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Combined Source and Channel Coding for Image Transmission Using Enhanced Turbo Codes in AWGN and Rayleigh Channel

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***Abstract*—**Any signal transmitted over a channel is corrupted by noise and interference. A host of channel coding techniques has been proposed to alleviate the effect of such noise and interference. Among these Turbo codes are recommended, because of increased capacity at higher transmission rates and superior performance over convolutional codes. The multimedia elements which are associated with ample amount of data are best protected by Turbo codes. Turbo decoder employs Maximum A-posteriori Probability (MAP) and Soft Output Viterbi Decoding (SOVA) algorithms. Conventional Turbo coded systems employ Equal Error Protection (EEP) in which the protection of all the data in an information message is uniform. Some applications involve Unequal Error Protection (UEP) in which the level of protection is higher for important information bits than that of other bits. In this work, enhancement to the traditional Log MAP decoding algorithm is being done by using optimized scaling factors for both the decoders. The error correcting performance in presence of UEP in Additive White Gaussian Noise channel (AWGN) and Rayleigh fading are analyzed for the transmission of image with Discrete Cosine Transform (DCT) as source coding technique. This paper compares the performance of log MAP, Modified log MAP (MlogMAP) and Enhanced log MAP (ElogMAP) algorithms used for image transmission. The MlogMAP algorithm is found to be best for lower Eb/N0 values but for higher Eb/N0 ElogMAP performs better with optimized scaling factors. The performance comparison of AWGN with fading channel indicates the robustness of the proposed algorithm. According to the performance of three different message classes, class3 would be more protected than other two classes. From the performance analysis, it is observed that ElogMAP algorithm with UEP is best for transmission of an image compared to Log MAP and MlogMAP decoding algorithms.

***Keywords*—**AWGN, BER, DCT, Fading, MAP, UEP.

I. Introduction

TURBO code was introduced in 1993 by Berrou, Glavieux and Thitimajashima [1], who reported extremely impressive results with performance close to Shannon's limit. Turbo code provides virtually error free communication or obtains much better coding gain beyond that of any other codes. This coding technique can also be used to provide a strong error correction solution to combat channel fading. They are recommended for increased capacity at high transmission rates due to their superior performance when compared to traditional convolutional codes. The process of Turbo coding scheme consists of recursive systematic encoding, interleaving, puncturing and decoding. Graphic signals like compressed still images are very susceptible to channel noise. So, channel coding techniques are employed to protect the transmitted graphical or visual signals. Since these multimedia signals occupy a large bandwidth even after compression, Turbo codes are suitable for guarding such signals. Rather than giving equal importance to entire data which is termed as EEP, this paper provides UEP technique with MlogMAP and ElogMAP as decoding algorithms. This UEP technique involves data partition using varying coding rates, to protect various components of an image "unevenly" based on their sensitivity to channel errors. Modified log MAP algorithm is accomplished by fixing an arbitrary value of scaling factor for inner decoder (S2) and an optimized scaling factor value for the outer decoder (S1). Enhanced log MAP algorithm is got by optimizing both the scaling factors S1 and S2. The value of scaling factor for which the BER is minimum at a given Eb/N0 is considered to be the optimum scaling factor.

The decoder of Turbo codes uses the maximum a posteriori (MAP) algorithm and Soft Output Viterbi Algorithm (SOVA) was used for decoding recursive systematic convolutional (RSC) codes in an iterative process. However, in practice the MAP, which is an optimal Turbo decoding algorithm, is too complex to be implemented practically. For that reason, two simplified versions of it were proposed, namely Logarithmic MAP (Log MAP) and Maximum Logarithmic MAP (Max Log MAP) [3]. The paper is organized as follows: Section I gives the introduction on Turbo codes, JSCC and UEP. Section II gives an overview of the turbo decoding algorithms, the MAP algorithm and its simplified version the Log MAP algorithm. Modified and Enhanced log MAP algorithms are introduced in Section III. Section IV presents simulation results and shows the performance analysis of proposed scheme in AWGN and Rayleigh fading channel.

