SAND2011-7231C
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Power Line Communications (PLC) for μGrid Stability and PHEV Balancing

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The University of Vermont

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Outline

- Objective
- Power Line Communications
- Secure, Scalable μGrid Agent Based Model
- Multipath in the Power Line Channel
- Noise
- Communications with QPSK
- Results
- Discussion

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Objective

- Characterize the PLC channel to determine bandwidth.
- Determine suitability of PLC for use in scalable μGrid.
    - PLC could be used for information transfer among agents
    - ‘Tagging’ of plug-in hybrid electric vehicle (PHEV) charging

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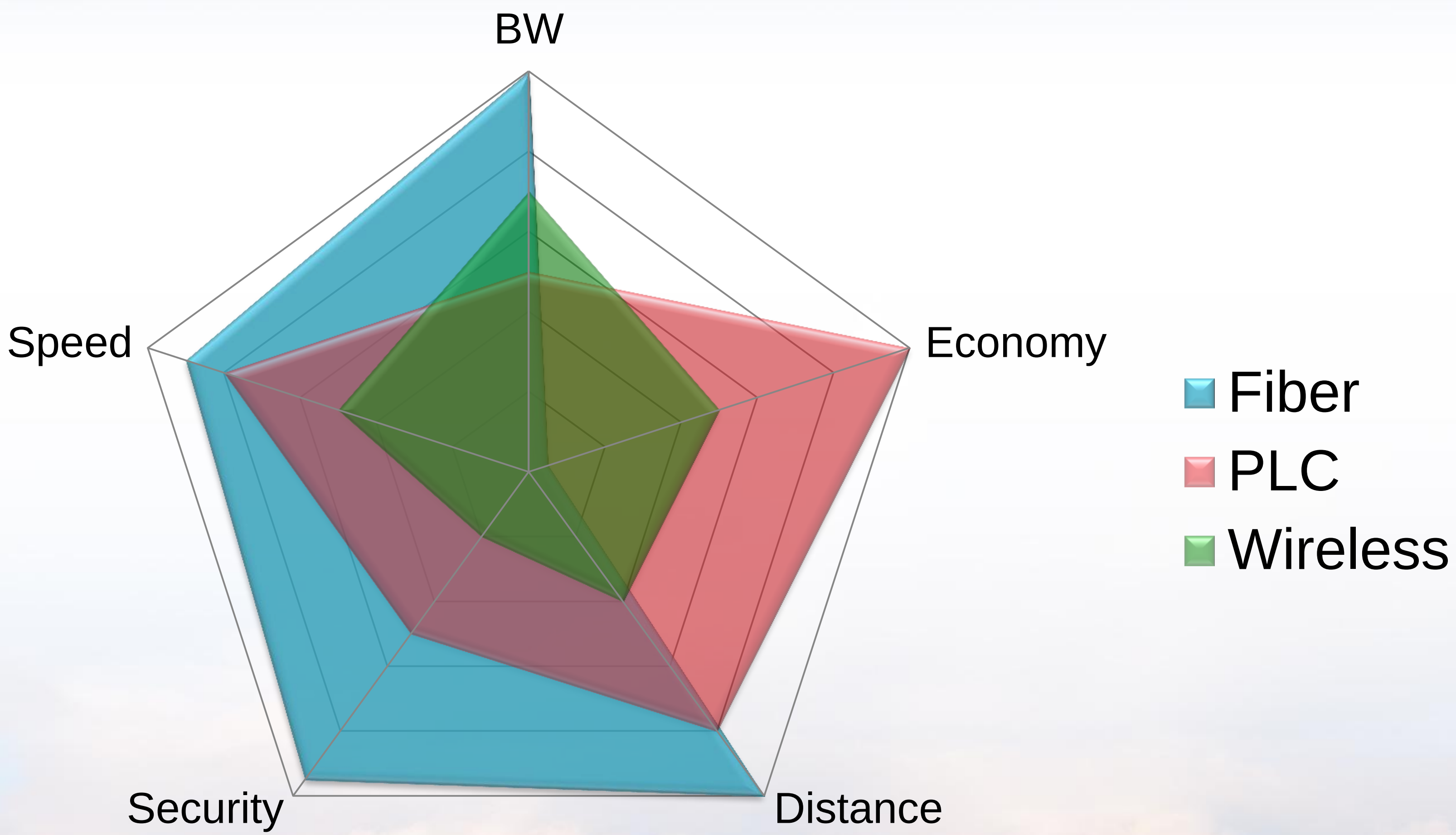
Why PLC?



