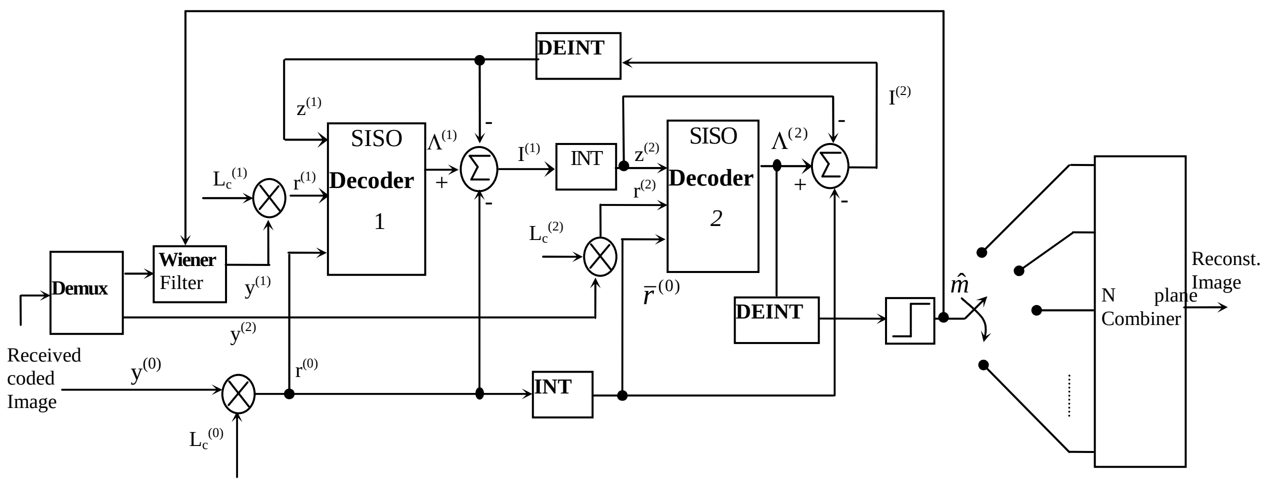


Figure 4: *The effects of the various slice combinations.*
(a) 0.Bit Plane+1.Bit plane (b) 0.Bit Plane+1.Bit plane+2.Bit plane
(c) 0.Bit Plane+1.Bit plane+2.Bit plane+3.Bit plane (d) 1.Bit plane+2.Bit plane
(e) 1.Bit Plane+2.Bit plane+3.Bit plane (f) 2.Bit plane+3.Bit plane



(a)



(b)