A. Joint Source Channel Coding (JSCC)

Joint source-channel coding (JSCC) [7], [8] is the most proficient scheme for wireless transmission and reception of analogue sources, because of its capacity to accomplish with varying channel qualities. It also has the ability to approach the theoretical bounds of transmission rates. Discrete Cosine Transform is used as source coding technique which provides spatial frequency compaction. It is the most optimum

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transform compared to other transforms in the intellect of energy compaction. The DCT works by separating images into parts of varying frequencies. During the process of quantization, the less important frequencies are removed and partial compression occurs. Hence it is termed as lossy compression scheme. During the decompression process, only the most important frequencies that remain are used to retrieve the image.

B. Unequal Error Protection

Unequal Error Protection Turbo Code [2], [9] is evolved from customary Turbo codes for providing concrete application. The UEP Turbo Codes provide high level of protection to the important part in the information source, thus improving the accuracy of decoding of important information.

The UEP is affected by crafting a new puncturing matrix scheme to the existing Turbo codes [2]. Assume the source encoders produce the binary symbol frames. Now each frame of the source signal will be divided into important and unimportant information based on varying code rate and redundancy weight. For a fixed decoding delay and complexity, a better code rate or low code rate (0.3333) with high redundancy gives lower bit error rate (BER) for the important information bits which is taken as class 3 in our simulation. For unimportant information bits, high code rate (0.6057) with less redundancy gives relatively higher BER. Such message group is taken as class 1. Table I shows the code rate and redundant bits for UEP used in the simulation.

TABLE I
UEP CODE RATE AND REDUNDANCY

Classes		3	2	1
Symbols		1000	1000	1000
Code rate	UEP	0.3333	0.3888	0.6057
Redundant bits	UEP	333	388	605

II. TURBO DECODING ALGORITHMS

A turbo decoder is an iterative decoder, in which multiple decoders share probability information with each other in an iterative fashion. The turbo decoder receives as its input a soft decision value from the demodulator. This soft decision value will represent the probability that the transmitted bit was a 1 or 0.

A. The MAP Algorithm

The MAP (Maximum a Posteriori) algorithm is based on soft inputs and soft outputs [3], [4]. The algorithm is also complex in nature. The Log MAP and Max Log MAP algorithms are two simple alternates of the MAP algorithm. In MAP algorithm, the Log Likelihood Ratio (LLR) of the information bit is given by

$$L(d_k) = \log\left[\frac{\sum_{S_k}\sum_{S_{k-1}}\gamma_1(S_{k-1},S_k)\alpha_{k-1}(S_{k-1})\beta_k(S_k)}{\sum_{S_k}\sum_{S_{k-1}}\gamma_0(S_{k-1},S_k)\alpha_{k-1}(S_{k-1})\beta_k(S_k)}\right] \quad (1)$$

where α is the forward state metric, β is the backward state metric, γ is the branch metric, and S_k is the trellis state at time k. Branch metrics for every potential trellis transition are computed as

$$\gamma_i(S_{k-1},S_k) = A_k P(S_k|S_{k-1})\exp\left[\frac{2}{N_0}\left(y_k^s x_k^s(i) + y_k^p x_k^p(i,S_{k-1},S_k)\right)\right] \quad (2)$$

where i = (0, 1), A_k is a constant, x_k^s and x_k^p are the encoded systematic data bit and parity bit, and, y_k^s and y_k^p are the noisy systematic data bit which is received and parity bit respectively [4].

B. The Log MAP Algorithm

To obviate the complex mathematical computations involved in the MAP algorithm, the computations can be done in logarithm domain [3], [4]. Moreover exponential and logarithmic calculations are eliminated by the following approximation

$$\max{}^*(x,y) \triangleq \ln\left(e^x + e^y\right) = \max(x,y) + \ln\left(1 + e^{-|y-x|}\right) \quad (3)$$

The last term in max*(.) operation uses a look-up table (LUT) for its calculation.

III. MODIFIED AND ENHANCED ALGORITHMS

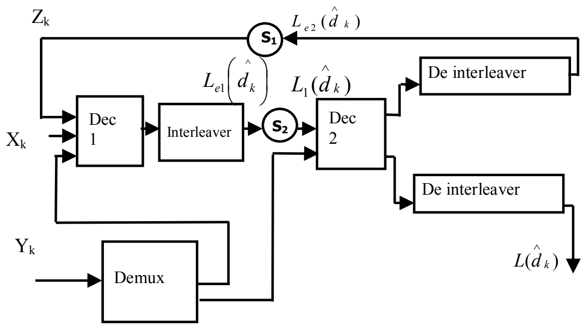

Fig. 1 Turbo Decoder with Double Scaling factor

Conventional Log MAP algorithm undergoes two distortions: [4], [6], [12] over optimistic detection of soft outputs and correlation between intrinsic and extrinsic information of the constituent decoders.

