Performance evaluation of a faster-than-Nyquist system based on turbo equalization and LDPC codes

Albert Abelló[1,2]

Damien Roque[2], Jean-Marie Freixe[1] and Sébastien Mallier[3]

[1]Eutelsat S.A.

[2]ISAE-SUPAERO
Univ. Toulouse

[3]Direction Générale de l'Armement

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Plan

1. Scarce radio spectrum ressources?
2. Improving spectral efficiency with faster-than-Nyquist (FTN)
3. Reaching the gap between complexity and performance
4. Towards practical implementations

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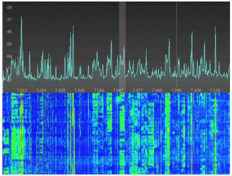
Challenges in wireless communications

High level trade-off in digital communications

- Transmitted power
- Error probability P_e
- **Bit rate** R_b
- **Bandwidth** B
- Decoding complexity



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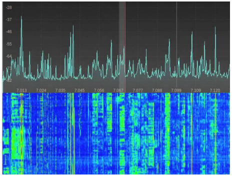

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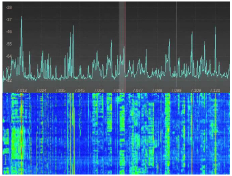

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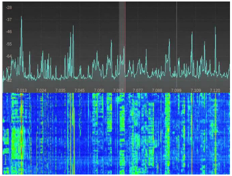

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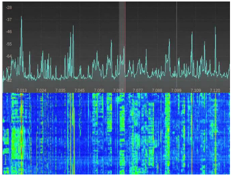

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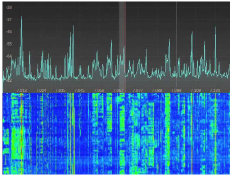

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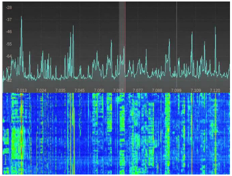

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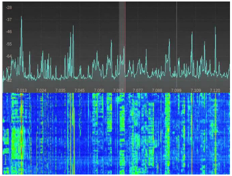

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- Increase of constellation size $M \uparrow \rightarrow \downarrow d_{sym} \rightarrow \uparrow P_e$
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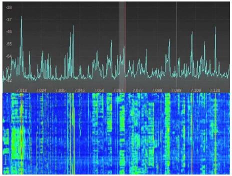

How to increase spectral efficiency at constant bandwidth?

- Increase of constellation size $M \uparrow \rightarrow \downarrow d_{sym} \rightarrow \uparrow P_e$
- Decrease of symbol spacing $T_s \downarrow \rightarrow$ introduction of interference that can be modeled

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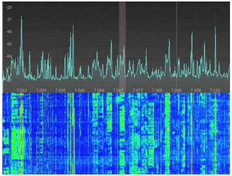

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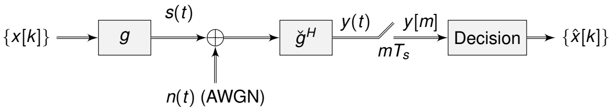
- Decrease of symbol spacing $T_s \downarrow \rightarrow$ introduction of interference that can be modeled and removed with a more complex receiver.

Modelling interference



$$s(t) = \sum_{k=-\infty}^{+\infty} x[k]\, g(t - kT_s), \quad x[k] \in \boldsymbol{A}, \quad |\boldsymbol{A}| = M \tag{1}$$

Noiseless discrete equivalent channel

- $h[l] = (g * \check{g}^H)(lT_s), \quad l \in [0, \ldots, L-1]$

Interference characterization [3]

- If $\frac{1}{T_s} \leq B$, the system can achieve $h[l] = \delta_{0,l}$ (Nyquist)
- If $\frac{1}{T_s} > B$, inevitably $h[l] \neq \delta_{0,l}$ (Mazo) [2]

