Performance Analysis of Fractionally Spaced Equalization in Non-linear Multicarrier Satellite Channels

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Presentation Overview

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1. Scenario
2. Channel impairments and System Constraints
3. System Architecture
4. Fractionally Spaced Equalization
5. Optimized Receiver De-mapping
6. Simulations
7. Conclusions
8. Acknowledgments

Outline

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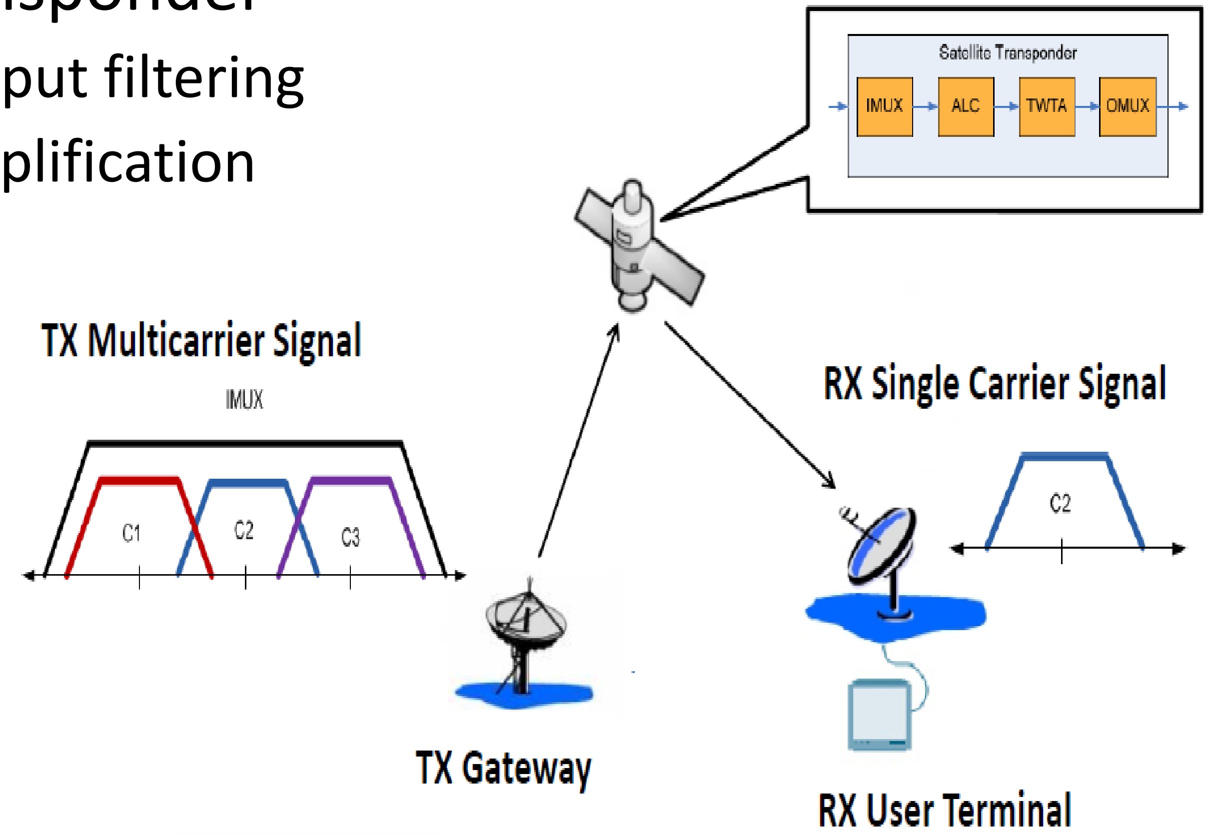
Scenario

- Multicarrier gateway uplink
- Multicarrier transponder
  - Joint input /output filtering
  - Joint power amplification