Commercially Available

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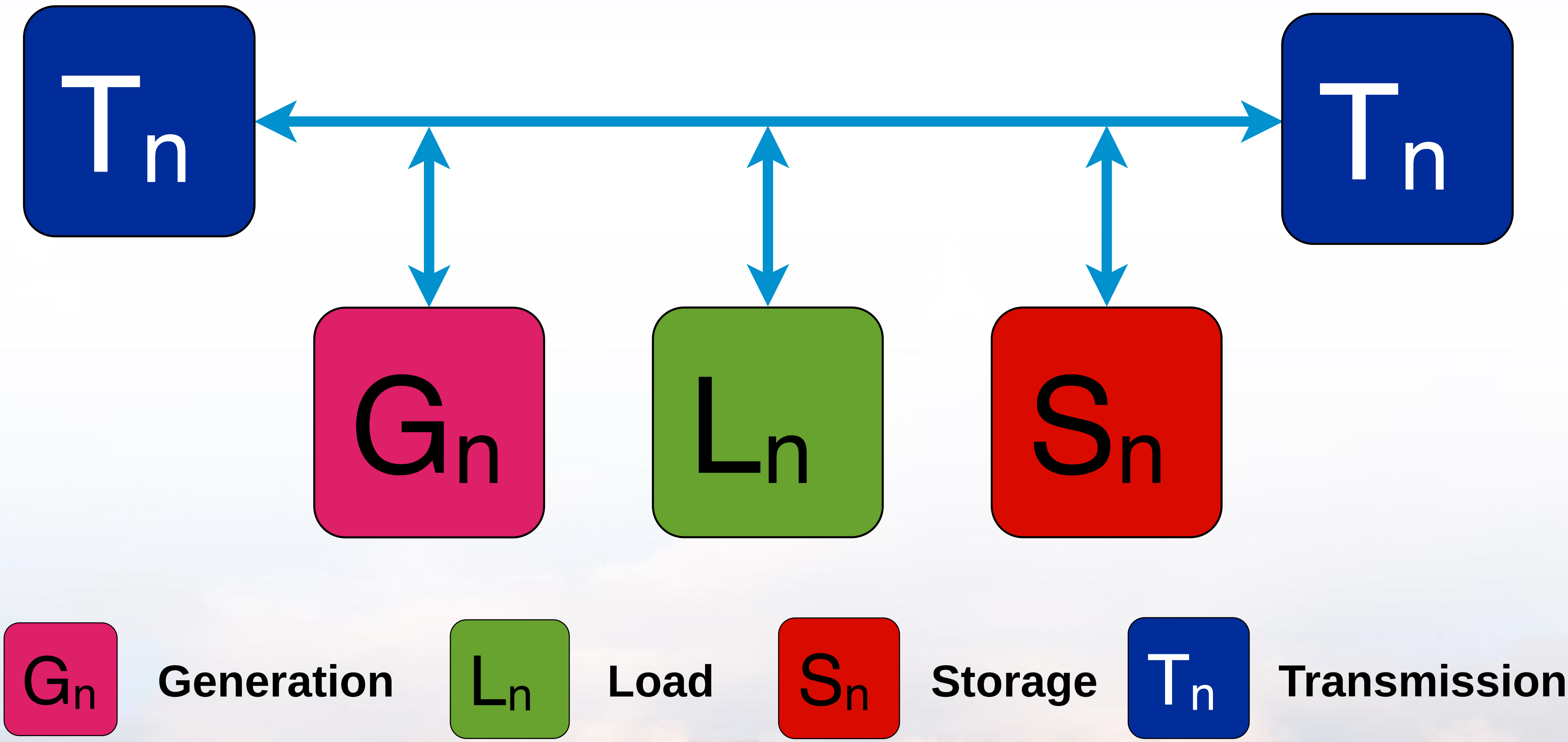
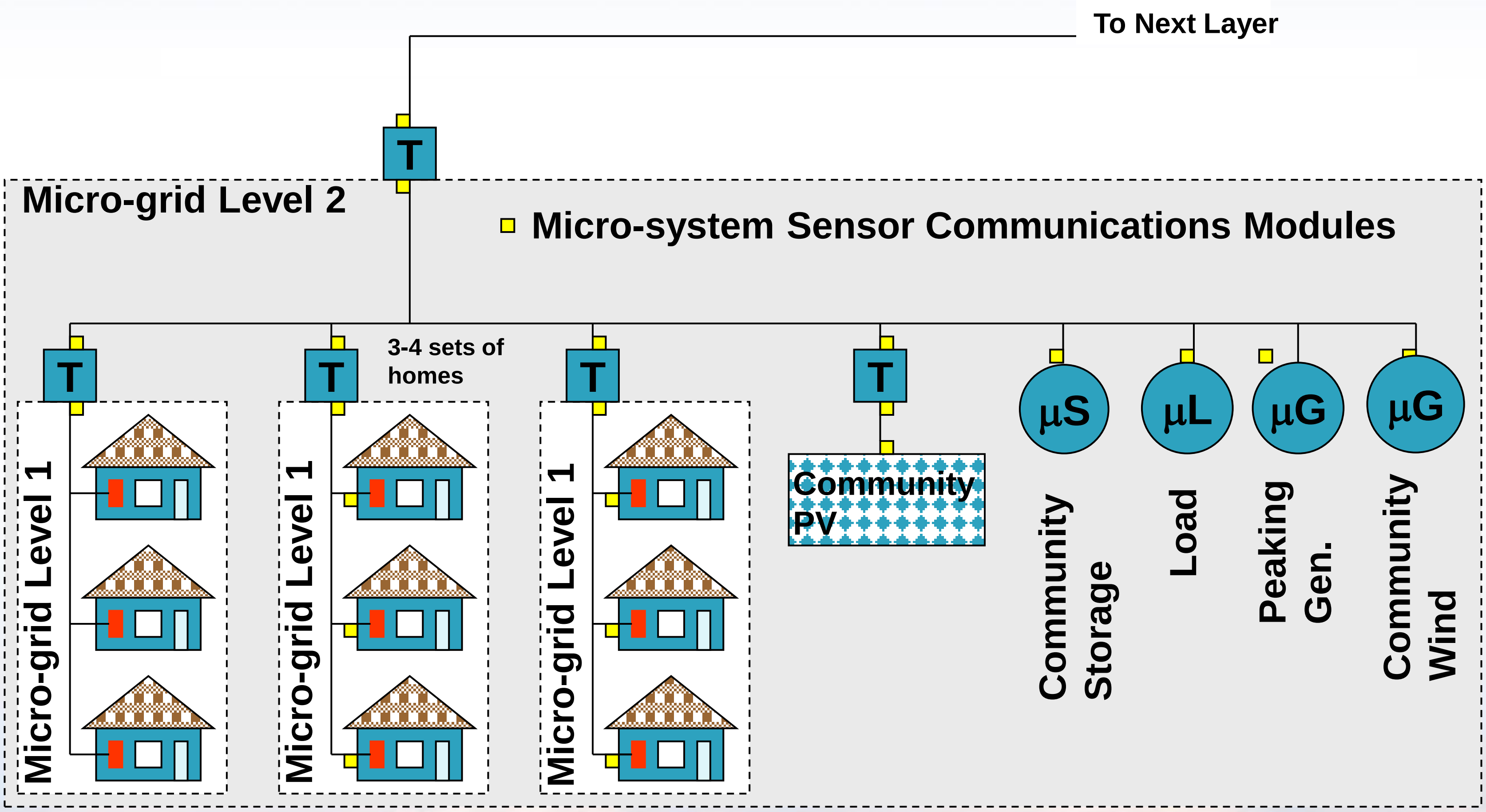
µGrid Multiagent Architecture



S. Y. Goldsmith, 4th international conference on integration of distributed and renewable resources, Albuquerque NM December, 2010

