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INSTITUT FÜR NACHRICHTENTECHNIK

International Symposium on Turbo Codes & Iterative Information Processing

A Discrete Information Bottleneck Receiver with Iterative Decision Feedback Channel Estimation

7‘th of December 2018, Hong Kong, China

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Outline

1. Motivation and Information Bottleneck Signal Processing
2. Considered Transmitter, Channel Model and Receiver Structures
3. Results and Conclusion

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Information Bottleneck Signal Processing

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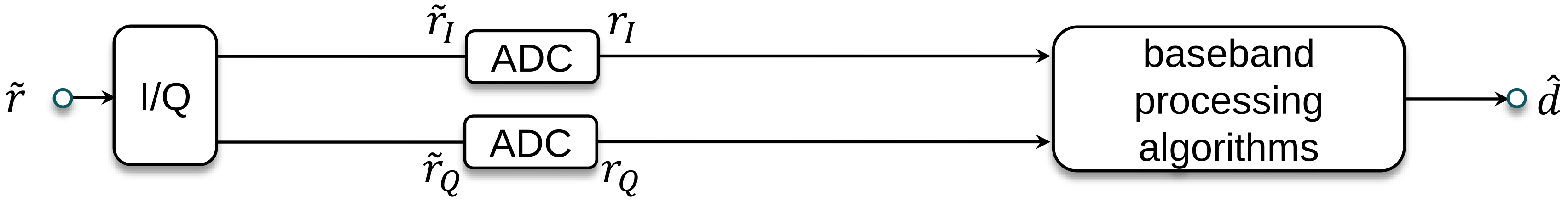
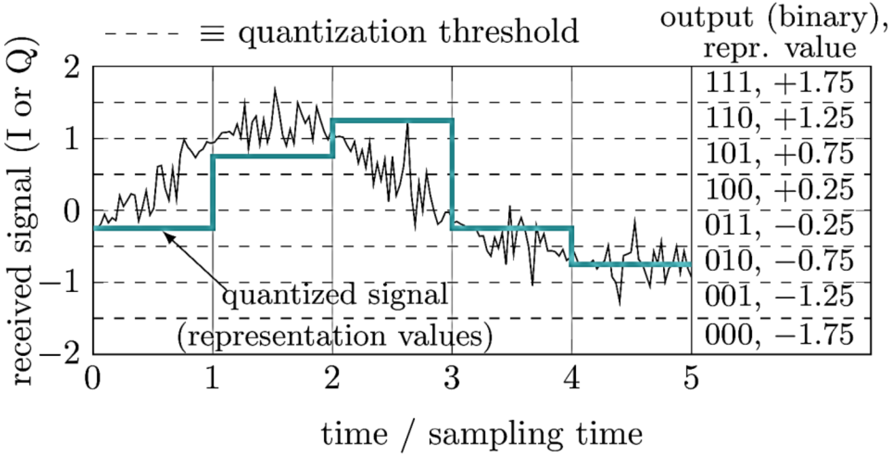
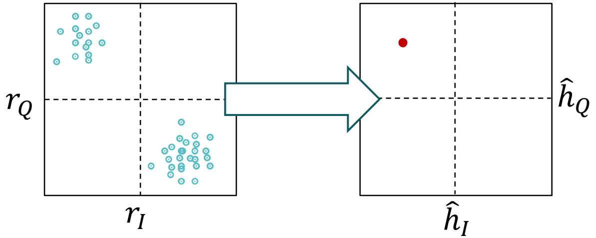
Consider the shown digital receiver layout…

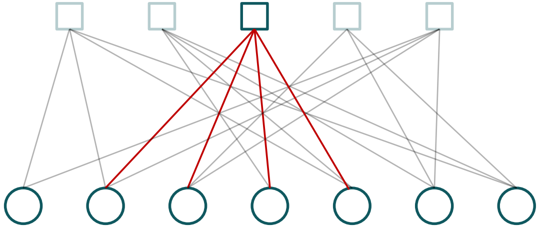




examples: channel estimation



LDPC decoding



Information Bottleneck Signal Processing

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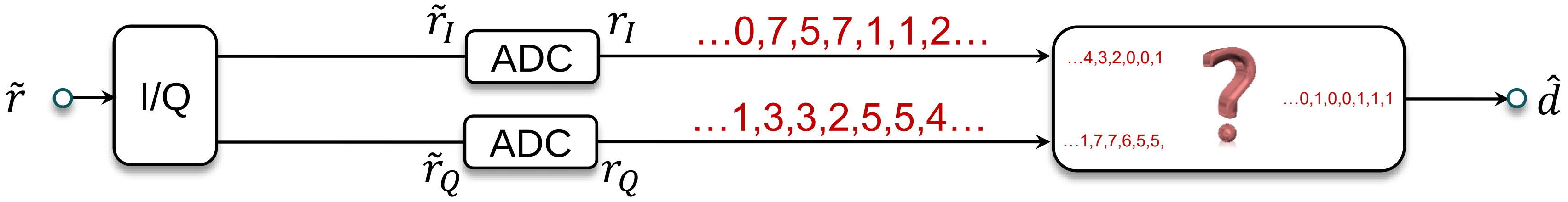
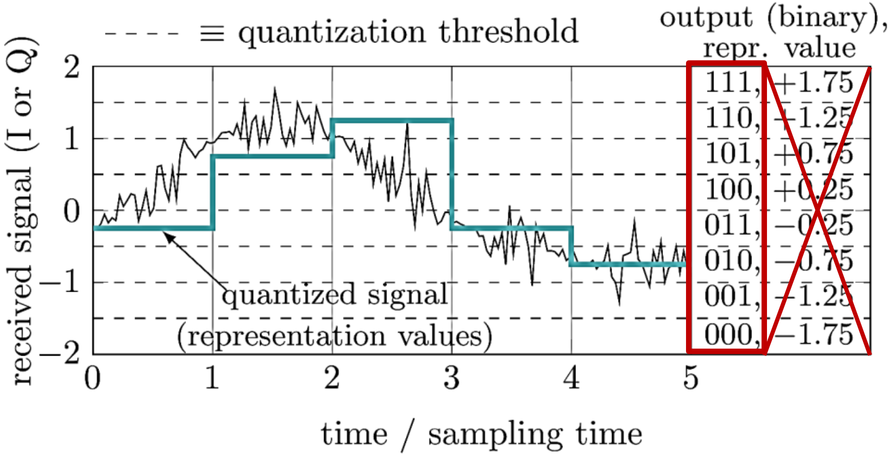
Consider the shown digital receiver layout…