- Advantages:
  - HW saving
  - Weight saving
  - Flexibility



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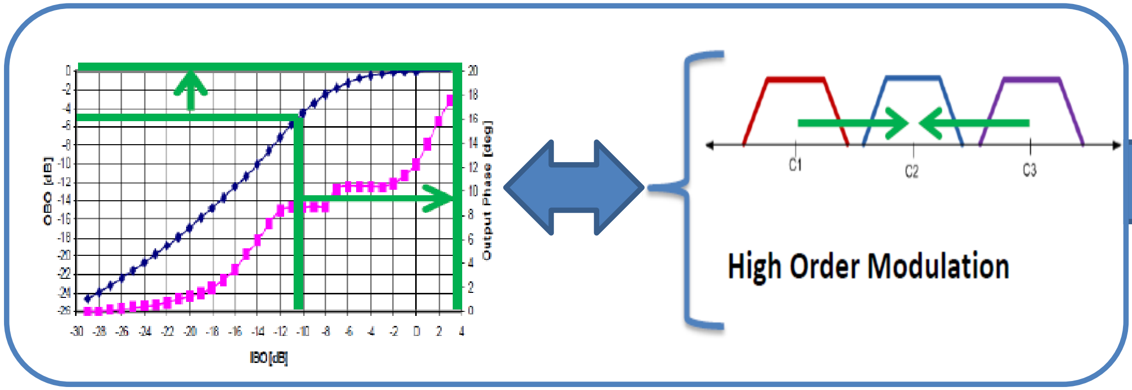
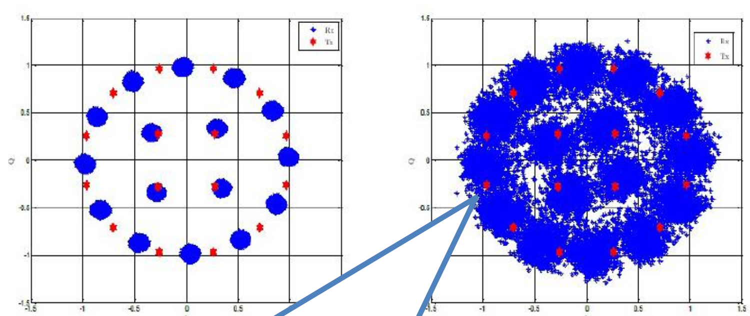
Channel Impairments and System Constraints

- Power & Spectral Efficiency Trade off



- System Contraints:
  - No On-board Signal Processing
  - Low complexity User Terminals



INTERMODULATION PRODUCTS

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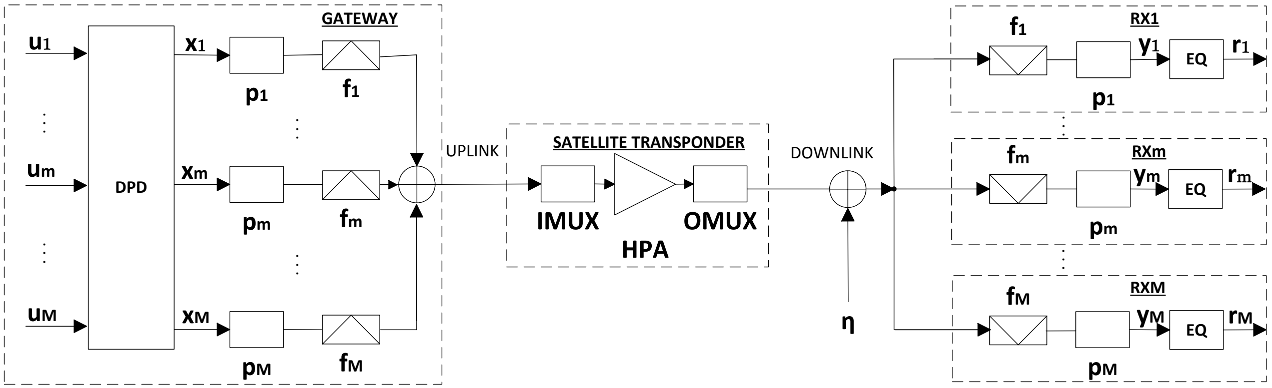
System Architecture

- Countermeasures Techniques:
  1. Multicarrier Predistortion at the gateway [1]
  2. Advanced Receiver Processing:
     1. Fractionally Spaced Equalization
     2. Optimized de-mapping at the user terminals (UT)



[1]R. Piazza, E. Zenteno, and e. al, *"Multicarrier digital predistortion/equalization techniques for non-linear satellite channels,"in Proc. 30th AIAA Intern.Commun. Satellite Syst. Conference (ICSSC*), Ottawa, Canada, Sep. *2012*.