Figure 5. *AW-TS System (a) Encoder (b) Decoder*

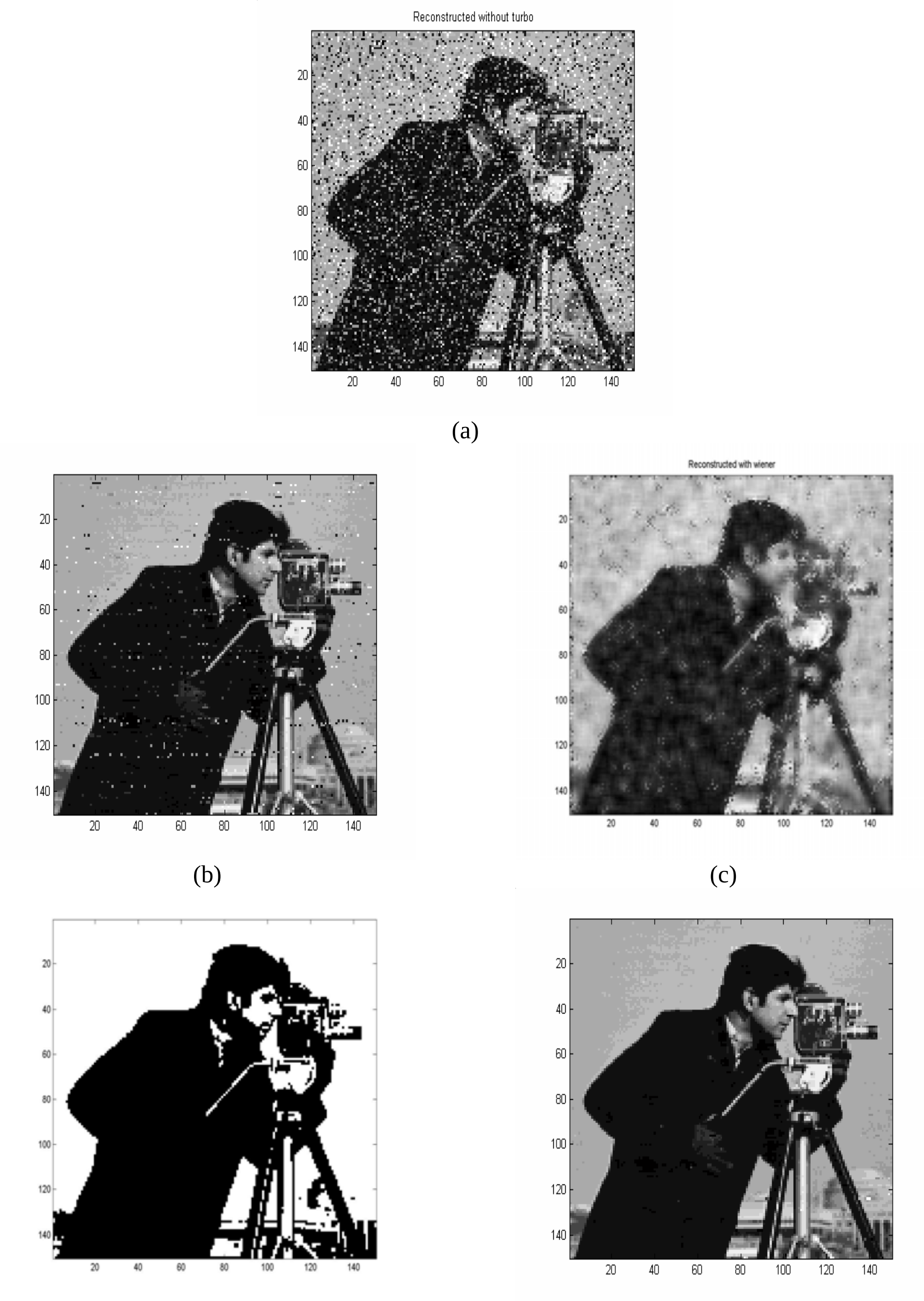
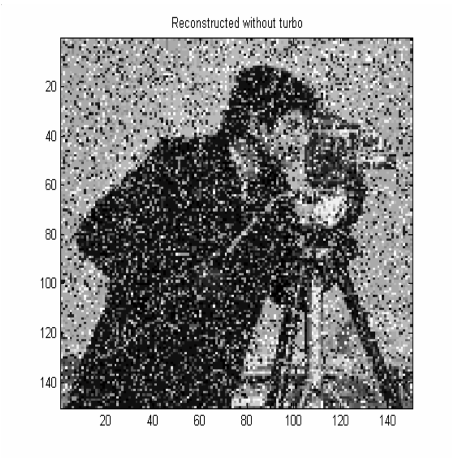
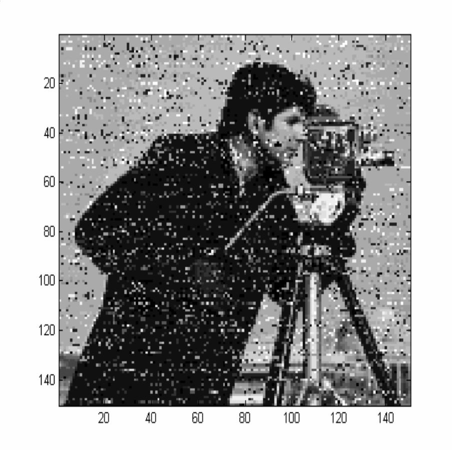


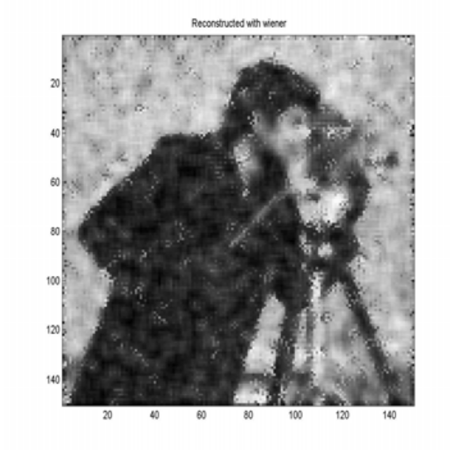
Figure 6. *Noisy 2D image and various simulation results for SNR=2dB*
(a) Corrupted image (b) Turbo processed image (c) Wiener processed image
(d) Most significiant partof AW-TS output (e) AW-TS processed image



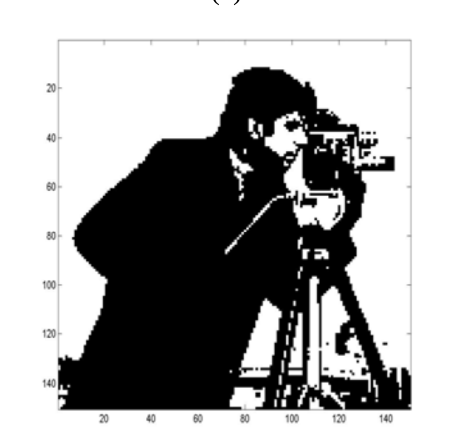
(a)