Interconnected μGrid



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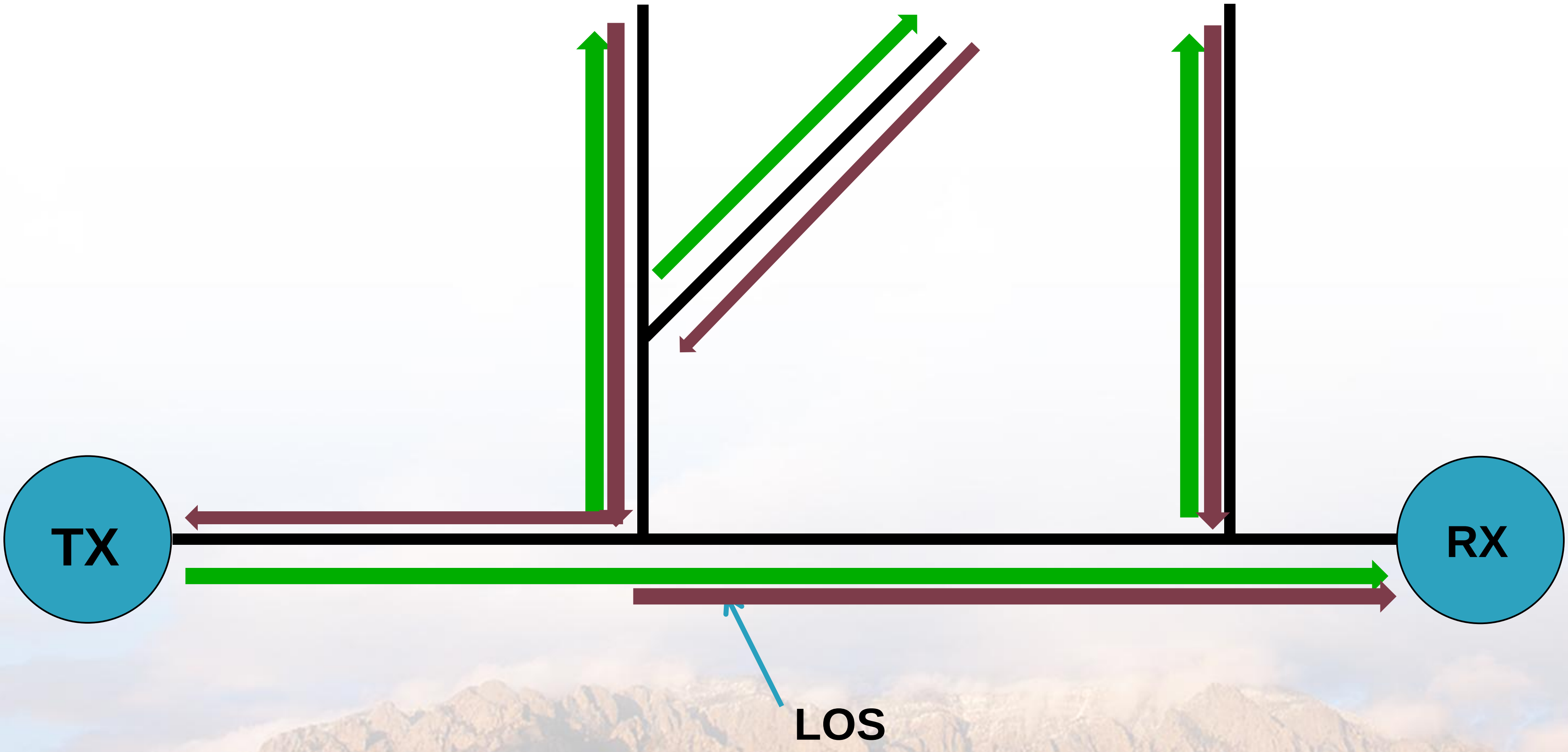
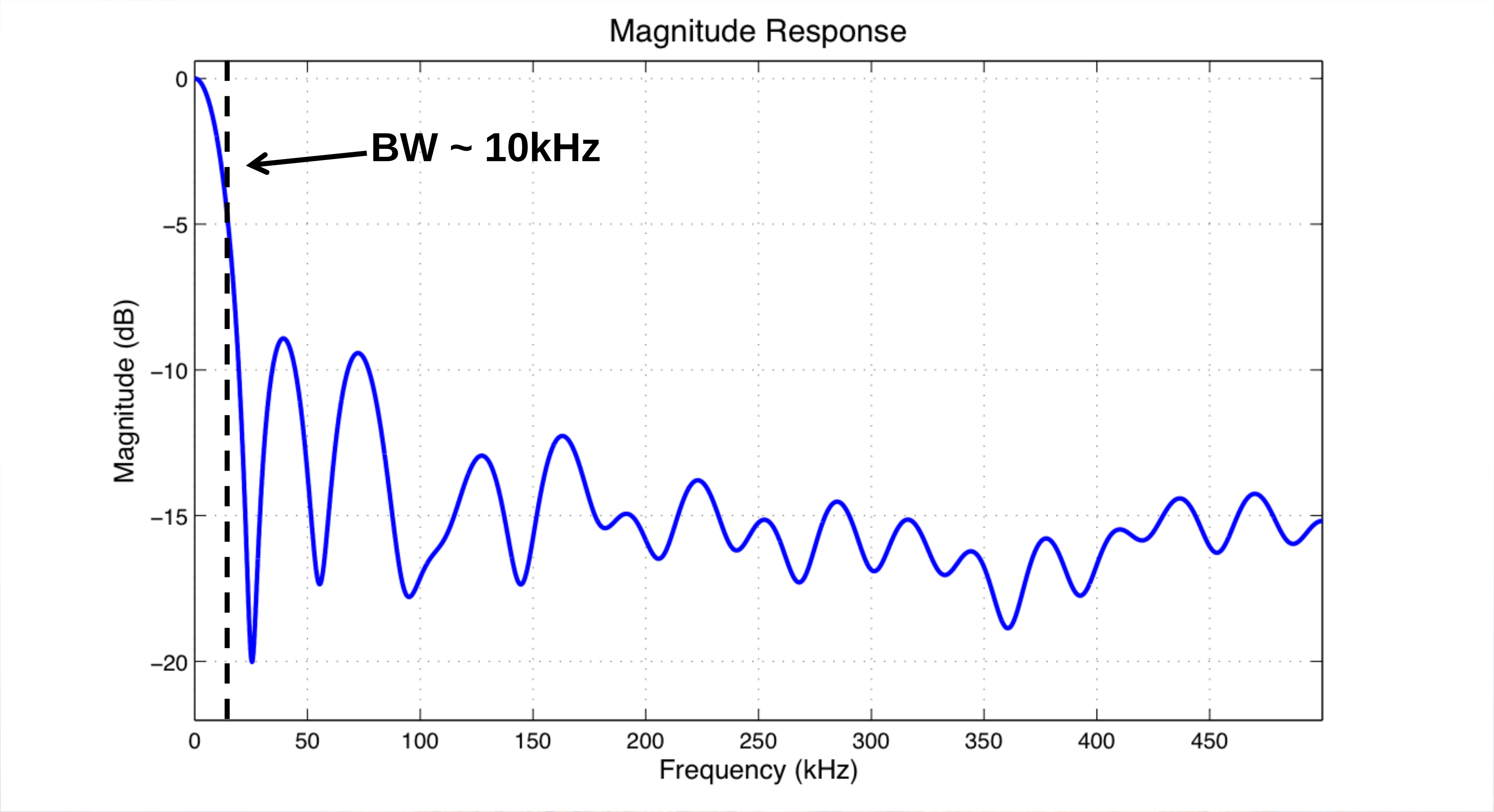
Multipath Source in PLC