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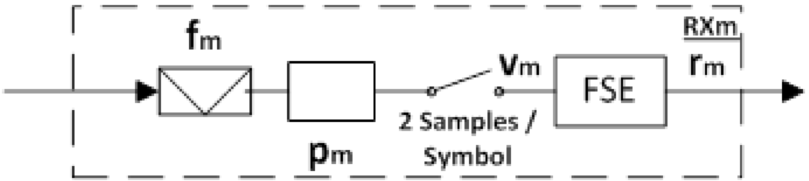
Fractionally Spaced Equalization

- Receiver equalization that exploits higher sampling rate [2]:
  - K>1 samples per symbol
- It aims to compensate for:
  - Non-constant group delay of the channel
  - Residual Linear and non-linear distortions
  - Non-optimal receiver sampling

[2]R. D. Gitlin, S. B. Weinstein, "Fractionally Spaced Equalization: An Improved Digital Transversal Equalizer," *Bell Systems Technical Journal*, 60:2, February 1981, available online http://archive.org/details/bstj60-2-275.

FSE Architecture

- FSE as Linear Filtering:
  - $\mathrm{r_m(n)} = \sum_{\mathrm{k_1}} \mathrm{b_m(k_1)}\, v_m\mathrm{(n - k_1)} = \boldsymbol{b}_m \boldsymbol{v}_m(n)$



- Parameters Estimation:
  - $\boldsymbol{b}_m = \mathrm{argmin}_{\mathrm{b_m}} \{\sum_{n=1}^{N} E[\, r_m(n) - u_m(n)]^2\}$
  - Standard Least Squares Solution
  - Adaptive and based on pilots

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Non-linear Bias in the RX symbols

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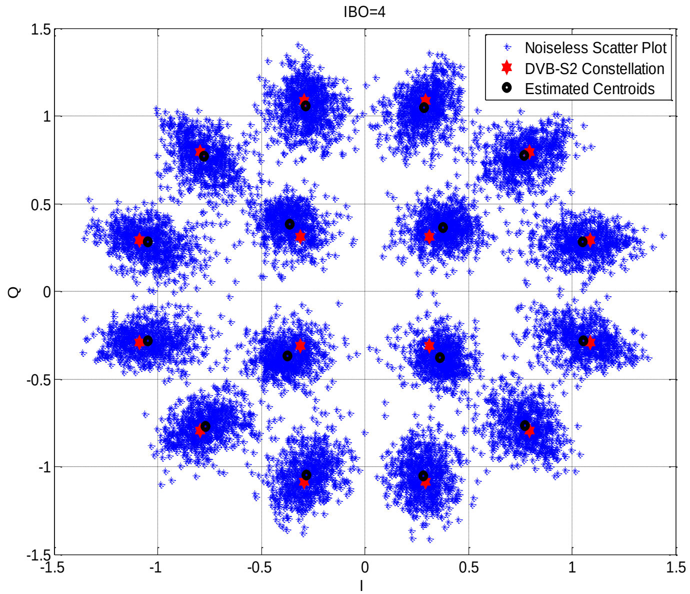
- Equalized symbols shows some residual non-linear bias w.r.t. to the reference constellation



- This bias degrades the bit error rate (BER) performance
  - Need to determine more accurate reference constellation for decoding

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Average and Centroids based De-mapping

- For linear systems average constellation de-mapping (ACD) suffices:
  - One scaling factor : $\beta = arg\min_{c} \frac{\sum_{k=1}^{M} \sum_{x \in \mathcal{F}_k} |x-c|^2}{\sum_{k=1}^{M} |a_k|^2}$
- For a general non-linear system we need one-to one re-mapping (CBD):
  - For each constellation point k:
    - Centroid $c_k = arg\min_{c} \sum_{x \in \mathcal{F}_k} |x-c|^2, \; k \in [1, M]$
  - Centroids estimation based on pilots

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Figure Of Merit

- Total Degradation:
  - Evaluated at a Target Packet Error Rate
  - Spectral Efficiency & HPA Power efficiency