Faster-than-Nyquist system

Introduction of non-linear processing: turbo equalization

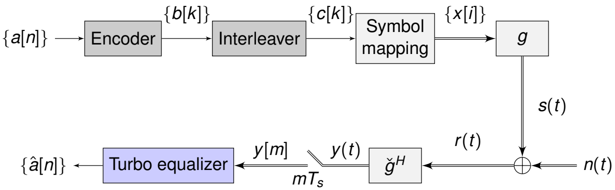


Figure: Block diagram of the faster-than-Nyquist system [4]

Turbo equalizer structure

Turbo equalization [5]: iterative exchange [1] between two blocks

- Equalizer: two approaches considering $h[l], \quad l \in \{0, \ldots, L-1\}$
  - Minimum Mean Square Error (MMSE) (complexity in $\mathcal{O}(ML)$)
  - *Maximum a Posteriori* (MAP) (complexity in $\mathcal{O}(M^L)$)
- Decoder: we use LDPC codes from DVB-S2 standard

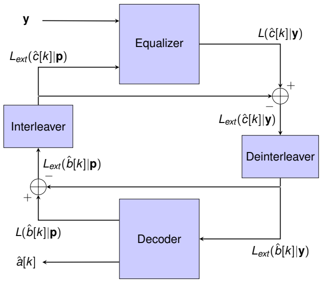


Figure: Turbo equalizer

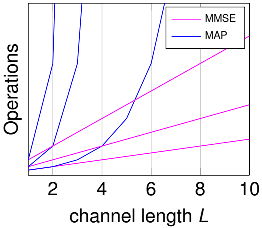


Figure: Equalizer's complexity for $M = 2, 4, 8$

Performance and complexity

Contribution

- Evaluation of MAP performance with short-length channel response models (truncated channels)
- Comparison between truncated (length L') MAP equalization and (length L) MMSE equalization

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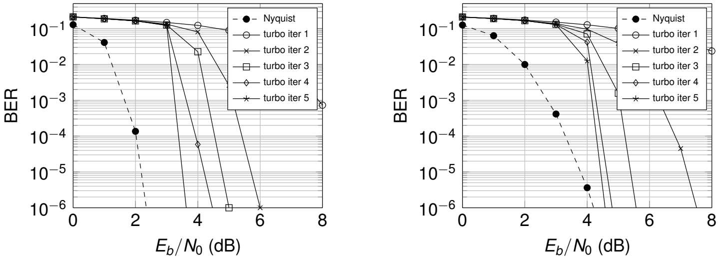
Can MAP outperform MMSE while keeping reasonable complexity?

Consider a truncated channel of length $L' < L$ such that

$$\sum_{m=0}^{L'-1} |h[m]|^2 \leq \beta, \quad \beta \in [0; 1[. \tag{2}$$

FTN MMSE-LDPC performance

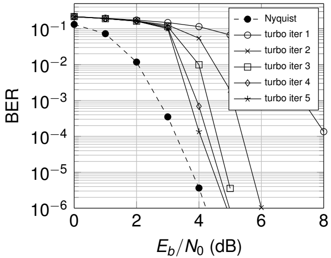


(a) 10 LDPC iterations

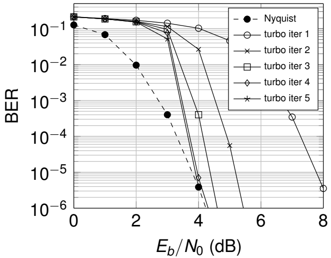
(b) 5 LDPC iterations

Figure: FTN MMSE-LDPC performance with $L = 9$, $\frac{1}{T_s B} = 1.4$

FTN MAP-LDPC performance



(a) 3-coefficient MAP ($L' = 3$)



(b) 5-coefficient MAP ($L' = 5$)

Figure: FTN MAP-LDPC performance with $\frac{1}{T_s B} = 1.4$

Summary

What do we achieve with faster-than-Nyquist?

1. Spectral efficiency gain in wireless communications systems;
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1. Spectral efficiency gain in wireless communications systems;
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What are the main challenges?

1. Trade-off between complexity and performance;
2. Real-time implementation: study on synchronization needed.

Summary

Thank you for your attention

Do you have any questions?

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