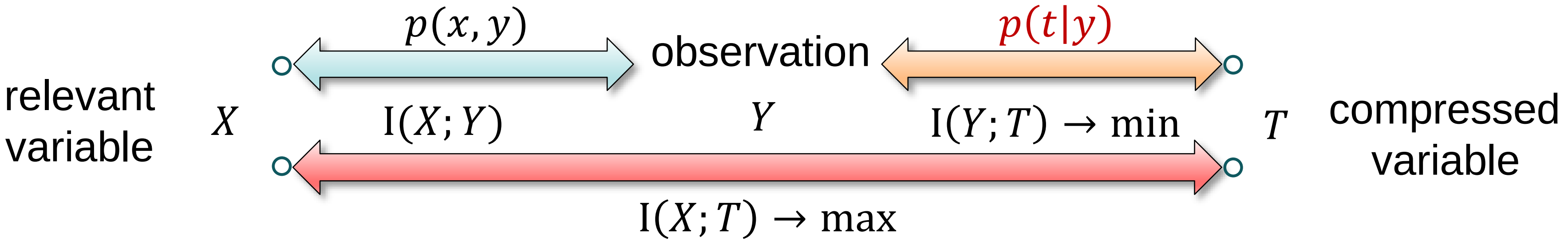
Mutual information is independent of representation values.

$$I(X;Y) = \sum_x \sum_y p(x,y) \log \frac{p(x,y)}{p(x)p(y)}$$

Coarse quantization → small bit width
Only process quantization indices?

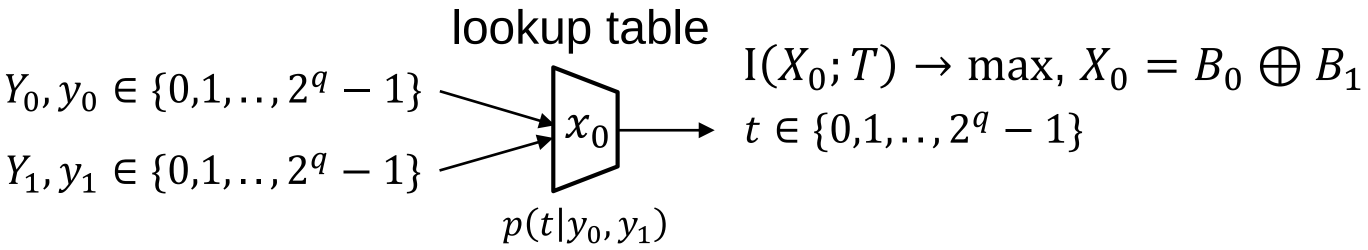
Proposal: Information Bottleneck method !

The Information Bottleneck Method



Workflow: $p(x,y) \rightarrow p(t|y), p(x|t), p(t)$

Example: Box-plus replacement



pair with discretized density evolution ➔ LDPC decoders working on quant. indices

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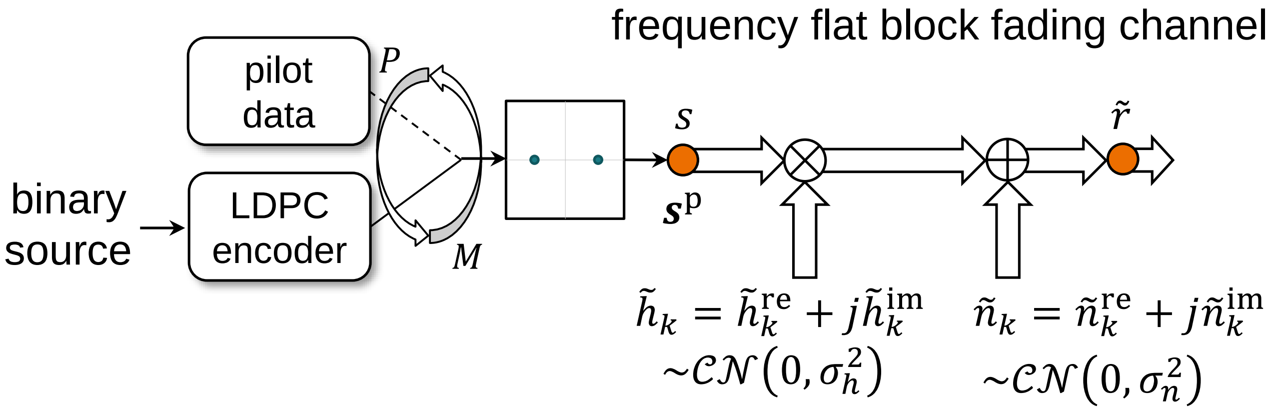
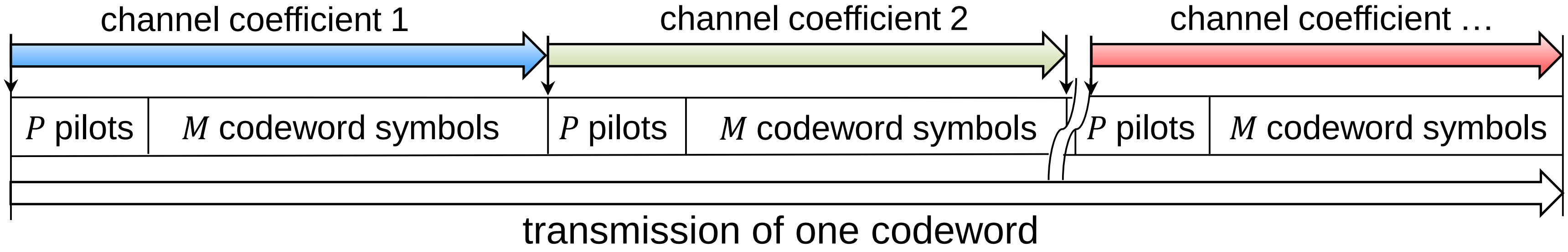
Considered Transmitter & Channel Model