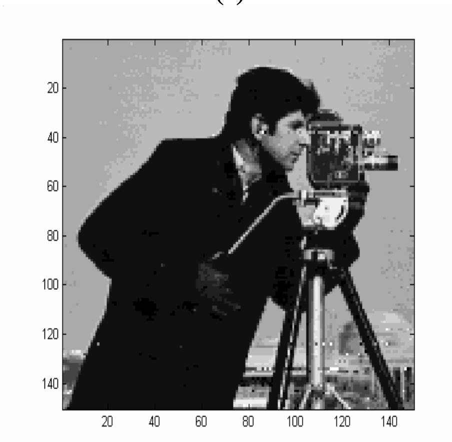
(b)



(c)



(d)



(e)

Figure 7 . *Noisy 2D image and various simulation results for SNR=1dB*
(a) Corrupted image with SNR= 1dB (b) Turbo processed image (c) Wiener processed image
(d) Most significiant part of AW-TS output (e) AW-TS processed image

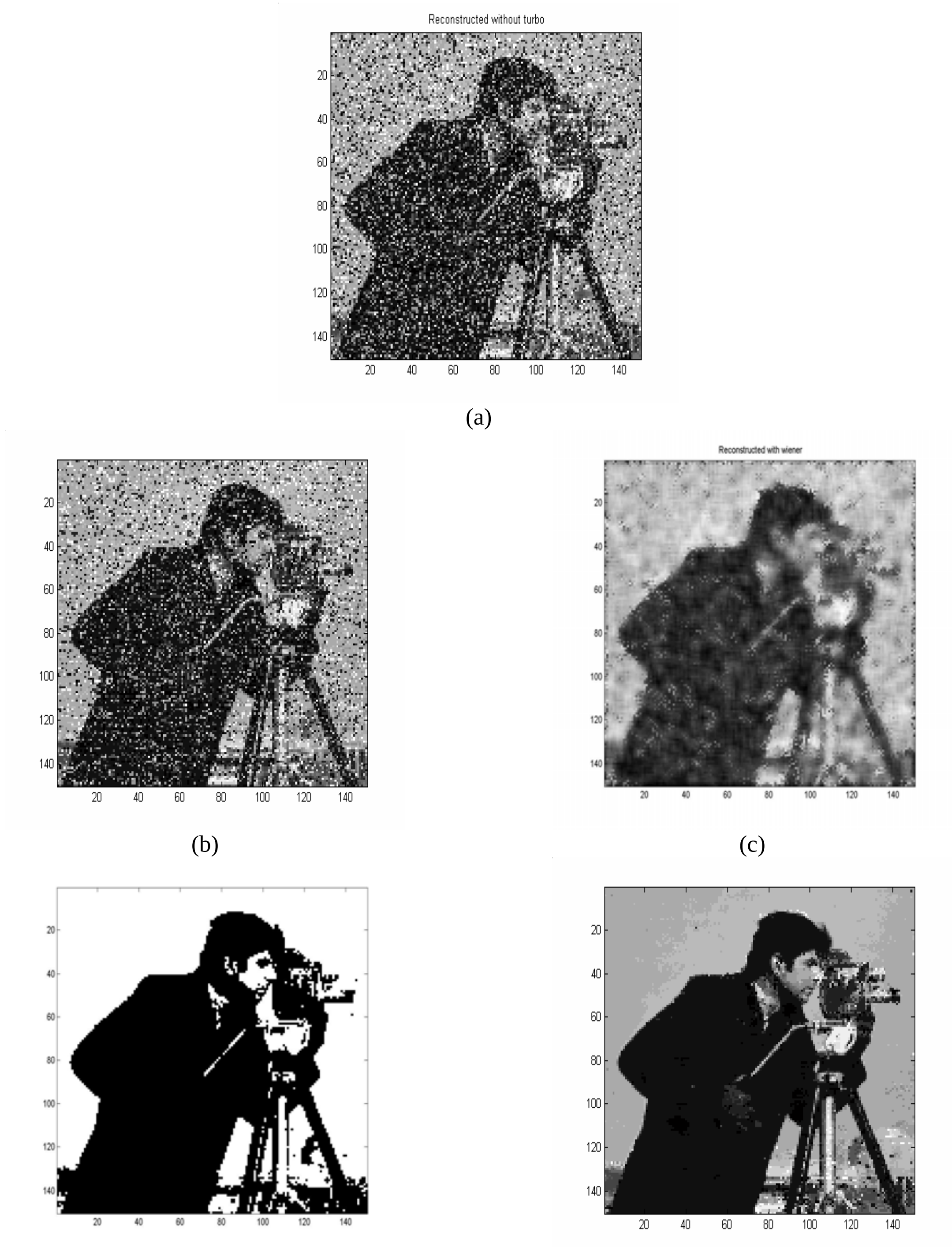
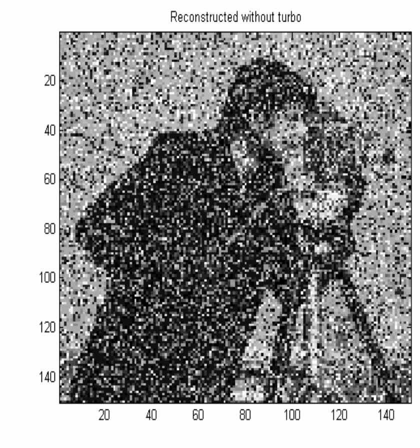
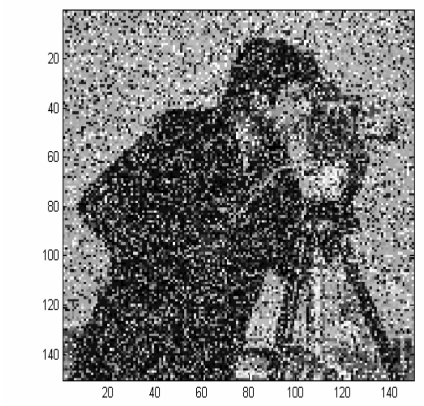


