important role in decoding. Thus, the non-uniform quantisation performs better than uniform quantisation especially for small n, say smaller than 7. For large n, however, both non-uniform and uniform quantisations do not further improve performance as n grows. Fig. 2 shows part of our simulation results in which the logarithmic parameter $\mu = 100$.

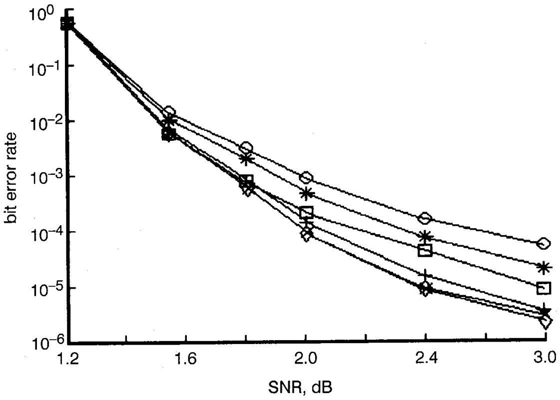

Fig. 2 *Decoding performance of non-uniform and uniform quantisations*

–□– non-quantisation
–○– 6-bit uniform quantisation with bound −20–+20
–∗– 6-bit non-uniform quantisation (μ-law) with bound −20–+20
–+– 8-bit non-uniform quantisation (μ-law) with bound −20–+20
–×– 10-bit non-uniform quantisation (μ-law) with bound −20–+20
–◇– 12-bit non-uniform quantisation (μ-law) with bound −20–+20

It is interesting that quantised decoding lowers the error floor at high SNRs, as shown in Fig. 2. Owing to the sign symmetry of (2), in the continuous decoding at high SNRs, few incorrectly observed data near zero combined with other large correct data make the *posterior* values of those variable nodes with medium correct observed data oscillate and make the error spread during iterations. After quantisation, however, the weak incorrect data will be quantised as the zero level and generate no more interference. That is why quantisation with erasure is often capable of achieving much better performance.

The average degrees of variable and check nodes are $a_v = 1/\sum_{j=2}^{d_l} \lambda_j/j$ and $a_u = 1/\sum_{i=2}^{d_r} \rho_i/i$, respectively. In fact, a_v is the same quantity as t, the average column weight, mentioned in the Introduction. The code rate is $R = 1 - a_v/a_u$. The proposed decoding only involves $N(1-R)(3a_u - 6) + N(3a_v - 3) < 6Na_v - 3N$ addressing in the tables per iteration.

Conclusions: A very fast quantised belief propagation algorithm for decoding LDPC codes has been presented. Various quantisation patterns can be used to improve the decoding performance without increased complexity and it can make the error floor lower. It makes practical applications of LDPC codes possible, and is of help in turbo decoding.

This method enables the use of the time-variant quantiser to improve the decoding performance only by additional operation tables. The quantisation for mid-variables q_1, q_2, r_1, and r_2 is also worthy of study. We observed that different quantisation patterns for them have their own effects on the decoding performance. Further work will seek optimal combination of quantisation schemes with its parameters.

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MIMO iterative decoding of serial concatenation using space-time trellis codes

Eun Jeong Yim, Dong Ku Kim and Hong-Yeop Song

A multiple input, multiple output (MIMO) iterative decoding structure of serial concatenated codes with space-time trellis code (STTC) as outer coder and rate-1 recursive convolutional encoders as inner code is proposed. To both preserve the full diversity gain of space-time code and achieve additional coding gain, the proposed MIMO iterative decoder decodes jointly the received symbol streams from all the transmit antennas. The bit error rate simulation of four-state STTC employing the proposed scheme shows additional 3 dB coding gain without reducing code rate compared to that achievable by STTC alone.