Considered Receiver Structures

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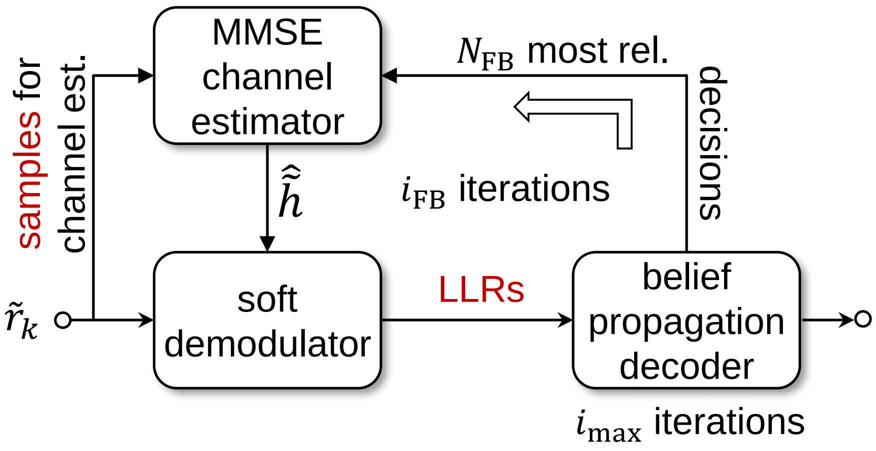
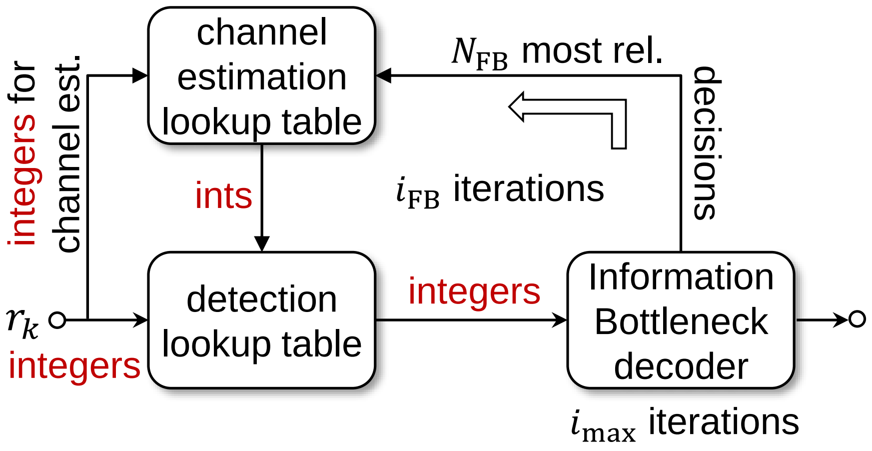
conventional receiver