The first distortion caused by the over optimistic detection of soft outputs reduces the decoder performance significantly. But the second kind of distortion has less effect on the decoder's performance. This paper aims to alleviate the degradation due to the first distortion caused by the over estimation of reliability values by scaling the extrinsic information exchanged between the constituent decoders. It is also important to note that there is a dependency of the Scaling Factor (SF) on E_b/N_0. The algorithms are modified by scaling the extrinsic information [5] $L_e(\hat{d}_k)$ with the chosen scaling factor before it enters the other decoder for subsequent iterations. MlogMAP algorithm is achieved by fixing an

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arbitrary scaling factor (S_2) for inner decoder chosen to be 0.755 and an optimized value for the outer decoder (S_1). For ElogMAP both the scaling factors S_1 and S_2 are optimized. The performance improvement with the scaling factor S_2 depends on E_b/N_0. Fig. 1 shows the multiplication of the extrinsic information $L_e(\hat{d}_k)$ with the optimized scaling factors S_1 and S_2 ahead of it is being fed back to the input and decoder 2 respectively [11]. It is given by,

$$z_k = \left[L_{e2}(\hat{d}_k) \right] \times S_1 \quad (4)$$

$$L_1(\hat{d}_k) = \left[\frac{2}{\sigma^2} x_k + L_{e1}(\hat{d}_k) \right] \times S_2 \quad (5)$$

IV. Simulation Results and Discussion

The simulation of the UEP Turbo coded system was carried out in AWGN and Rayleigh fading channels. The transmission and retrieval of an image is simulated using MATLAB to show the effects of Joint Source and Channel Coding. The simulation parameters are

- Number of frames transmitted - 500 frames
- Length of each frame - 2500bits
- Code rate

  For important components of message: 1/3

  For unimportant components of message: 1/2
- Generator Sequence - [1 1 1 ; 1 0 1]
- Type of Interleaver used : 2048 bit random interleaver [10]
- No of iterations - 8
- Channel – AWGN and Rayleigh fading
- Size of original image-206x345
- Size of compressed image-50x50

A. Scaling Factor for Enhanced Log MAP

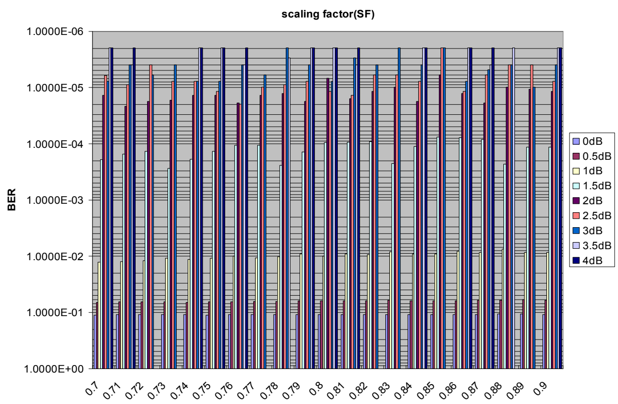

Fig. 2 BER plot for various Scaling Factors and E_b/N_0 with code generator (7,5) and punctured

Modified Log MAP algorithm (MlogMAP) is the variant of Log MAP algorithm with the difference that the inner decoder takes on arbitrary scaling factors (S_2) while scaling factor (S_1) of the outer decoder is optimized. In Enhanced Log MAP, both S_1 and S_2 are optimized. Fig. 2 shows the plot of various scaling factors against BER for different E_b/N_0 because the scaling factor S_2 depends on E_b/N_0. Table II shows the optimized scaling factor against E_b/N_0. It is also found that for E_b/N_0 greater than 1.0dB the optimized scaling factor is 0.85, for which the BER is minimum. Table III shows the summary of scaling factors for MlogMAP and ElogMAP. It is found for ElogMAP S_1 and S_2 are optimized.