HPA efficiency loss

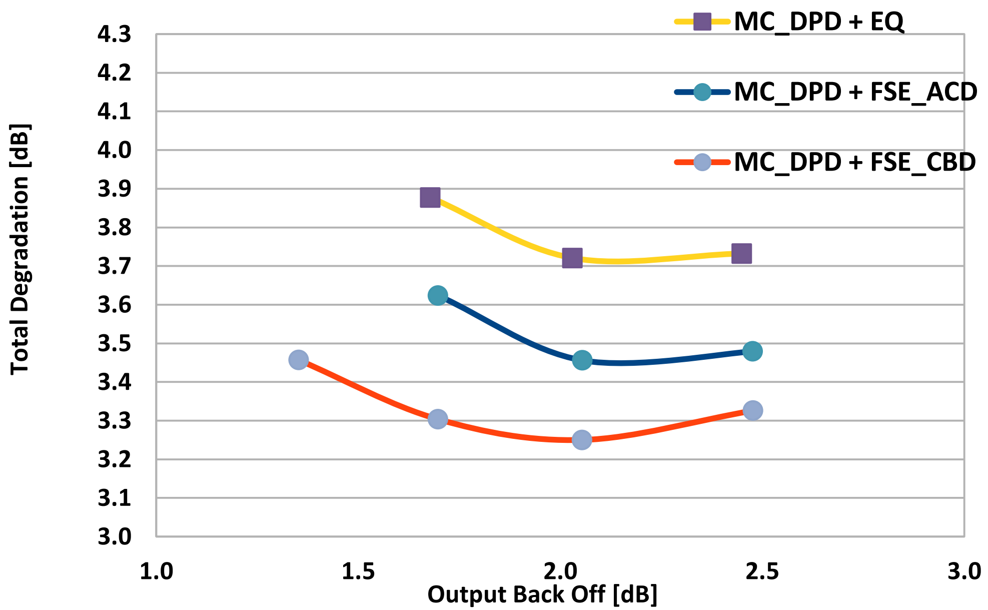
$$\mathrm{TD} = \left.\frac{\mathrm{E_b}}{\mathrm{N_0}}\right|_{\mathrm{NL}} - \left.\frac{\mathrm{E_b}}{\mathrm{N_0}}\right|_{\mathrm{Ideal}} + \mathrm{OBO}.$$

Code loss

where $\mathrm{OBO} = \mathrm{P_{out}}/\mathrm{P_{sat}}\big|_{dB}$

TD Performance Two Carriers Satellite Channel (1)

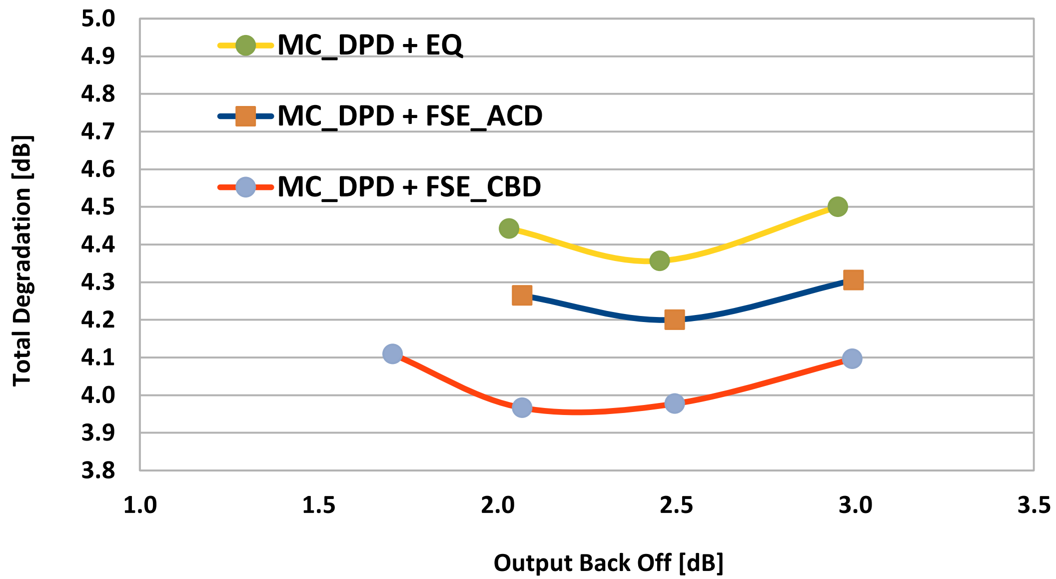
- Setting: 16.36 Mbaud, 16 APSK, Roll-off=0.2, LDPC with Code Rate=3/4, Transp. BW=36MHz



- EQ: Baseline symbols spaced equalization
- FSE with Average Const. Decoding provides 0.2 dB over EQ
- Centroids decoding provides additional 0.15 dB
- Total of 0.3-0.4 dB of gain

TD Performance Two Carriers Satellite Channel (2)