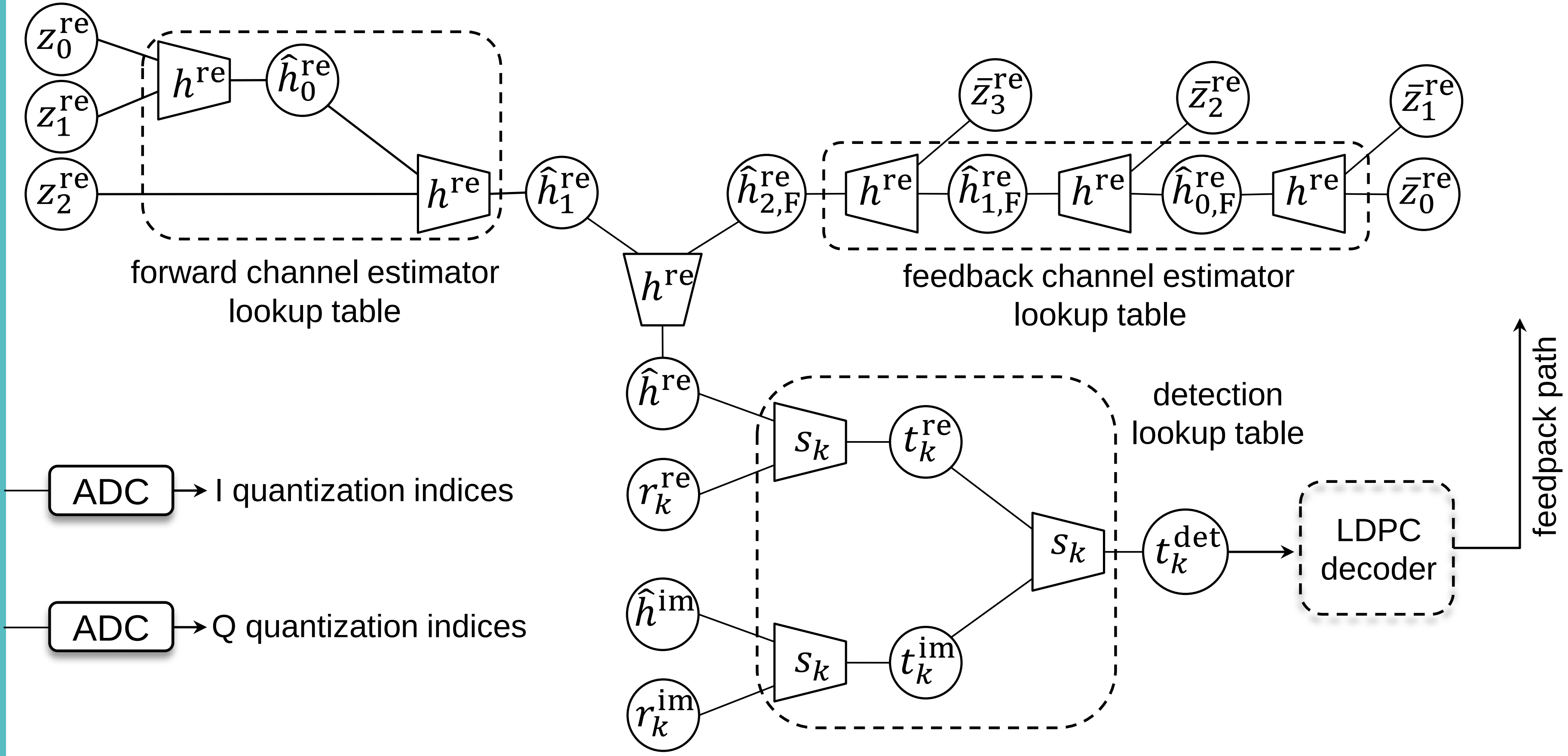
- Representation values from $\mathbb{R}$ and $\mathbb{C}$
- Well known algorithms
- Floating point or fixed point precision

proposed receiver

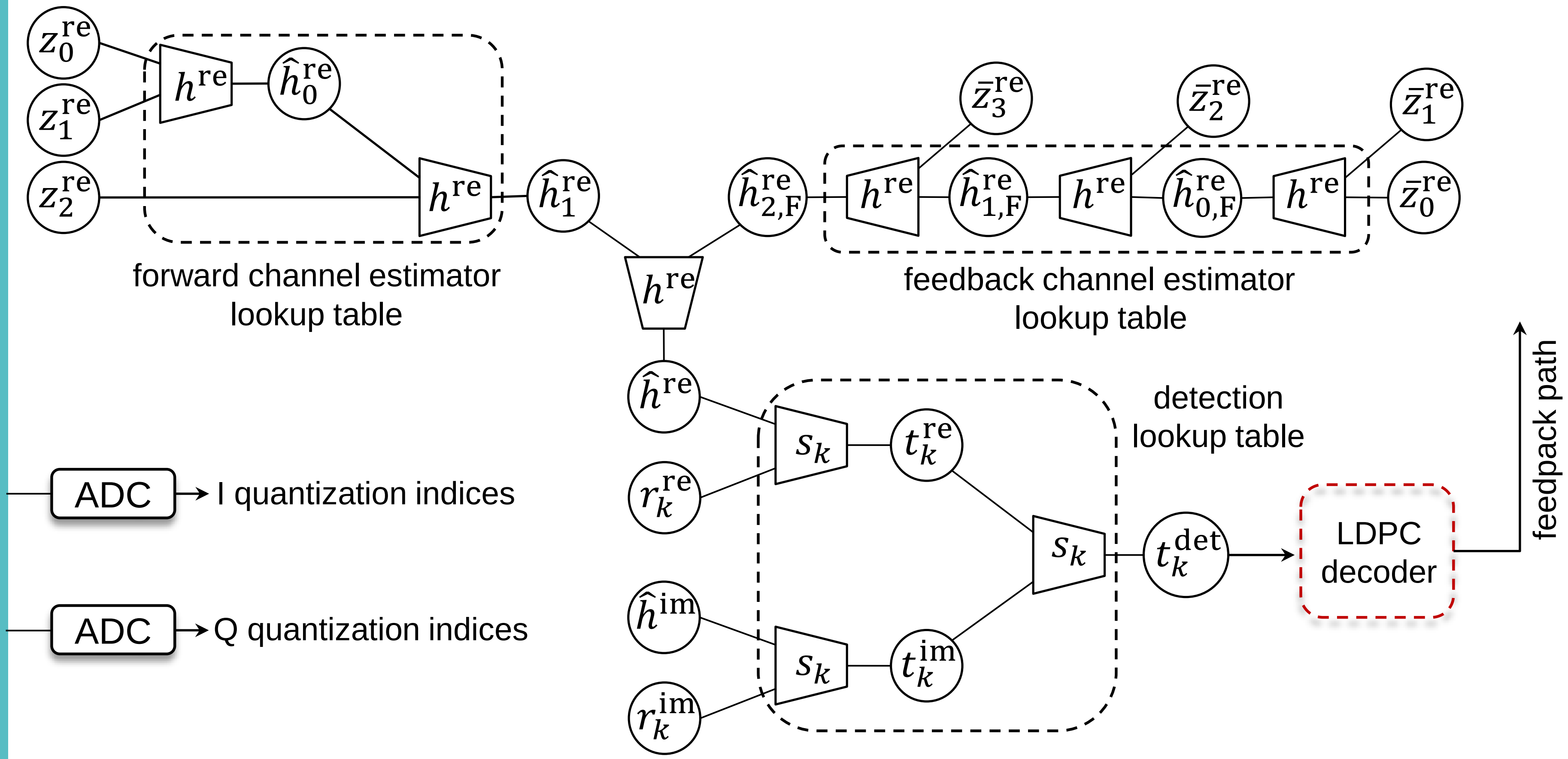


- Quantization indices from $\{0,1,\ldots,Q-1\}$
- Relevant information preserving LUTs
- 5 to 8 bit integers processed