Frequency Response



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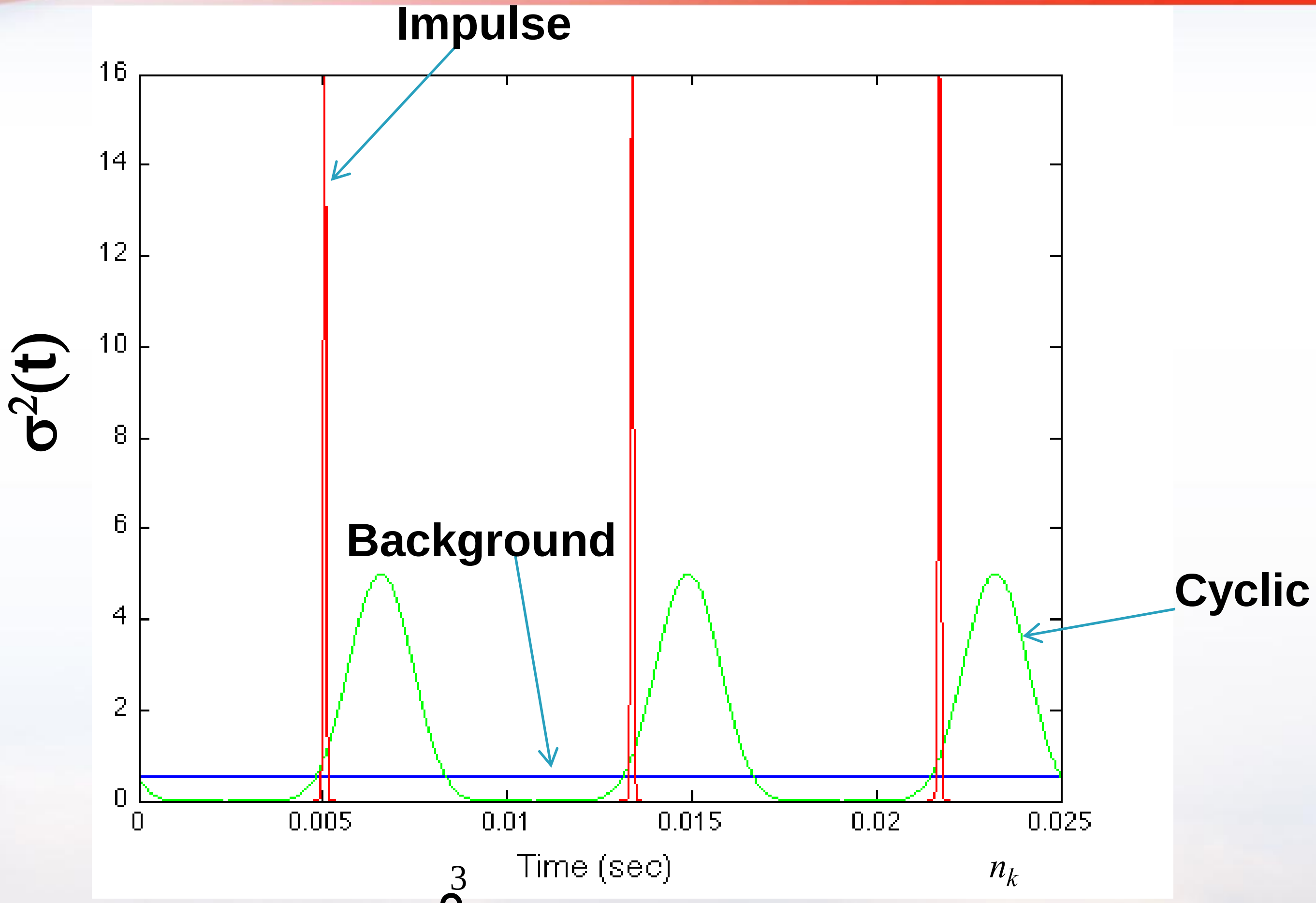
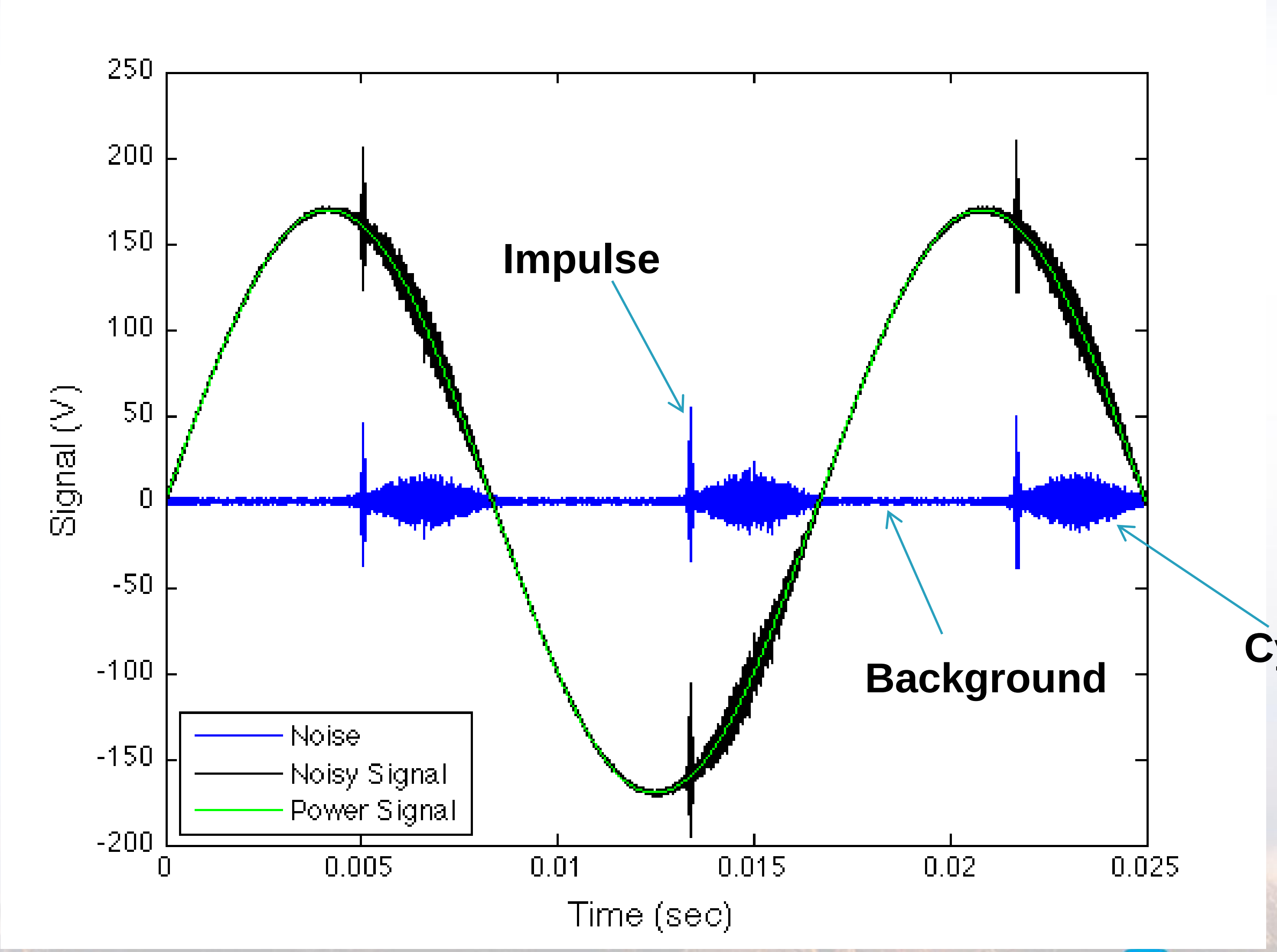
Cyclostationary Noise



$$\sigma^2(t) = \sum_{k=1}^{3} A_k \,|\sin(2\pi F_{AC} t + \theta_k)|$$

M. Katayama , S. Itou , T. Yamazato and A. Ogawa "Modeling of cyclostationary and frequency dependent power-line channels for communications", *Proc. 4th Int. Symp. Power Line Commun. Appl.*, p.123 , 2005.