TABLE II
OPTIMIZED SCALING FACTOR (S2) FOR VARYING E_B/N_0

E_b/N_0(dB)	Scaling Factor (S_2)	BER
0	0.89	1.0800E-01
0.5	0.89	5.9358E-02
1	0.88	7.4698E-03
1.5	0.85	7.5571E-05
2	0.85	5.8887E-06
2.5	0.85	1.9629E-06
3	0.85	1.9629E-06
3.5	0.85	1.6211E-06
4	0.85	1.6211E-06

TABLE III
SUMMARY OF SCALING FACTORS

Decoding Algorithm	Scaling factor	
	Decoder 1(S_1)	***Decoder*** 2(S_2)
MlogMAP	0.9*	0.755
ElogMAP	0.9*	0.85*

*- optimized scaling factors

Fig. 3 shows the performance of Turbo decoding algorithms log MAP, Modified log MAP and Enhanced log MAP for class 1 (least important) message.

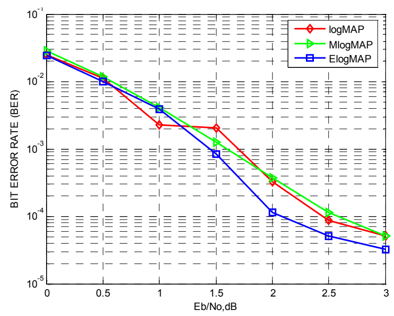

Fig. 3 Comparison of Turbo decoding algorithms for class 1 in AWGN Channel

It is found that BER of Enhanced log MAP algorithm at 3dB is $3.2\times10^{-5.}$ At E_b/N_0 of 1.5dB and above ElogMAP algorithm is better whereas for lower E_b/N_0 values (<1.5dB), MlogMAP and ElogMAP yield similar results. From this analysis ElogMAP is considered to be best for class 1.

Fig. 4 shows the Comparison of decoding algorithms for class2. The BER results show that ElogMAP is better at 1dB and above. BER of ElogMAP algorithm is found to be 1.2×10^{-5} at 3dB and it improves for higher E_b/N_0.

Fig. 5 shows the comparison of Turbo decoding algorithms for class 3 (most important) message bits in AWGN channel.

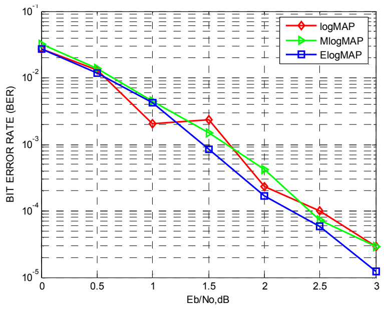

Fig. 4 Comparison of Turbo decoding algorithms for class2 in AWGN Channel

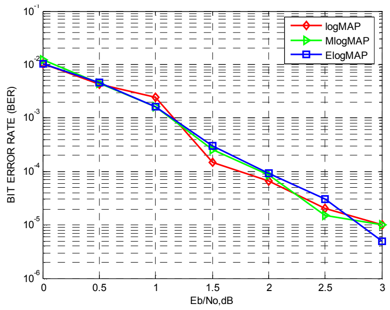

Fig. 5 Comparison of Turbo decoding algorithms for class 3 in AWGN Channel

The performance of Turbo decoding algorithms for class 3 shows that BER of ElogMAP algorithm is 5.2×10^{-6} at 3dB. MlogMAP and ElogMAP produce similar results up to 2.5dB. From this analysis both MlogMAP and ElogMAP are best suitable for transmission of message bits in class 3 over AWGN channel. Also it is found that class 3 achieved least BER than class 1 and 2. Hence most important message class achieves more protection at the cost of increased redundancy.

Fig. 6 shows the comparison of three decoding algorithms in fading channel for class 1(least important messages). From this performance comparison, the enhanced algorithm (ElogMAP) performs better than other two algorithms. BER approaches to zero when it reaches at 3dB. The use of optimized scaling factor improved the performance of enhanced algorithm in terms of BER.

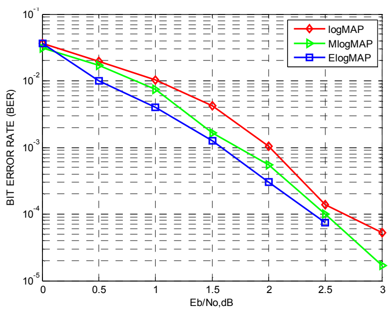

Fig. 6 Performance of decoding algorithms for class 1 in fading channel

Fig. 7 shows the performance of various decoding algorithms for transmission of class 2 message bits. The results show that Enhanced algorithm has superior performance. BER reaches the value 2.7×10^{-5} at 3dB.