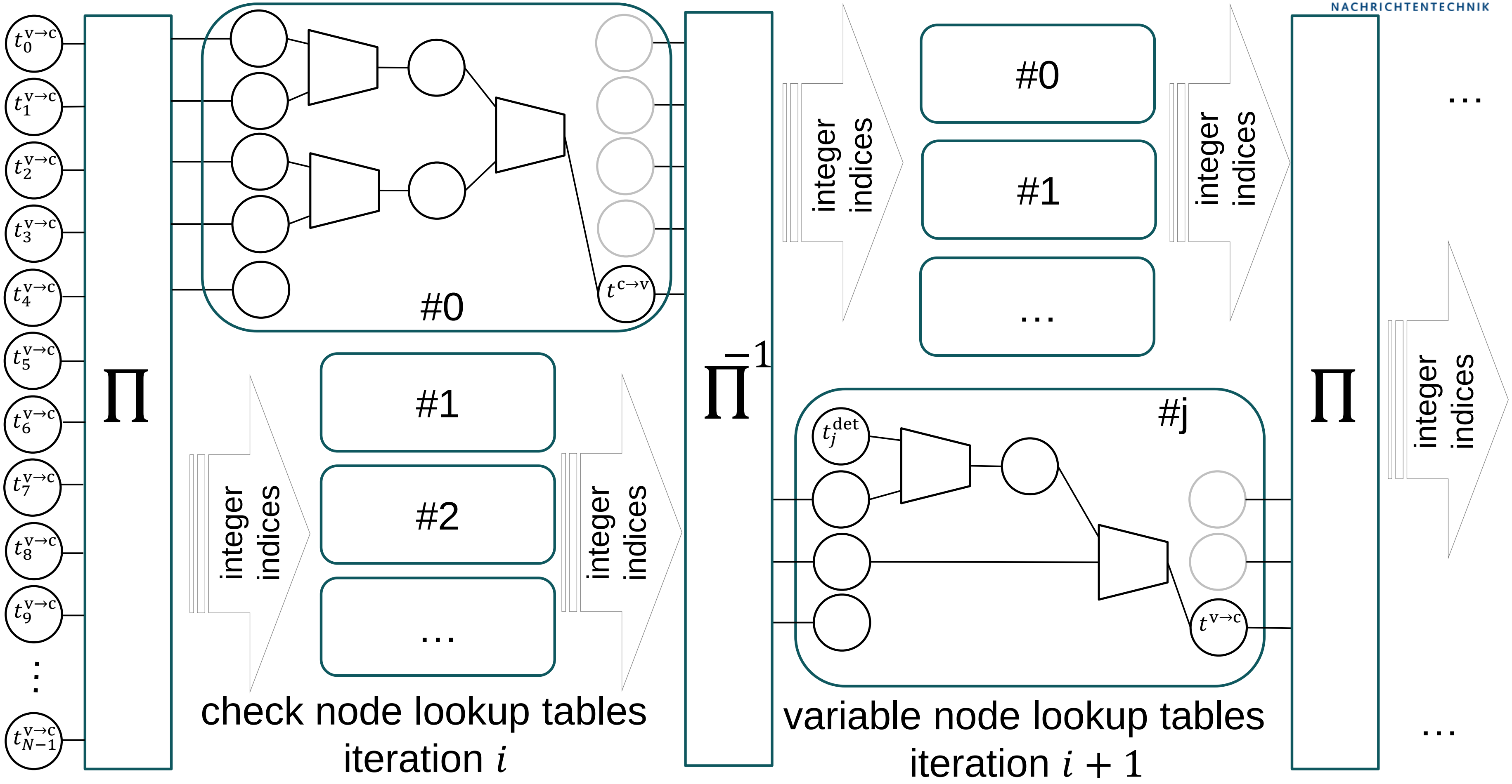
Information Bottleneck Receiver



Information Bottleneck Receiver



Information Bottleneck LDPC Decoder



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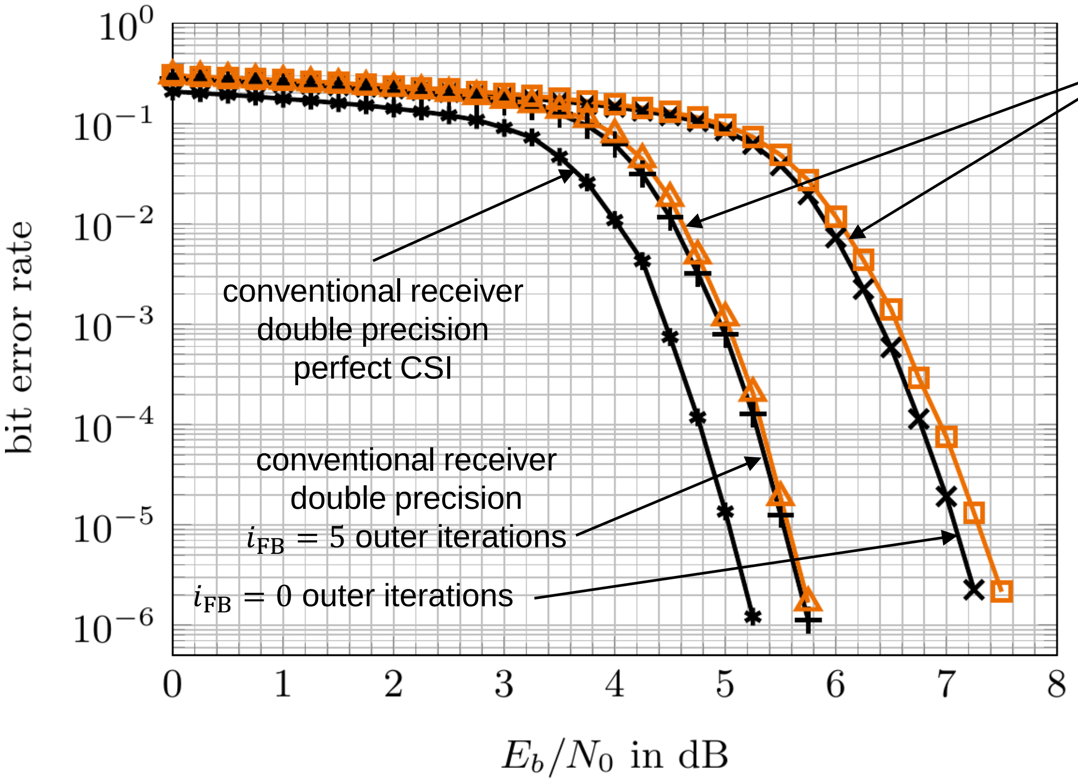
Results

frequency flat block fading channel, length 8000 $(3{,}6)$-regular LDPC (max. 25 decoder iterations), pilot overhead$\approx 8\%$, i_{FB} outer iterations

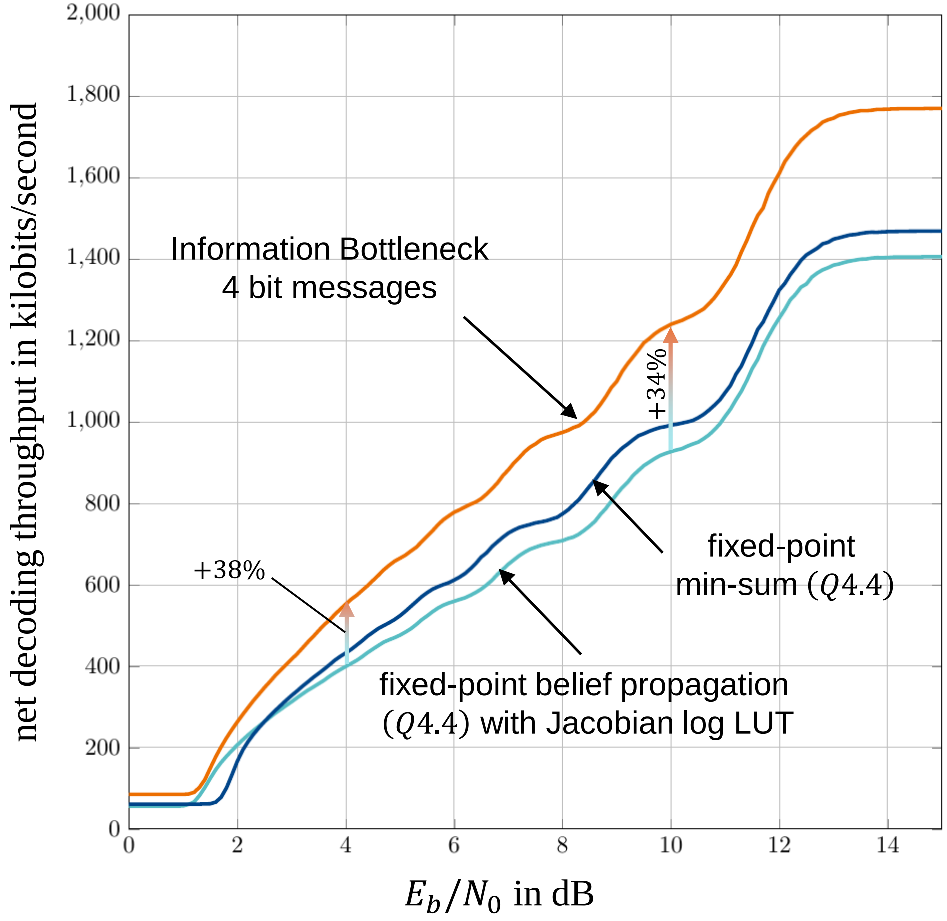


proposed Information Bottleneck with $i_{\mathrm{FB}} = 0$ and $i_{\mathrm{FB}} = 5$ and **static LUTs**

LOOKUP TABLES IN THE INFORMATION BOTTLENECK RECEIVER

component	cardinality	bit width	table entries	table size
channel estim.	$Q^{\mathrm{ce}} = 256$	8 bit	157 696	0.158 MB
detection	$Q^{\mathrm{det}} = 32$	5 bit	18 432	0.012 MB
LDPC decoder	$Q^{\mathrm{dec}} = 32$	5 bit	179 200	0.112 MB
ADC	$2^{q} = 32$	5 bit	31 decision thresholds	

Complexity Gains?