Noise Manifestation



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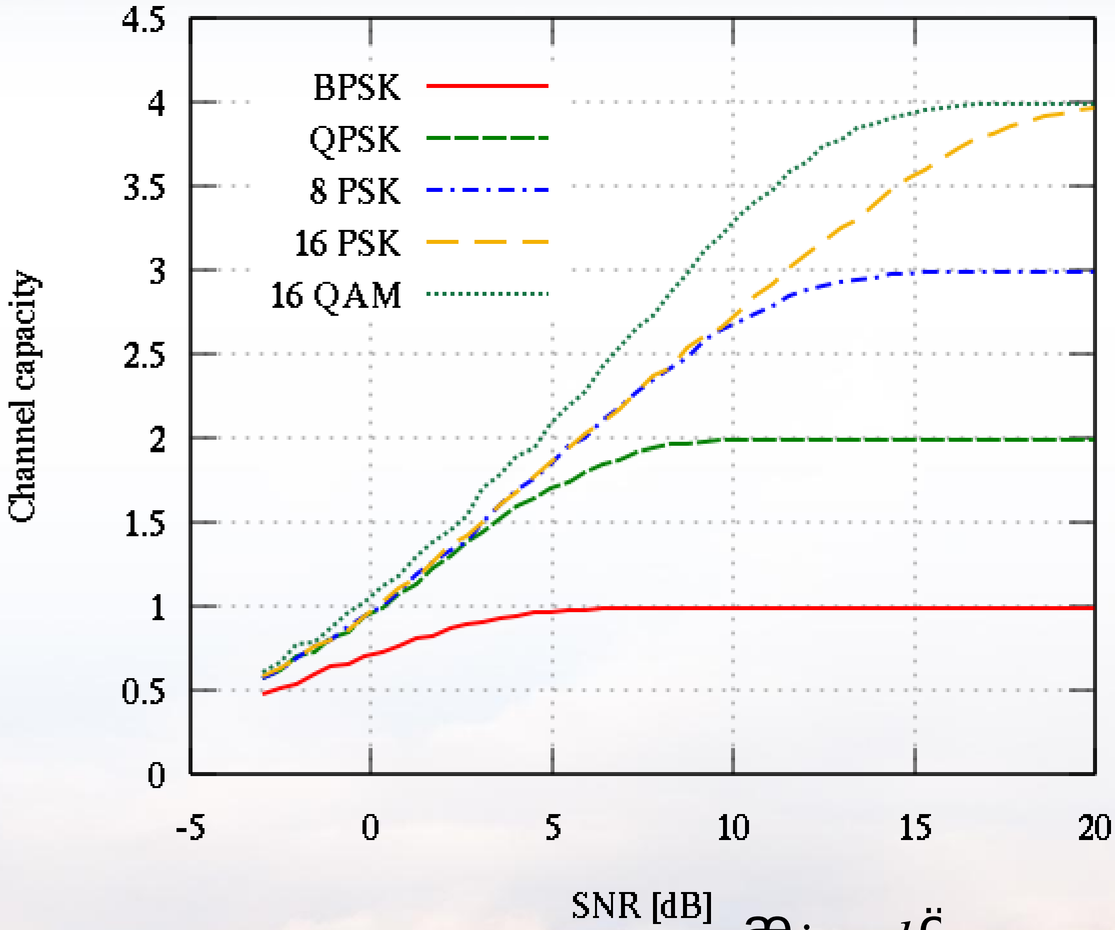
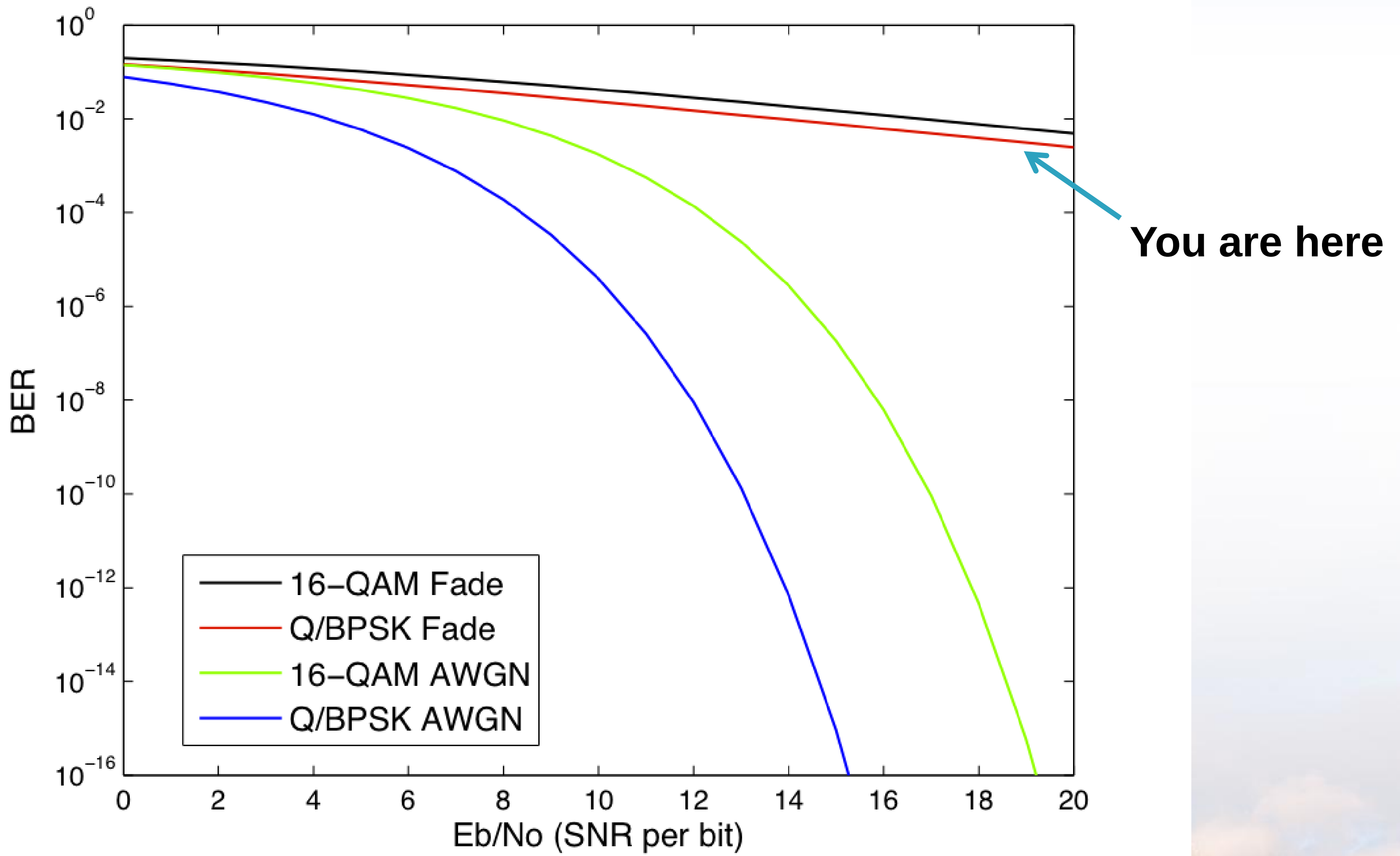
Throughput Performance