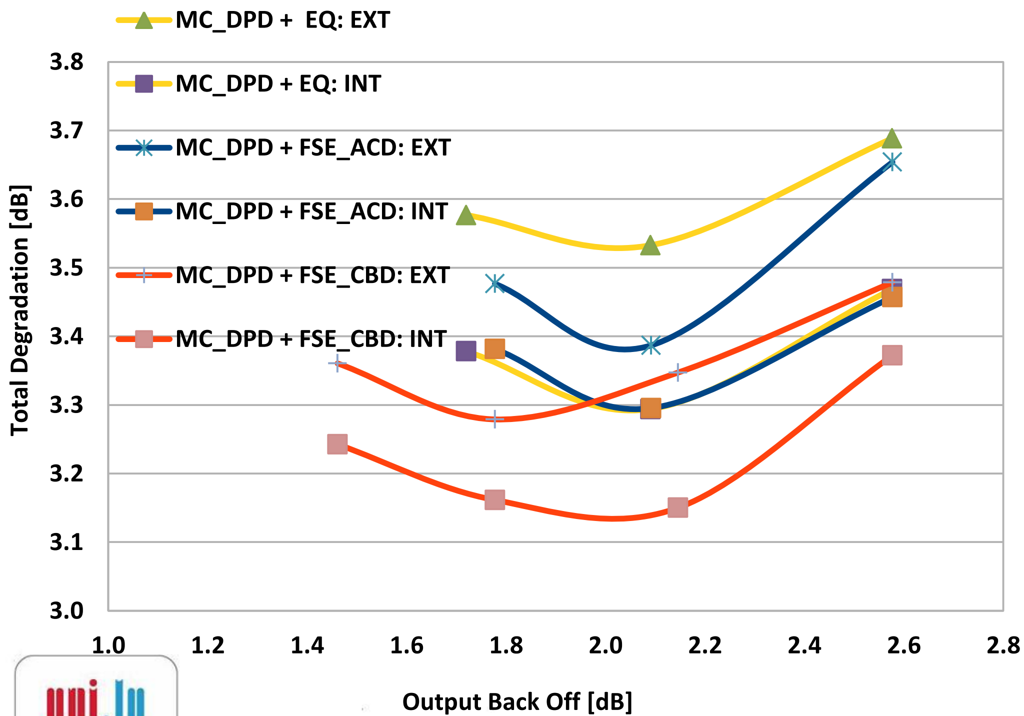
- Setting: 18 Mbaud, 16 APSK, Roll-off=0.2, LDPC with Code Rate=3/4, Transp. BW=36MHz



- Higher baud-rate leads to higher degradation
- FSE with Average Const. Decoding provides 0.15dB over EQ
- Centroids decoding provides additional 0.25 dB
- Total of ~0.4 dB of gain

TD Performance Triple Carriers Satellite Channel (1)

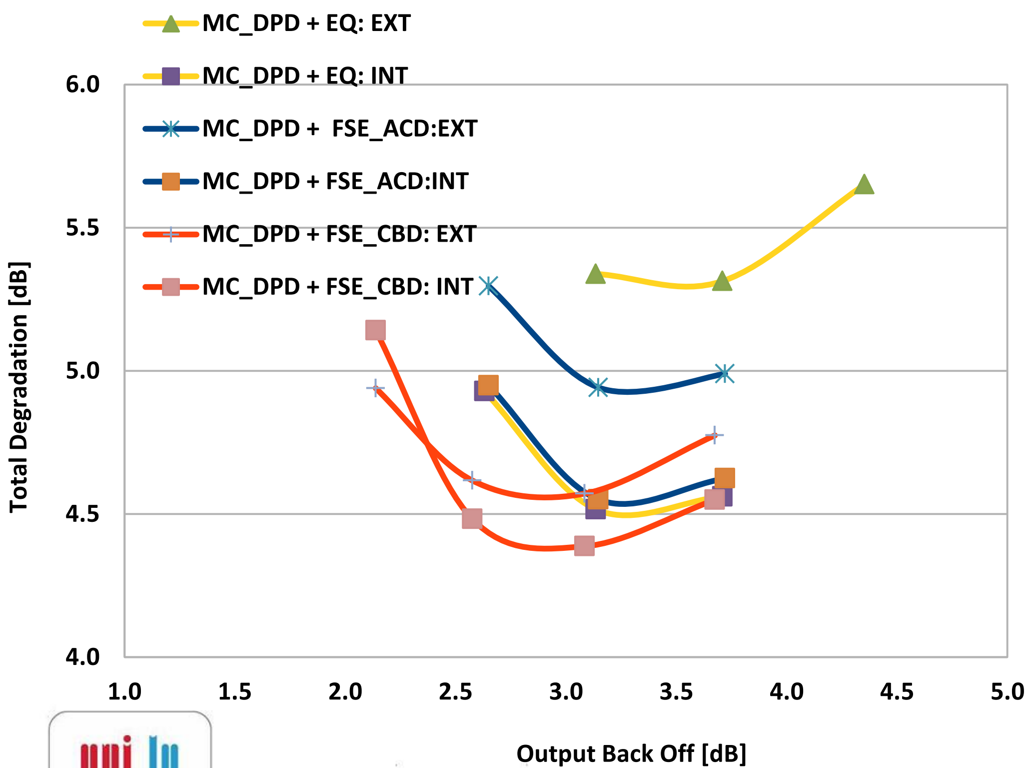
- Setting: 10 Mbaud, 16 APSK, Roll-off=0.2, LDPC with Code Rate=3/4,Transp. BW=36MHz