From this analysis, it is shown that class2 achieves less BER than class 1 at E_b/N_0 of 2.5dB.

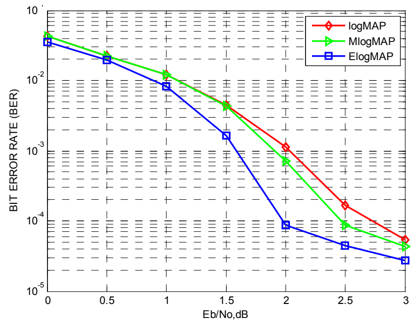

Fig. 7 Performance of decoding algorithms for class2 in fading channel

Fig. 8 shows the performance of log MAP, Modified log MAP and Enhanced log MAP for class 3 (most important) messages in fading channel.

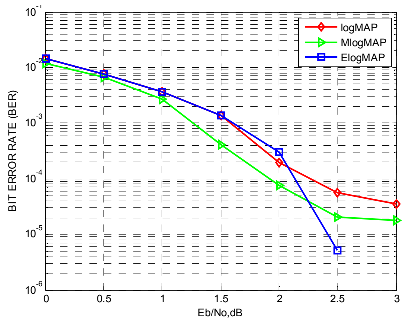

Fig. 8 Performance of decoding algorithms for class 3 in fading channel

The modified algorithm performs better at lower E_b/N_0 values and for E_b/N_0 of 2.5dB and above ElogMAP algorithm performs well.

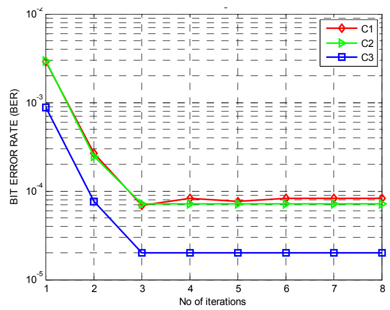

Fig. 10 Performance of different classes of UEP in AWGN Channel using ElogMAP for varying iterations

Fig. 9 is a plot between BER and iteration for three classes in UEP using Enhanced log MAP algorithm. Performance analysis shows that class 3 is more protected and achieves least BER than other two classes. Also class 3(C3) reaches a stable BER of 2×10^{-5} from 3rd iteration. So, the computational complexity of the algorithm is reduced, by reducing the number of iterations from 8 to 3. Both class 1&2 yield similar results. Class 3 yields more optimum results than class 2 and class 1.The low BER of class 3 indicates that it will be more protected in ElogMAP algorithm than other two classes.

Fig. 10 shows the performance of Enhanced log MAP algorithm in AWGN and fading channel

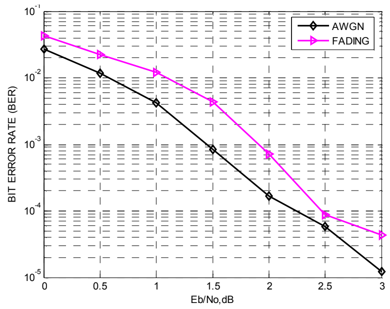

Fig. 11 Performance of ElogMAP algorithm in two different channels

The comparison result shows that Additive White Gaussian Noise channel performs better than Rayleigh fading channel.

Fig. 11 shows results on applying DCT, Turbo encoding decoding and IDCT for an image. Table IV shows the Peak Signal to Noise Ratio (PSNR) values for the output image for various decoding algorithms. It is found that compared to Log MAP, MlogMAP has improved PSNR.

TABLE IV
PSNR VALUES FOR THE OUTPUT IMAGE FOR VARIOUS DECODING ALGORITHMS

Decoding Algorithm	PSNR(dB) at E_b/N_0=2dB
Enhanced Log MAP	15.9246
Modified Log MAP	15.09
Log MAP	14.9775

On comparing the PSNR values of MlogMAP and ElogMAP, the later showed performance improvement of 0.9dB in AWGN channel.

V. CONCLUSION

This work presents an efficient image transmission by means of joint source and channel coding which takes advantage of the superior performance of Turbo coding and Discrete Cosine Transform. The modified log MAP algorithm is found to be best for lower E_b/N_0 values but for higher E_b/N_0 Enhanced log MAP performs better with optimized scaling factors. The performance comparison of AWGN with fading channel indicates the robustness of the proposed algorithm. According to the performance of three different message classes, class3 would be more protected than other two classes. From the performance analysis, it is clear that Enhanced log MAP algorithm is best for transmission of an image compared to Log MAP and Modified log MAP decoding algorithms. It is also observed that, due to the less computational complexity achieved by reducing the number of iterations used, the ElogMAP algorithm provides for easy implementation.