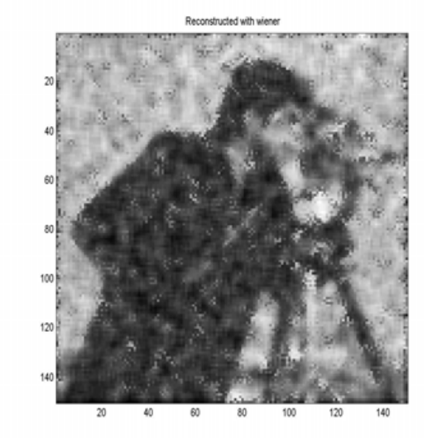
Figure 8. *Noisy 2D image and various simulation results for SNR=0dB*
(a) Corrupted image with SNR= 0dB (b) Turbo processed image (c) Wiener processed image
(d) Most significiant part of AW-TS output (e) AW-TS processed image



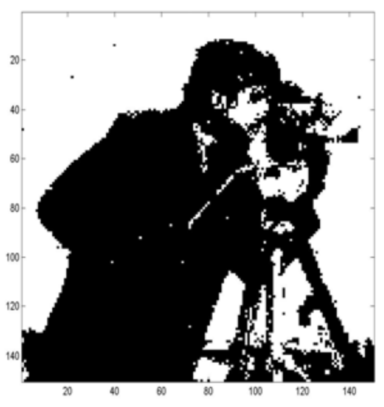
(a)



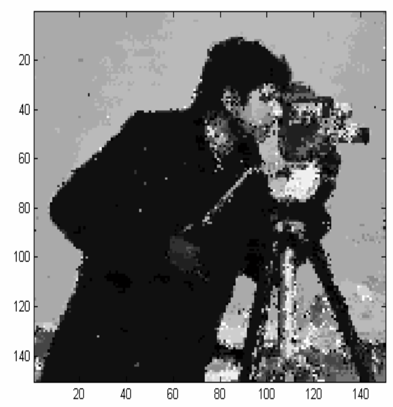
(b)



(c)

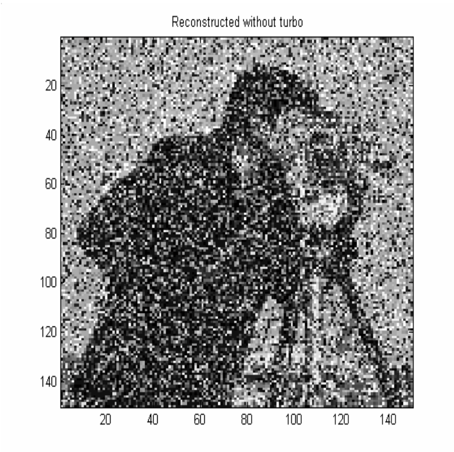


(d)

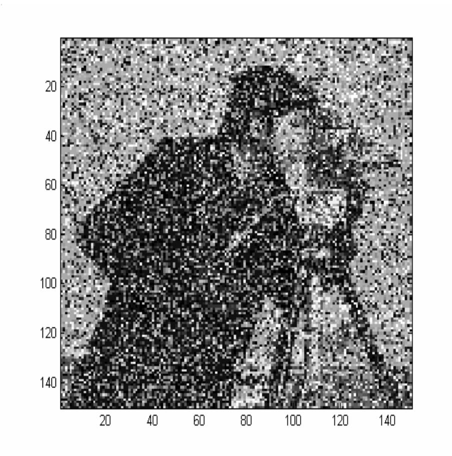


(e)

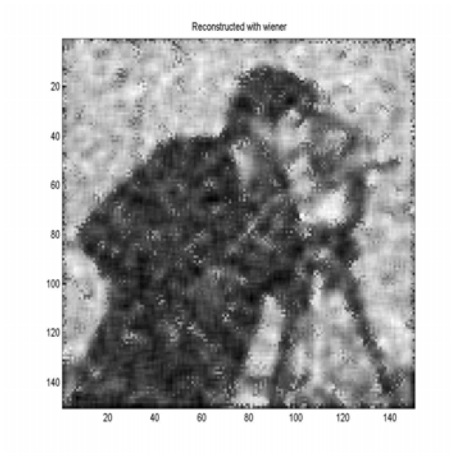
Figure 9. *Noisy 2D image and various simulation results for SNR= -1dB*
(a) Corrupted image with SNR= -1dB (b) Turbo processed image (c) Wiener processed image (d) Most significiant part of AW-TS output (e) AW-TS processed image