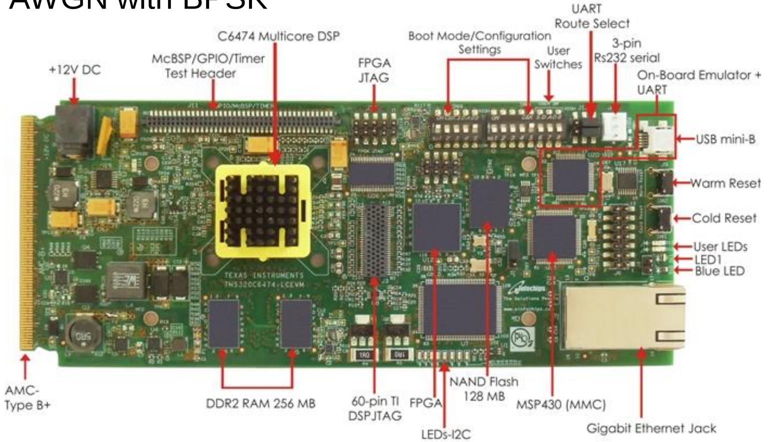


→ Conventional LDPC decoder → VS → Information Bottleneck LDPC decoder →

implementation on TI TMS320C6474 DSP for software defined radio application

length 8000 $(3{,}6)$-regular LDPC (max. 50 iterations)

AWGN with BPSK



…to be presented at ICSPCS'2018

Conclusion

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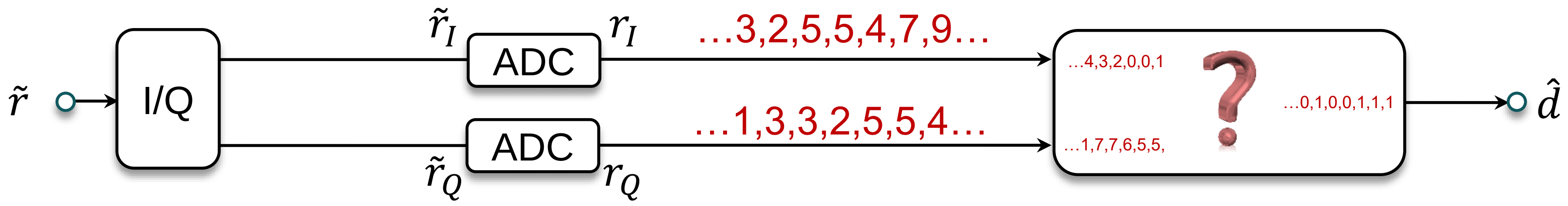
One can build good receivers which only process quantization indices.

Signal processing becomes information processing.

IB design minimizes bit width with maximum preservation of relevant information.

Performance is almost optimal (double precision reference)!



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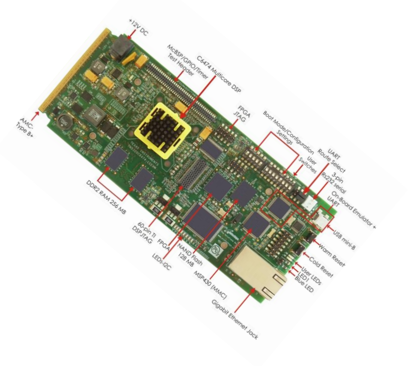