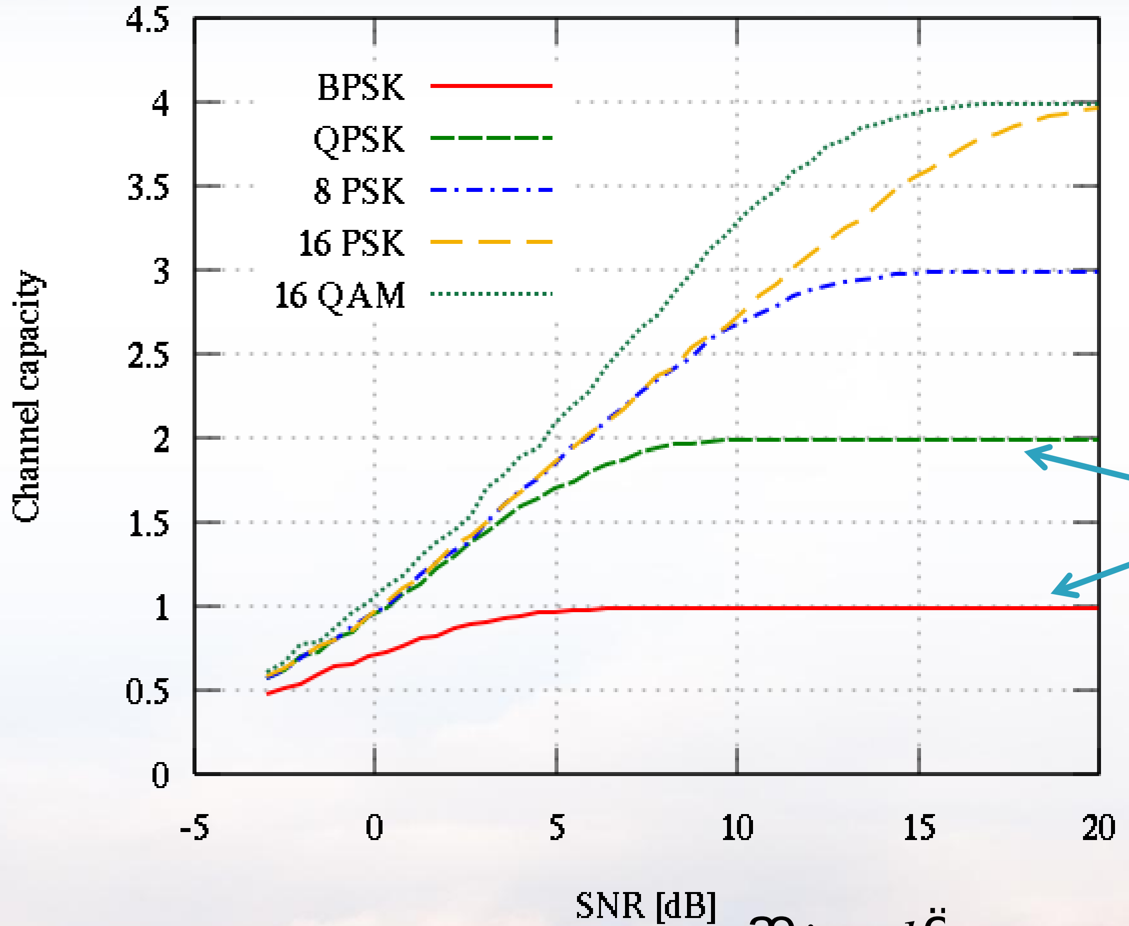


$$SNR_{dB} = 20\log_{10}\left(\frac{signal}{noise}\right)$$

BER Performance



Throughput Performance

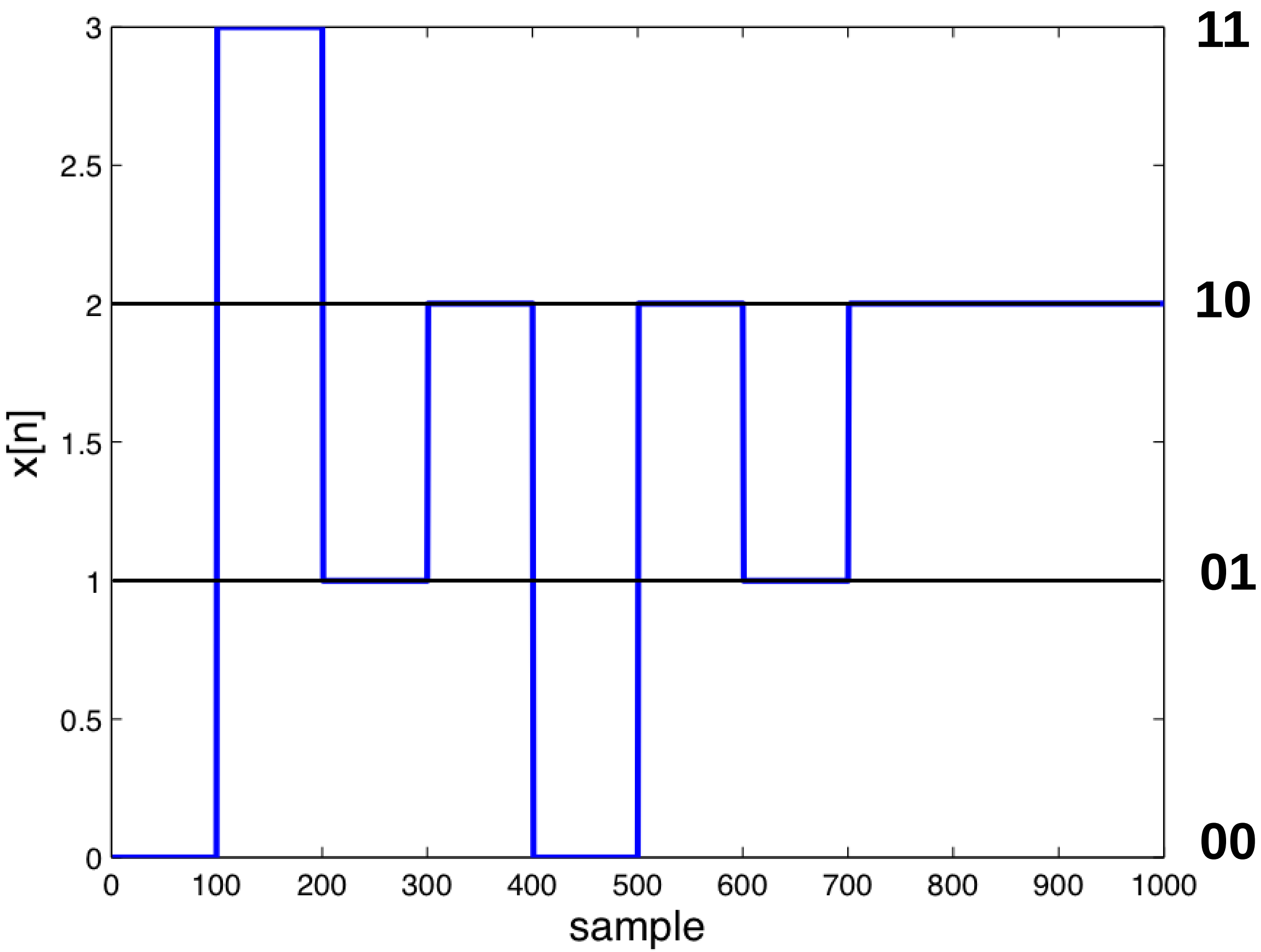


Same BER Performance!