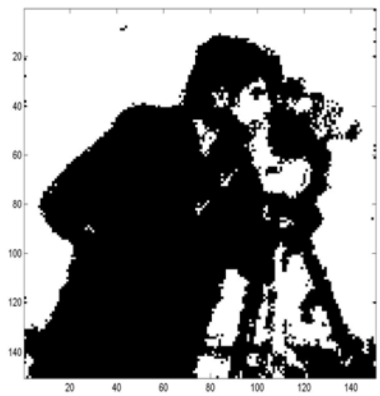
(a)



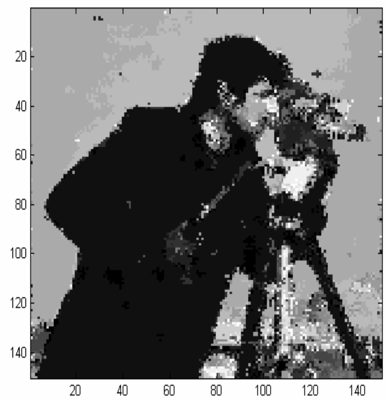
(b)



(c)

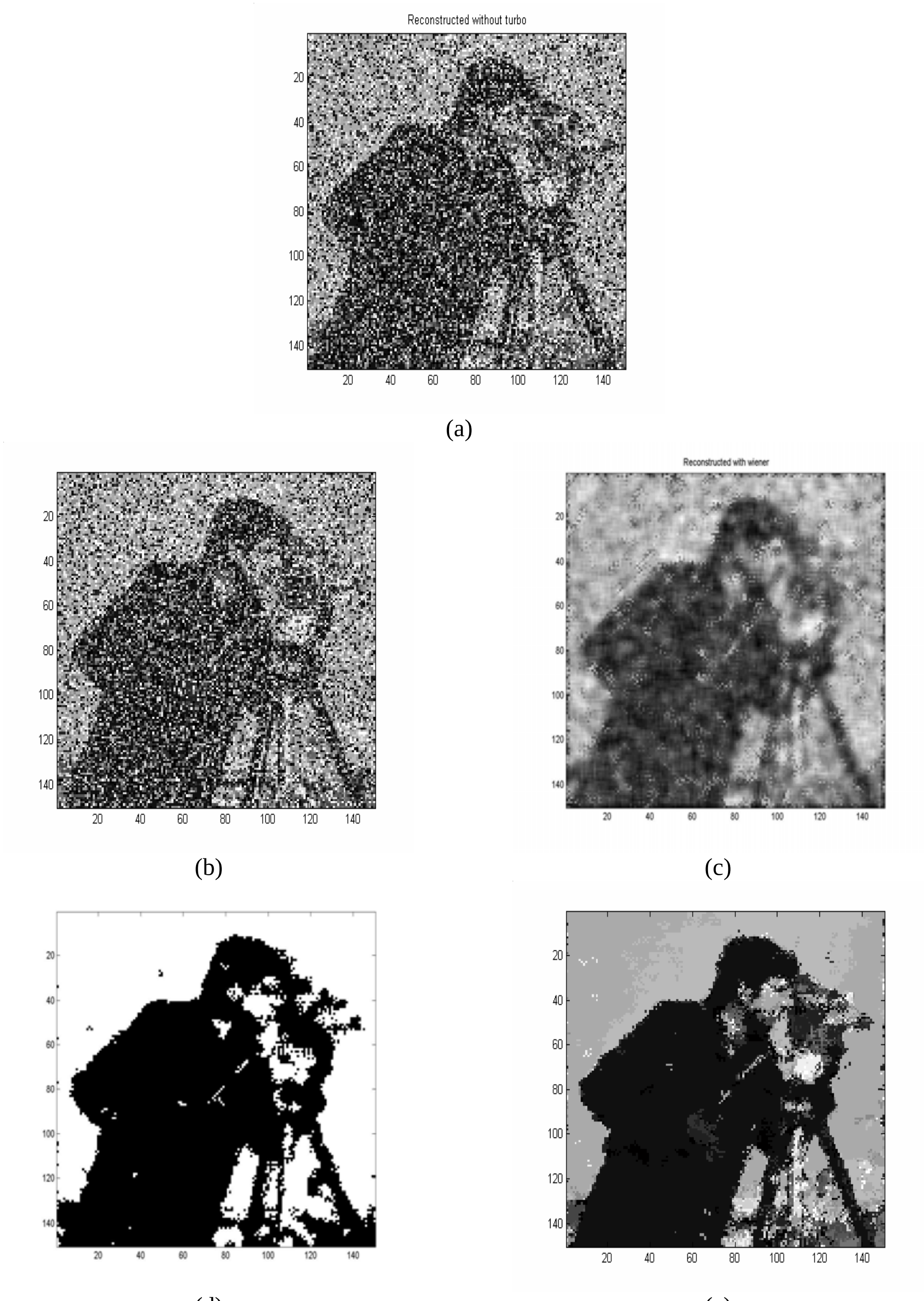


(d)