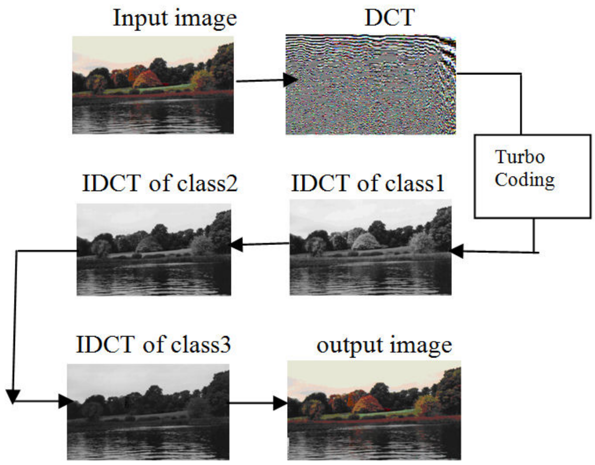

Fig. 12 Image transmission and retrieval using JSCC

REFERENCES

[1] C. Berrou, A. Glavieux, and P. Thitimajshima, “Near Shannon Limit Error-Correcting Coding and Decoding: Turbo-Codes*”, Proc. IEEE ICC ’93,* Geneva, Switzerland, pp. 1064-1070, 1993.

[2] Zhou, Zude, and Chao Xu. "An improved Unequal error protection turbo Codes." *In IEEE International Conference on Wireless Communications, Networking and Mobile Computing*, vol. 1, pp. 284-287, 2005.

[3] P Robertson, E. Villebrun and P. Hoher,”A Comparison of Optimal and Sub-Optimal Map Decoding Algorithms Operating in the Log Domain”, *Proc. IEEE ICC ’95*, Seattle, USA, pp. 1009-1013, 1995.

[4] Gnanasekaran, T., and V. Aarthi. "Effect of constraint length and code rate on the performance of enhanced turbo codes in AWGN and Rayleigh fading channel." *WSEAS Transactions on Communications* Vol.10, No. 5, pp. 137-146, 2011.

[5] Colavolpe G, Ferrari G “Extrinsic Information in Iterative Decoding, A Unified View”, *IEEE Trans. Comm*., Vol.49, pp.2088–2094, 2001.

[6] C Chaikalis, J M Noras, “Implementation of an improved reconfigurable SOVA/log-MAP turbo decoder in 3GPP”, *Proc. IEE 3G2002*, London, UK, pp.146-150, 2002.

[7] Qian Mao & Boqing Xu, “A New Scheme to Improve the Quality of Compressed Image Transmission by Turbo Unequal Error Protection Codes”, *Seventh International Conference on Intelligent Information Hiding and Multimedia Signal Processing*, pp. 226-229, 2011.

[8] Wang, Hanxin, Cuitao Zhu, Chengyi Xiong, and Shaoping Chen. "Joint source-channel coding with unequal error protection using asymmetric turbo codes." *In 15th IEEE International Conference on Advanced Communication Technology (ICACT)*, pp. 1-10, 2013.

[9] Xu, Liangliang, Lin Wang, Shaohua Hong, and Huihui Wu. "New results on radiography image transmission with unequal error protection using protograph double LDPC codes." *In 8th IEEE International Symposium on Medical Information and Communication Technology (ISMICT)*, pp. 1-4, 2014.

[10] Blackert, W.J., Hall, E.K., Wilson, S.G., “Turbo Code Termination and Interleaver Conditions,” *Electronics Letters*, Vol 31, Nov 1995.

[11] T. Gnanasekaran and K. Duraiswamy, “Application of scaling factors for MAP and SOVA for Robust performance in Forward Error Correction”, *International Journal of Recent Trends in Engineering*, Vol. 1, No. 3, pp. 47-51, 2009.

[12] Gnanasekaran, T., V. Aarthi, and N. S. Pradeep. "Performance enhancement of modified turbo decoding algorithms for mobile

WiMAX." *Australian Journal of Electrical & Electronics Engineering* Vol.9, No. 2, pp. 153-163, 2012.