- External carrier degraded by the MUX filters edge
- FSE with Average Const. Decoding provides up to 0.1dB over EQ
- Centroids decoding provides additional~ 0.15 dB
- Total ~0.2 dB of gain

TD Performance Triple Carriers Satellite Channel (2)

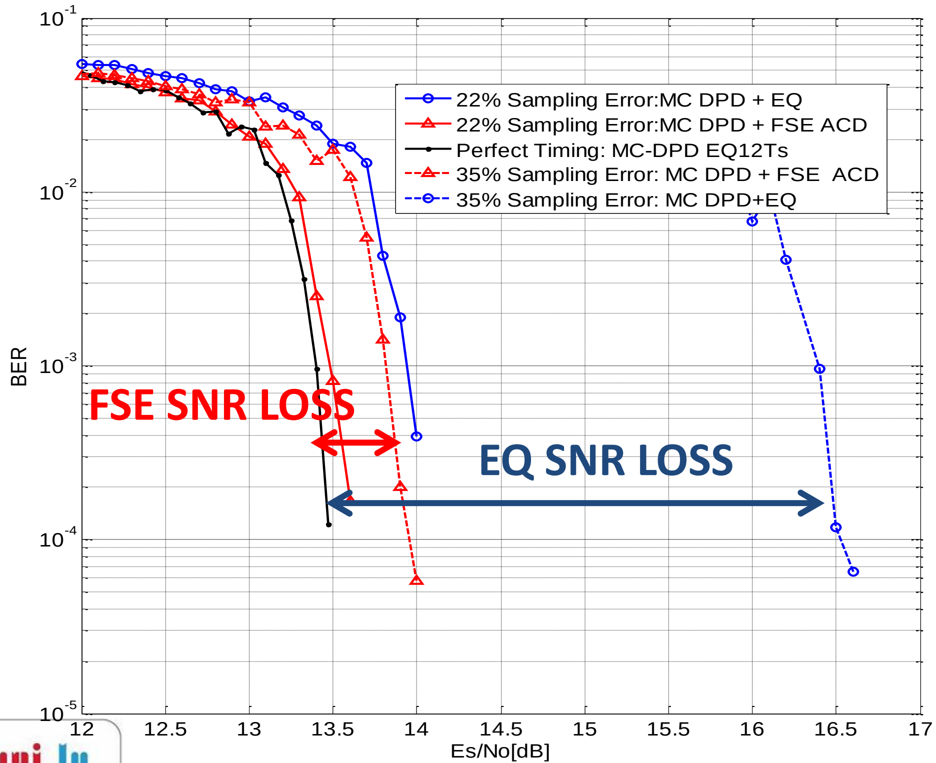
- Setting: 10 Mbaud, 32 APSK, Roll-off=0.2, LDPC with Code Rate=4/5,Transp. BW=36MHz



- Higher Spectral efficiency leads to higher degradation
- FSE with Average Const. Decoding provides up to 0.25 dB to over EQ
- Centroids decoding provides additional~ 0.25 dB
- Total ~0.5 dB of gain

Robustness to Sampling Error: Central carrier of a Three Carrier Channel

- Setting: 16 APSK, Roll Off=0.2, IBO=4 dB, LDPC with Code Rate=3/4,Transp. BW=36MHz



- Standard EQ is very sensitive to sampling
- FSE compensates substantially for the sampling error
  - 22% :perfect recovery
  - 35%: only 0.5 dB of loss

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Conclusion

- UT FSE equalization evaluated for multicarrier satellite channels:
  - Provides about ~0.1/0.2 dB of gain when multicarrier predistortion is applied at the GW
  - Is shown to be robust with respect to sampling accuracy
- Optimized Symbols de-mapping:
  - Provides additional ~0.1-0.3 dB of gain
  - Low complexity

Acknowledgement & Contact

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