(e)

Figure 10. *Noisy 2D image and various simulation results for SNR=-2dB*
(a) Corrupted image with SNR= -2dB (b) Turbo processed image (c) Wiener processed image
(d) Most significiant part of AW-TS output (e) AW-TS processed image



(a) (b) (c) (d) (e)

Figure 11. *Noisy 2D image and various simulation results for SNR=-3dB*
(a) Corrupted image with SNR=-3dB (b) Turbo processed image (c) Wiener processed image
(d) Most significiant part of AW-TS output (e) AW-TS processed image

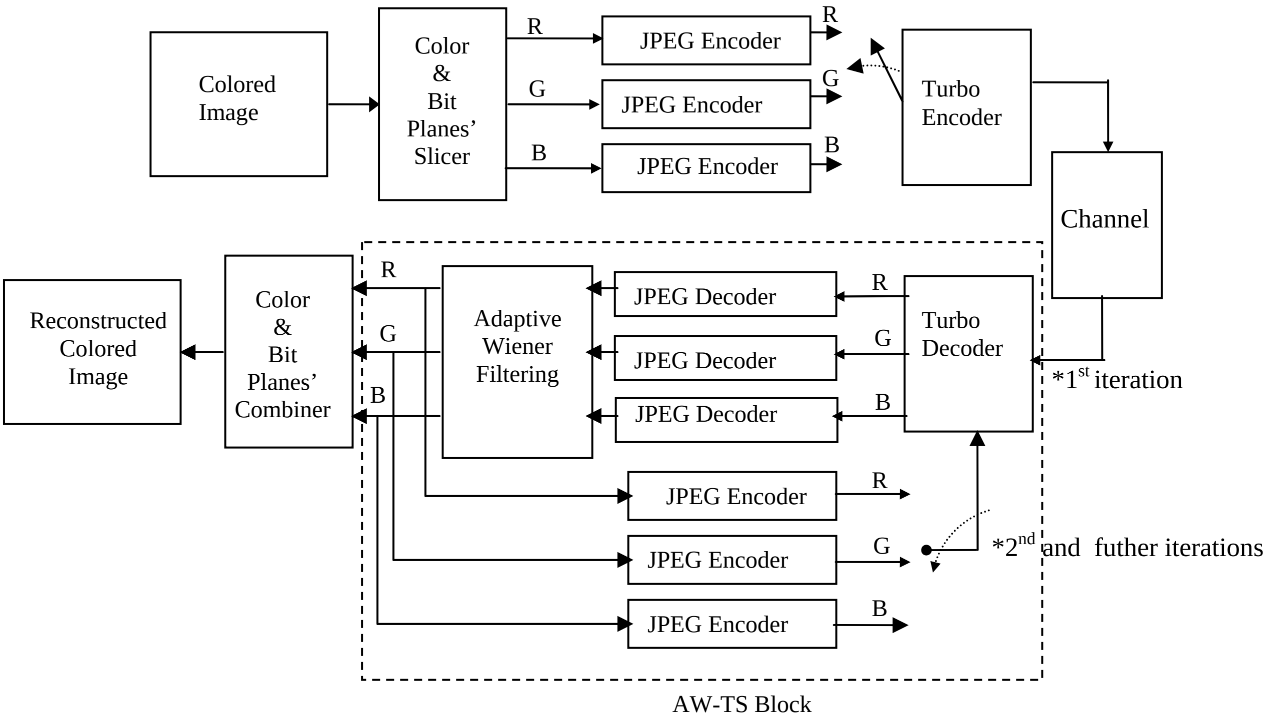
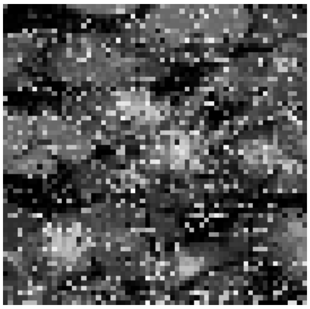
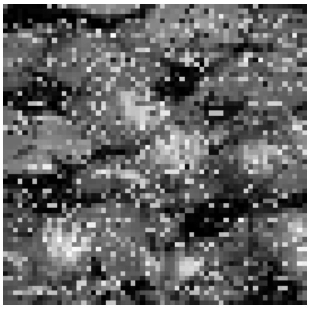
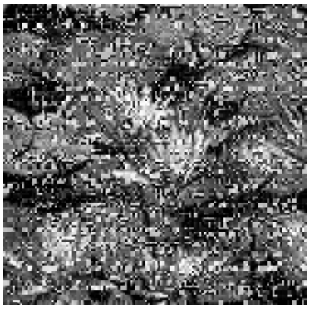