$$SNR_{dB} = 20\log_{10}\left(\frac{signal}{noise}\right)$$

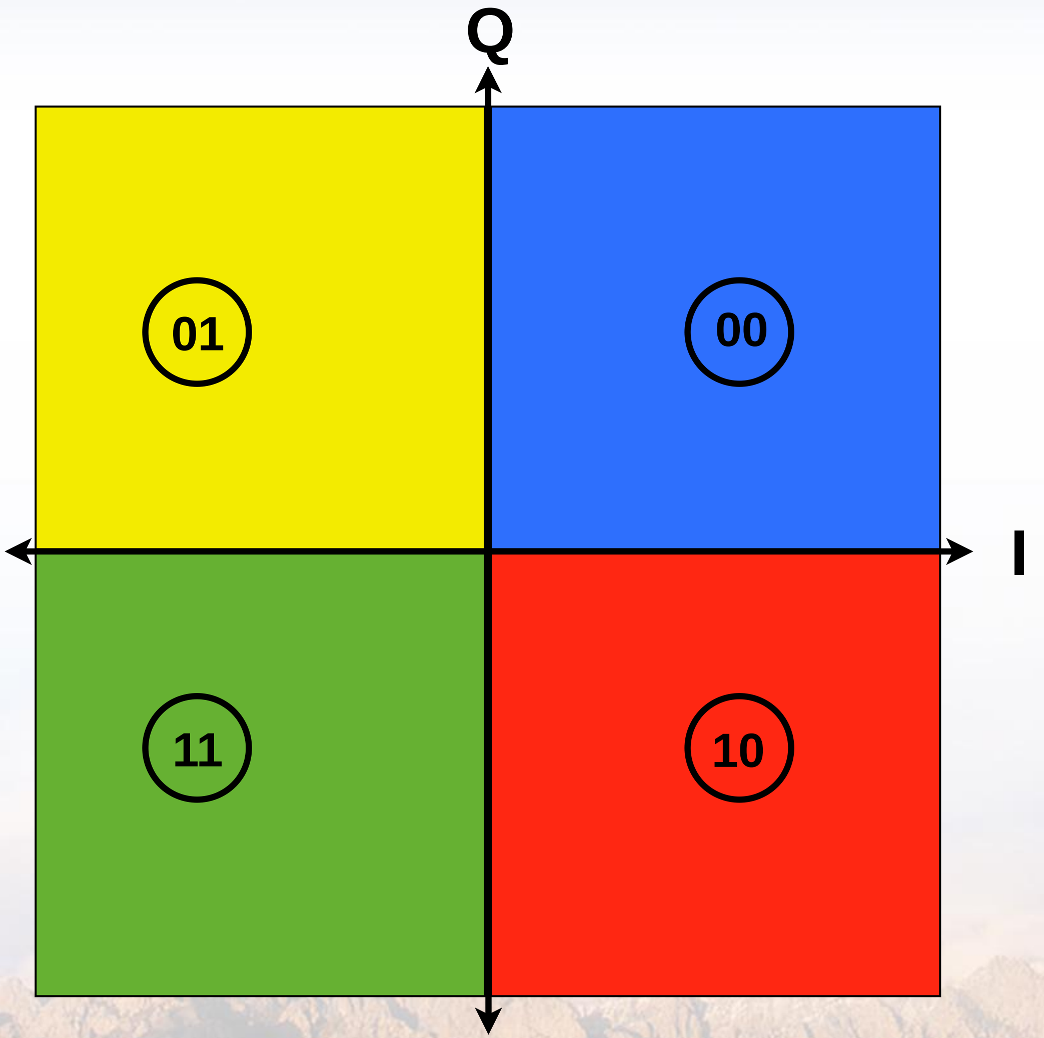
http://en.wikipedia.org/wiki/File:Channel_capacity_for_complex_constellations.svg

Bit Stream



3
2.5
2
1.5
1
0.5
0
x[n]
0
100
200
300
400
500
600
700
800
900
1000
sample
11
10
01
00