Introduction: Space-time trellis code (STTC) is a technology combining multiple transmit/receive antennas and channel coding. For the wireless multiple input, multiple output (MIMO) channel, STTC provides higher data rate and more reliability since it exploits both the temporal and spatial dimensions on the construction of code designs. This code is designed to provide full diversity gain while obtaining some coding gain. A concatenation of STTC as inner code and channel coding as outer code has been studied to provide coding gain leading to reduction of whole code rate compared to that of STTC alone [1].

The encoder structure proposed in this Letter is based on [2]. This structure composed of rate-1 recursive convolutional code as inner code and STTC as outer code. To preserve full diversity gain of STTC, the received symbols streams from all the transmit antennas are jointly decoded at the inner decoder based on the single decoding structure. Two MAP decoders for STTC and recursive code are used for iterative decoding.

Serial concatenated codes with space-time trellis codes and rate-1 recursive code: Encoder structure: Fig. 1*a* shows the encoder structure of concatenation of STTC and N recursive coder of rate-1 in which N is the number of transmit antenna. To preserve full diversity which can be also obtained by using STTC alone, the ith interleaver and inner code ($i = 1, 2, \ldots, N$) should be set to have the same structure for each branch, which maintains the full diversity gain of STTC during the iterative decoding process and makes the proposed encoder distinctive from the encoder structure of [2].

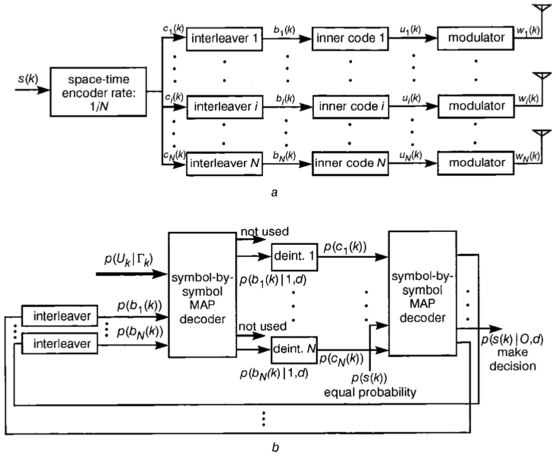

Fig. 1 *Concatenated code with space-time codes as outer code*

a encoder structure
b decoder structure

Decoder structure: Symbols $w_i(k)$, $(i = 1, 2, \ldots, N)$ from each branch of transmitter are decoded jointly by the first MAP decoder. Since symbols are decoded simultaneously, the transmitted signal maintains full rank code construction and ultimately full diversity gain is obtained. Therefore, the decoder structure in Fig. 1*b* can achieve full diversity gain in decoding STTC. Each decoder carries out a symbol-by-symbol MAP sequence decoding [3] in a symbol time. The whole decoding process is iterative by using the structure of two MAP decoders and N interleavers.

Sectionalisation: Since modulation symbols are non-binary while encoded output symbols of rate-1 recursive coder are binary, the decoding process for the rate-1 recursive codes has to be working on symbol level. Therefore, sectionalisation [4] of the original trellis structure is required. The sectionalisation results in the trellis in which the branch represents multiple coded bits and adjacent states are connected by multiple branches [4]. Proper sectionalisation provides a useful trellis structure for decoding and can lead to an effective decoding method: the sectionalised trellis has smaller buffer size than the original, while the computational complexity remains more or less the same.

Fig. 2 shows an original trellis structure and the corresponding sectionalised one for rate-1 recursive code. This structure is constructed based on assuming quaternary phase shift keying (QPSK) transmission. Parallel branches represent the transitions leaving from the same state and merging into the same state in every other instant in the original trellis. Each branch expresses multiple coded bits.