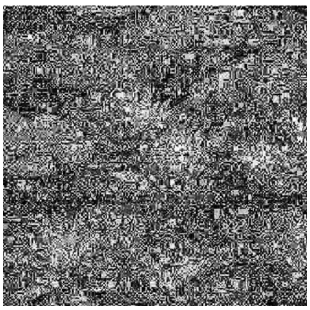
***Figure 12**. AW-TSwJBC system model*


(a)


(d)


(b)


(e)


(c)

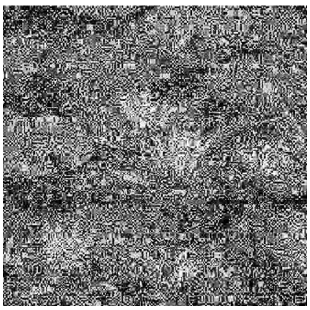

(f)

Figure 13. *Reconstructed Image for SNR=1dB*
- *(a) Totaly 96.875 compression (with 87.5 % JPEG and 75 % Bit Plane)*
- *(b) Totaly 93.75 compression (with 75 % JPEG and 75 % Bit Plane)*
- *(c) Totaly 87.5 compression (with 50 % JPEG and 75 % Bit Plane)*
- *(d) Totaly 93.75 compression (with 87.5 % JPEG and 50 % Bit Plane)*
- *(e) Totaly 87.5 compression (with 75 % JPEG and 50 % Bit Plane)*
- (f) *Totaly 75 compression (with 50 % JPEG and 50 % Bit Plane)*