QPSK Constellation



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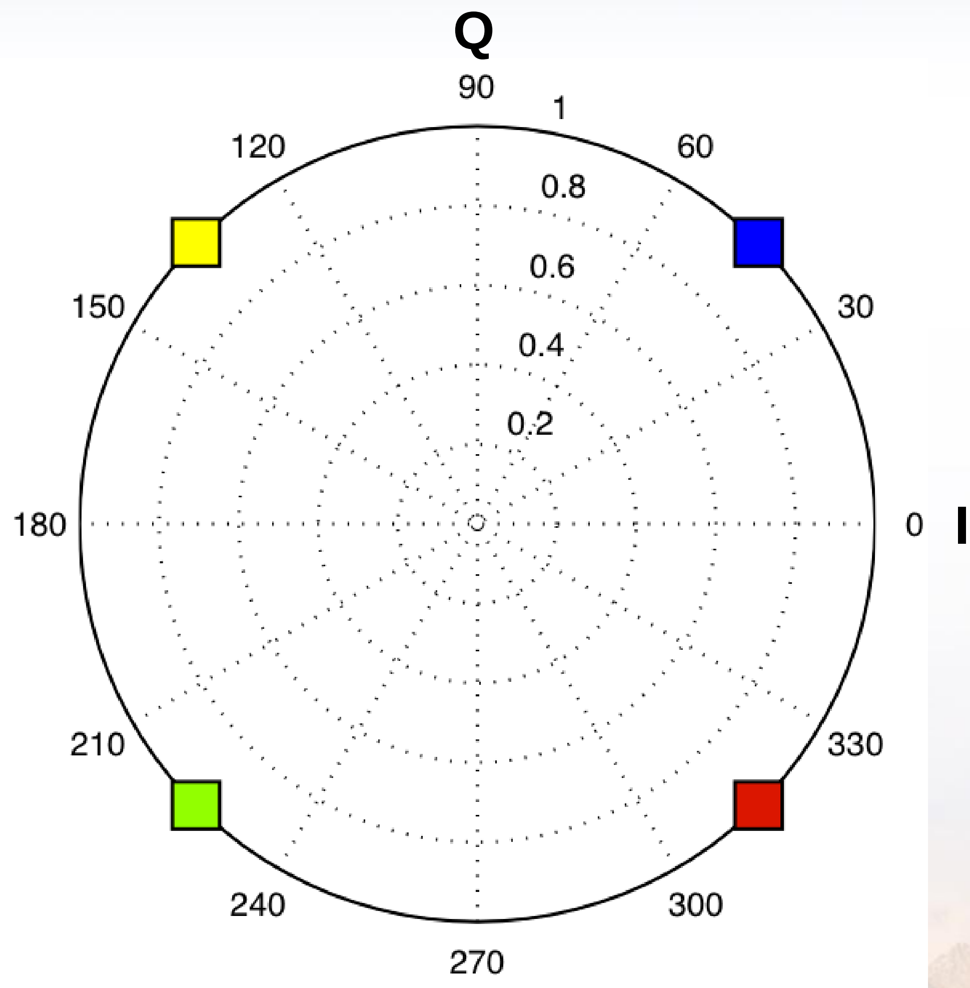
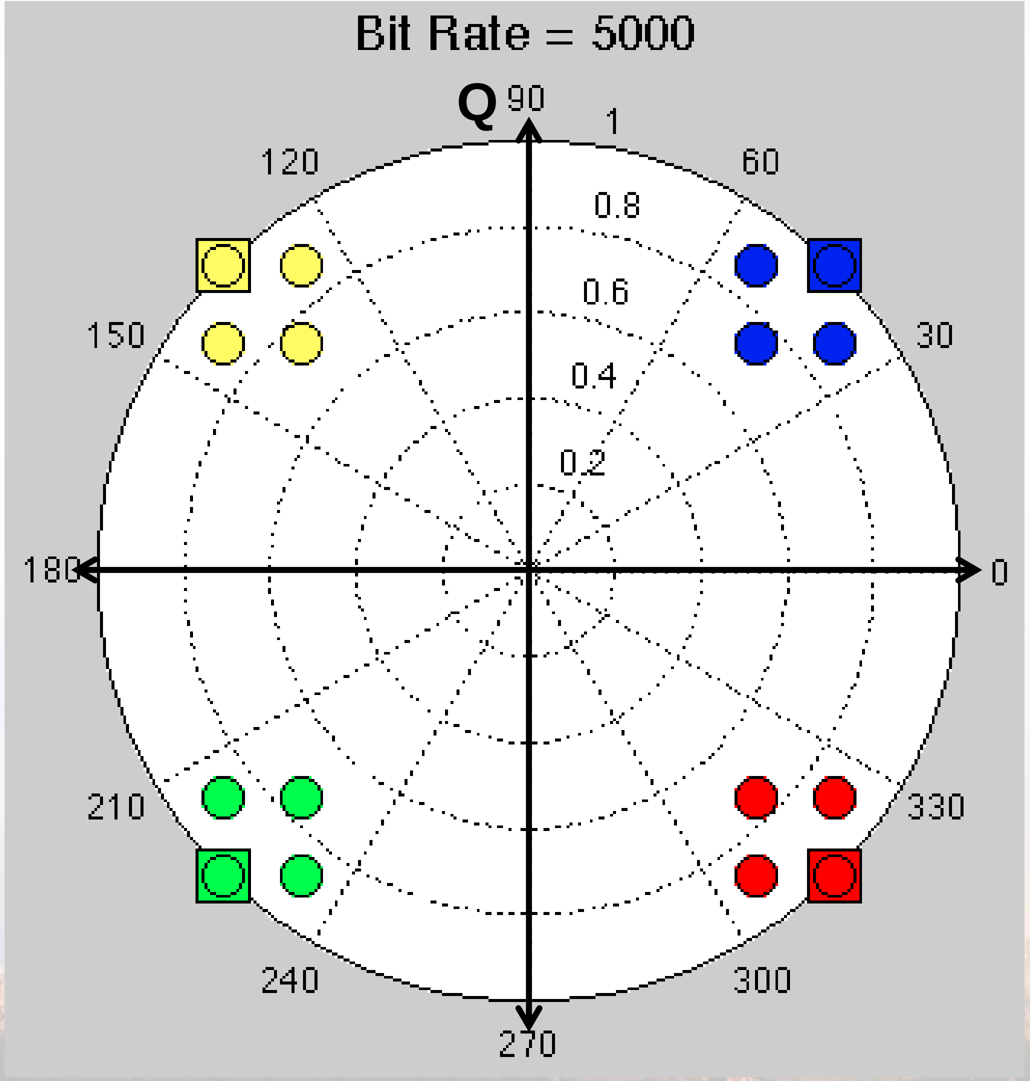
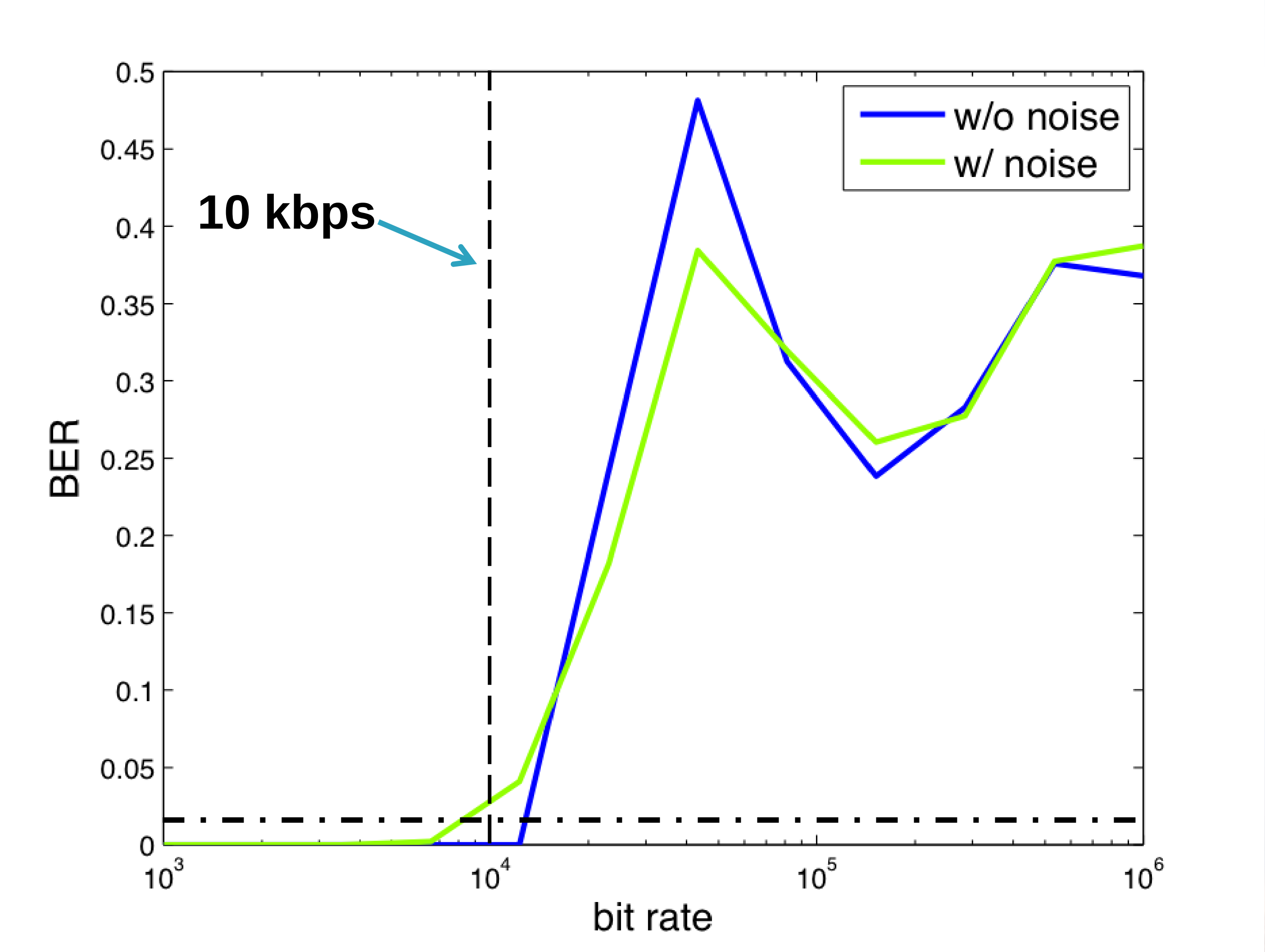
Ideal Constellation



Constellation with Multipath and Noise



Bit Error Rate Performance



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Conclusions

- This model shows a bandwidth of ~ 10kHz
- With more intelligent communications throughput could be improved (OFDM)
- Intelligent allocation of bandwidth is necessary
- Higher sampling rates could improve SNR but attenuate faster

Future Work

- Noise data from μGrid to improve accuracy
- Real distribution of loads/generators in μGrid
- Investigate communication requirements for stability in low inertial systems
- Is it up to the inverter?
- Isolate stochastic generation with storage?

Questions?