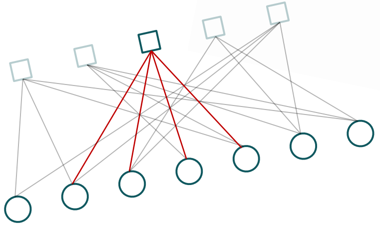

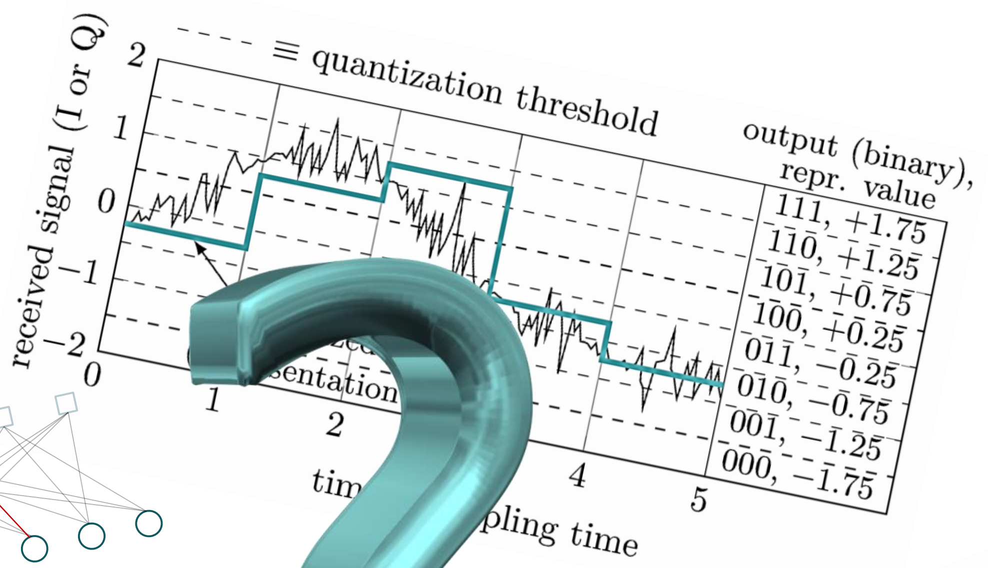

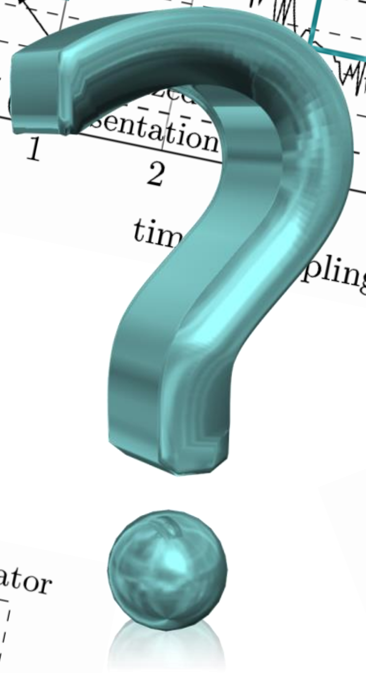

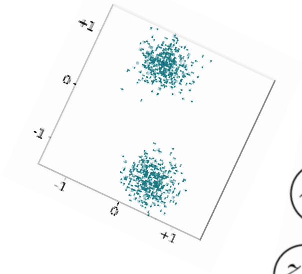

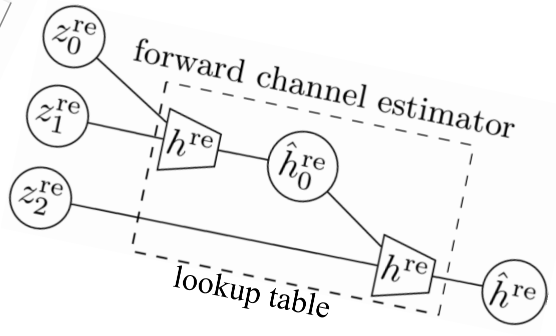

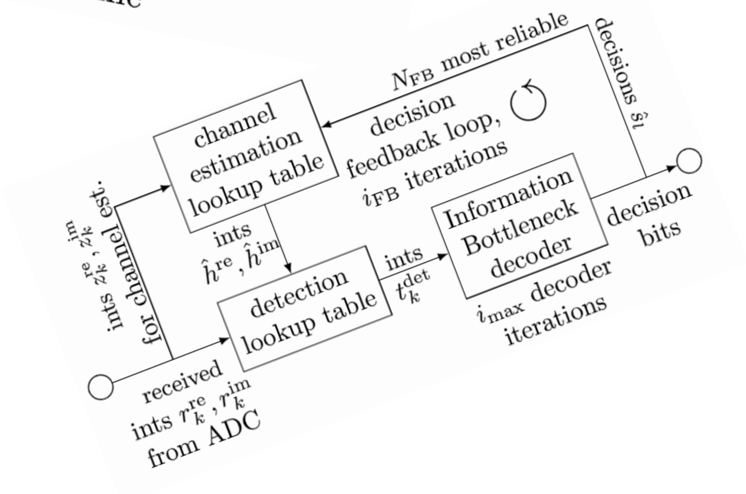

References

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[1] F. J. C. Romero and B. M. Kurkoski, “LDPC decoding mappings that maximize mutual information,” IEEE Journal on Selected Areas in Communications, vol. 34, no. 9, pp. 2391–2401, Sep. 2016.

[2] M. Meidlinger and G. Matz, “On irregular LDPC codes with quantized message passing,” in IEEE 18th International Workshop on Signal Processing Advances in Communications (SPAWC), Sapporo, Japan, Jul. 2017, pp. 1–5.

[3] R. Ghanaatian, A. Balatsoukas-Stimming, T. C. Müller, M. Meidlinger, G. Matz, A. Teman, and A. Burg, “A 588-gb/s LDPC decoder based on finite-alphabet message passing,” IEEE Transactions on Very Large Scale Integration (VLSI) Systems, vol. 26, no. 2, pp. 329–340, Feb. 2018.

[4] J. Lewandowsky and G. Bauch, “Information-optimum LDPC decoders based on the information bottleneck method,” IEEE Access, vol. 6, pp. 4054–4071, Jan. 2018.

[5] J. Lewandowsky, M. Stark, and G. Bauch, “Information bottleneck graphs for receiver design,” in IEEE International Symposium on Information Theory, 2016. (ISIT), Barcelona, Spain, Jul. 2016, pp. 2888–2892.

[6] N. Tishby, F. C. Pereira, and W. Bialek, “The information bottleneck method,” in Proceedings 37th Allerton Conference on Communication and Computation, Monticello, VA, USA, 1999, pp. 368–377.

[7] J. A. Zhang and B. M. Kurkoski, “Low-complexity quantization of discrete memoryless channels,” in International Symposium on Information Theory and Its Applications (ISITA), Monterey, CA, USA, Nov. 2016, pp. 448–452.

[8] A. Genz, “Numerical computation of multivariate normal probabilities,” Journal of Computational and Graphical Statistics, vol. 1, no. 2, pp.141–149, 1992.

[9] M. C. Valenti and B. D. Woerner, “Iterative channel estimation and decoding of pilot symbol assisted turbo codes over flat-fading channels,”IEEE Journal on Selected Areas in Communications, vol. 19, no. 9, pp. 1697–1705, Sep. 2001.

References

[10] S. Park, B. Shim, and J. W. Choi, "Iterative channel estimation using virtual pilot signals for MIMO-OFDM systems," IEEE Transactions on Signal Processing, vol. 63, no. 12, pp. 3032–3045, Jun. 2015.

[11] Z. Zhang, L. Dolecek, M. Mainwright, V. Anantharam, and B. Nikoli, "Quantization effects in low-density parity-check decoders," in IEEE International Conference on Communications (ICC), Glasgow, UK, Jun. 2007, pp. 6231–6237.