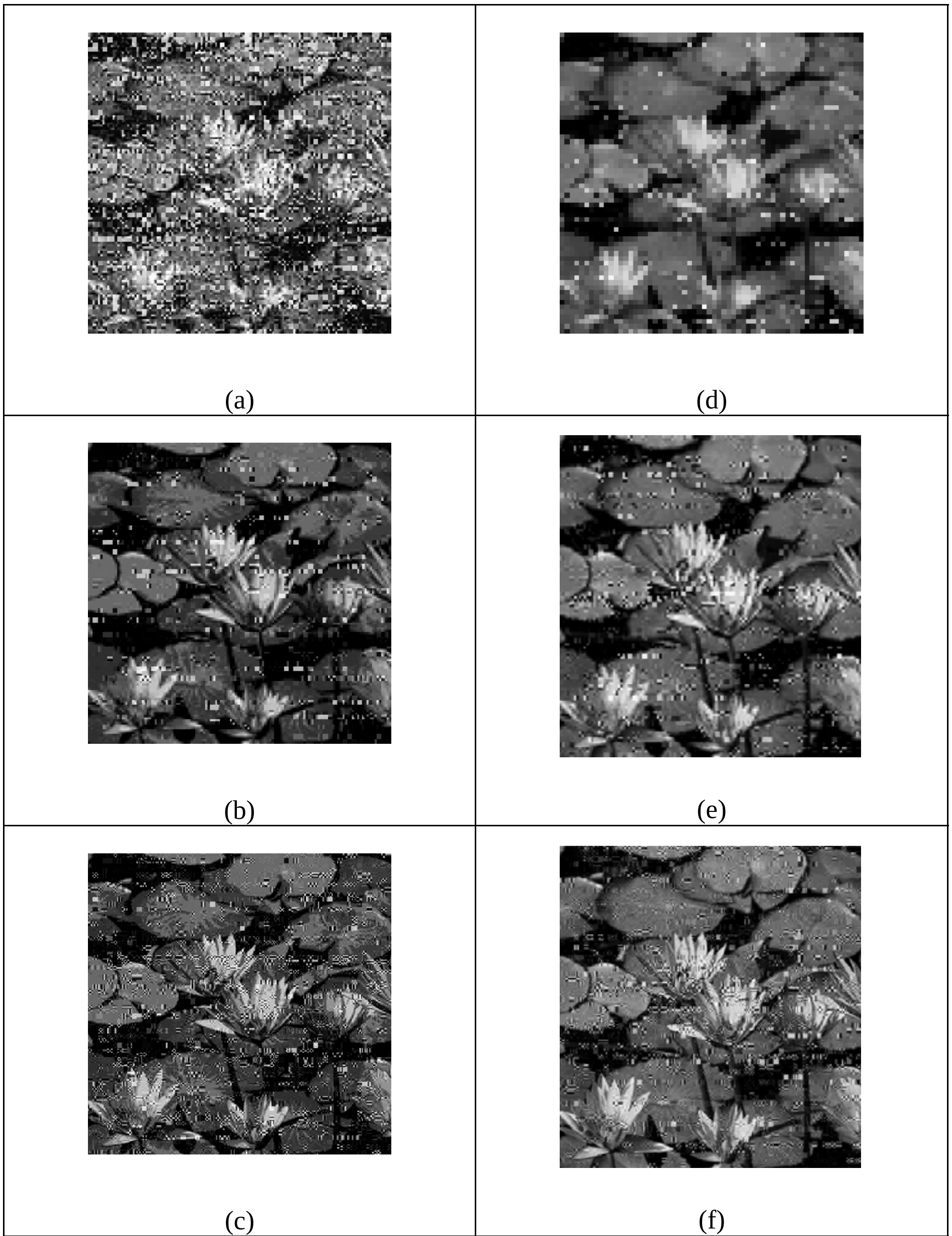


Figure 14. *Reconstructed Image for SNR=2dB*

(a) Totaly 96.875 compression (with 87.5 % JPEG and 75 % Bit Plane)
(b) Totaly 93.75 compression (with 75 % JPEG and 75 % Bit Plane)
(c) Totaly 87.5 compression (with 50 % JPEG and 75 % Bit Plane)
(d) Totaly 93.75 compression (with 87.5 % JPEG and 50 % Bit Plane)
(e) Totaly 87.5 compression (with 75 % JPEG and 50 % Bit Plane)
(f) Totaly 75 compression (with 50 % JPEG and 50 % Bit Plane)

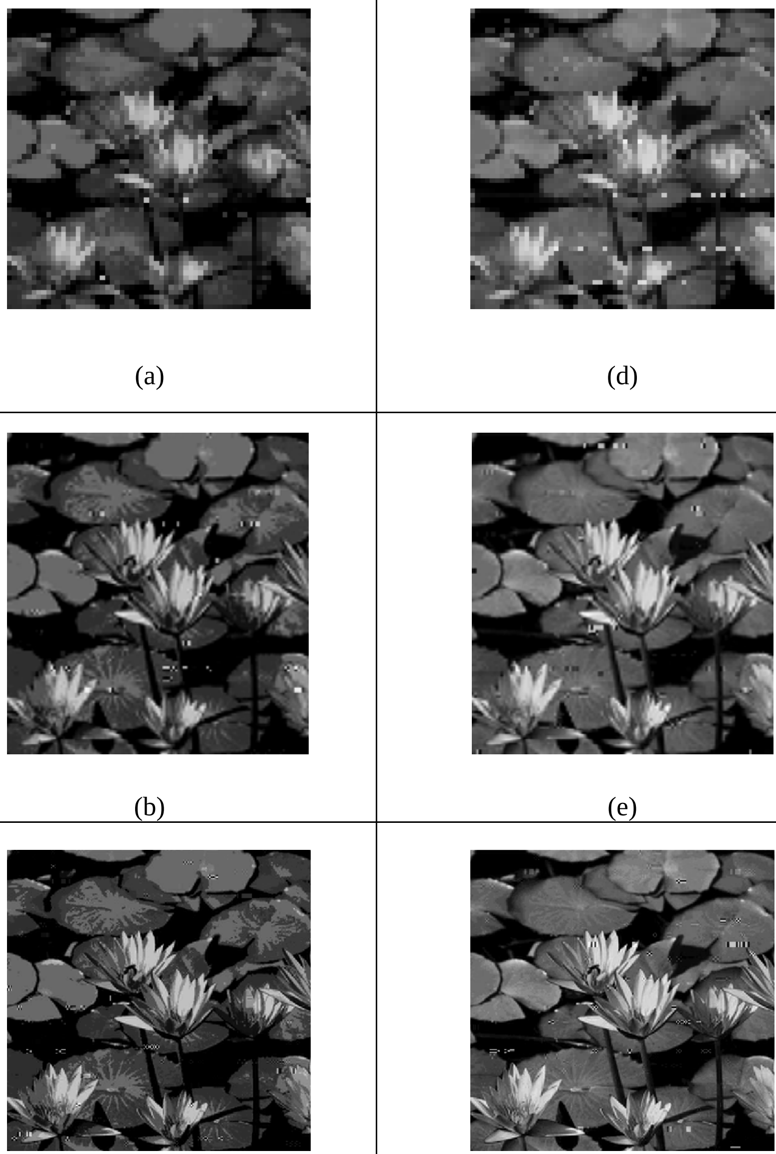


Figure 15. *Reconstructed Image for SNR=3dB*

- *(a) Totaly 96.875 compression (with 87.5 % JPEG and 75 % Bit Plane)*
- *(b) Totaly 93.75 compression (with 75 % JPEG and 75 % Bit Plane)*
- *(c) Totaly 87.5 compression (with 50 % JPEG and 75 % Bit Plane)*
- *(d) Totaly 93.75 compression (with 87.5 % JPEG and 50 % Bit Plane)*
- *(e) Totaly 87.5 compression (with 75 % JPEG and 50 % Bit Plane)*
- *(f) Totaly 75 compression (with 50 % JPEG and 50 % Bit Plane)*