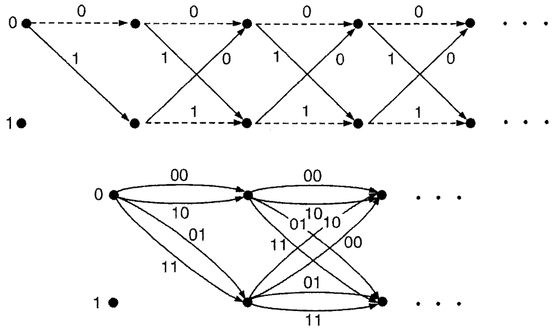

Fig. 2 *Trellis structure of rate-1 recursive convolutional code*
a original trellis structure
b sectionalised trellis structure

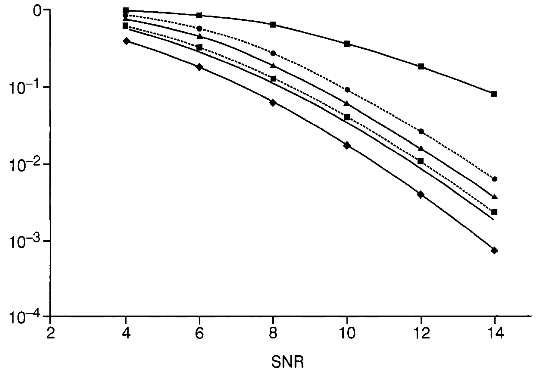

Fig. 3 *FER performance of SCC using four-state STTC*
——■—— SCC_STTC: iteration 1
——▲—— SCC_STTC: iteration 3
———— SCC_STTC: iteration 5
——◆—— SCC_STTC: iteration 7
---●--- STTC-eight-state
---■--- STTC-four-state

Results: The frame error rate (FER) performance of a serial concatenated code with STTC and rate-1 recursive convolutional code is investigated for MIMO iterative decoding on quasi-static flat fading channel. Tarokh's four-state code is used as an outer code and a bit random interleaver is applied. Interleaver size is one frame of 130 symbols. Fig. 3 shows the FER performance of MIMO iterative decoding based on the serial concatenated code (SCC) using STTC and random bit interleaver. The FERs of the MIMO iterative decoding method are shown for SCC with Tarokh's four-state and eight-state STTC. After three iterations the MIMO iterative decoding method has better performance over Tarokh's four-state STTC. At five iterations, it obtains 2.5 dB gain over Tarokh's four-state STTC at 10^{-2} FER and has similar performance over Tarokh's eight-state STTC at 10^{-2} FER. After seven iterations, MIMO iterative decoding method outperforms Tarokh's eight-state STTC by 1 dB.

Conclusion: We have proposed an eight-MIMO iterative decoding structure of serial concatenated codes with space-time trellis code and rate-1 recursive convolutional codes. The results of this method have been investigated by a structure with simple rate-1 recursive code and short interleaver. We expect better performance by using a more complex recursive inner code and longer interleaver.

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Experimental demonstration of chirped duobinary transmission

M. Wichers, W. Kaiser, T. Wuth and W. Rosenkranz

The first experimental demonstration of the modulation format 'chirped duobinary transmission' (CDBT) is reported. The dispersion tolerance of the CDBT format in the nonlinear regime is enhanced significantly so that the maximum transmission distance of conventional duobinary transmission can be increased and error-free transmission over 277 km uncompensated standard singlemode fibre is achieved.

Introduction: An optical duobinary signal can be generated by the use of a Mach-Zehnder modulator (MZM). Usually the MZM is symmetrically driven in push-pull configuration so that a chirp-free duobinary signal can be achieved. The benefits of chirp-free duobinary transmission (DBT) in the linear regime at low fibre launch power are increased bandwidth efficiency and improved dispersion tolerance [1, 2]. However these improvements are degraded substantially in the nonlinear regime owing to self-phase modulation (SPM) limitations. In [3] a threshold-like decrease of the dispersion tolerance, the so-called nonlinear duobinary limit, at approximately 8 dBm optical fibre input power was found. Beyond this limit dispersion tolerance of duobinary transmission now shows no significant improvement compared to conventional binary NRZ modulation.

In [4] we proposed a new modulation format, called chirped duobinary transmission (CDBT), which helps to overcome these SPM limitations by an additional phase modulation of the duobinary signal. This modulation format improves the dispersion tolerance especially in the nonlinear regime by the combined influence of pre-chirp, chromatic