



SAND2011-7231C

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Power Line Communications (PLC) for μ Grid Stability and PHEV Balancing

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The University of Vermont

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Outline

- **Objective**
- **Power Line Communications**
- **Secure, Scalable μ Grid 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 μ Grid.**
 - **PLC could be used for information transfer among agents**
 - **‘Tagging’ of plug-in hybrid electric vehicle (PHEV) charging**



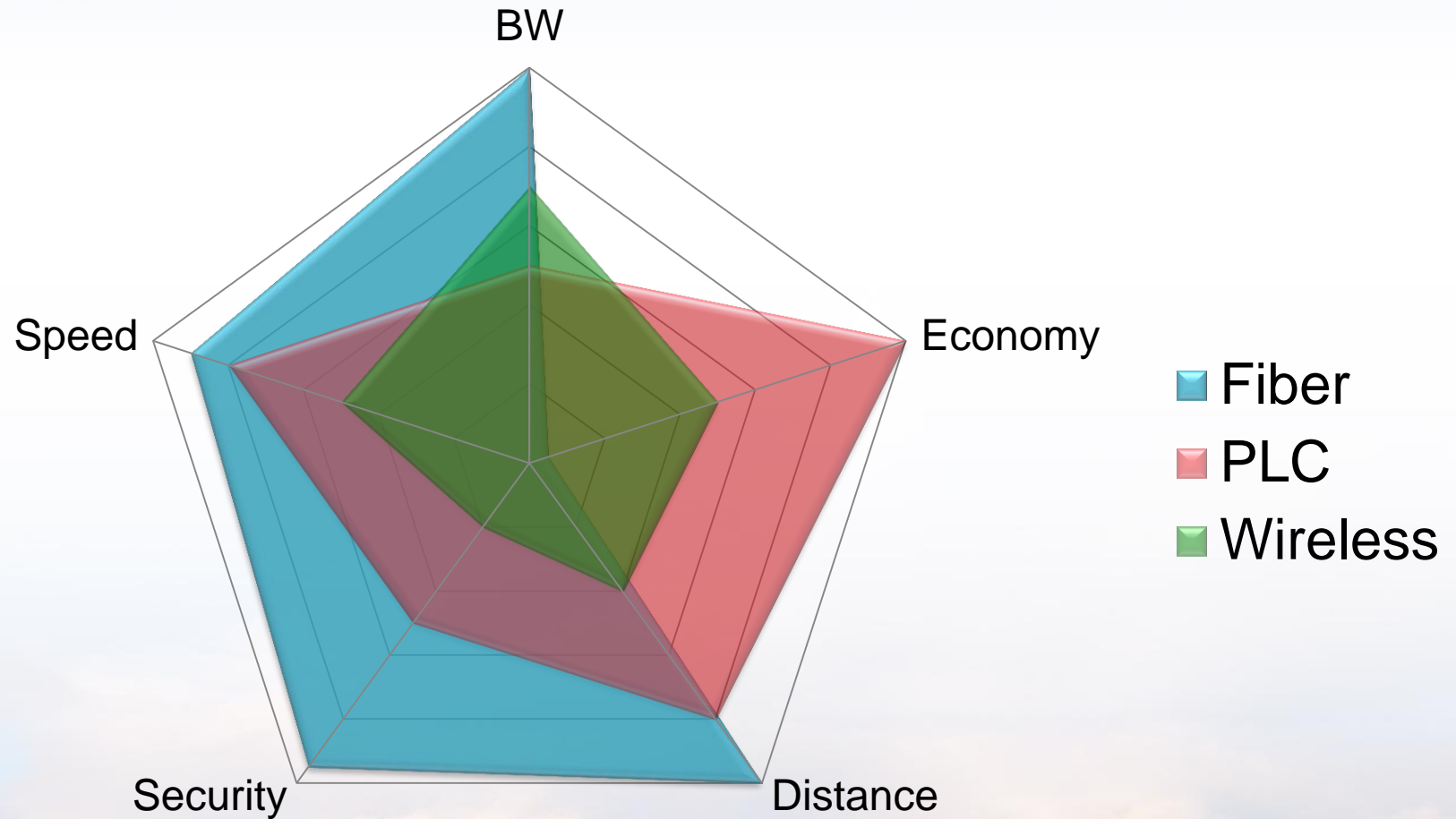


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Why PLC?



Commercially Available



Aclara™ DRU

DEMAND RESPONSE UNIT

TWACS® PROAsys™

POWER RELIABILITY OUTAGE ASSESSMENT SYST

TWACS® CST

CAPACITOR CONTROL SOLUTION

When energy demand is high, the Aclara DRU reduces peak-power costs without impacting customer service.

The Aclara Demand Response Unit (DRU) is a one- or two-phase device that curbs demand and safeguards against under-voltage or under-frequency conditions. At the heart of the DRU is the unique Intelligent Comfort™ system, which employs a patented, adaptive load-control algorithm and a unique, 24-hour energy-use appliance profile to provide adaptive control while eliminating the need for complex system modeling.



Positive outage notification and restoration confirmation saves time and money and improves customer satisfaction.

TWACS PROAsys helps utilities make use of the data they collect from AMI to quickly assess system status and identify outages. Application reports voltage at the meter, monitors power reliability and verifies customer-reported outages. PROAsys differentiates between momentary and sustained outages, allowing utilities to quickly determine where to send repair crews, and reducing the time to complete restoration of service.



Central administration of capacitor banks helps dispatchers make better distribution decisions and reduces costly on-site maintenance.

The TWACS CST (capacitor switching transponder), operating with TWACS Master Station software, allows utilities to actively manage grid reliability and efficiency. The two-way solution can monitor circuit voltage, neutral current, and contact closure of the capacitor bank, thereby allowing remote management of capacitance in the distribution network. Remote management helps utilities reduce losses due to reactive power flow and avoid power-purchase penalties.



Each TWACS CST delivers

On-demand status information
Provides troubleshooting, alarms, voltage profiles, and bank status

Cost efficiencies
Reduces overhead related to capacitor bank patrols and line loss

System intelligence
Provides real-time voltage, status, and error reports, and synchronizes daily and seasonal requirements

Safety improvements
Eliminates manual switching

Problem notification
Monitors neutral currents to pinpoint partial bank failures and blown fuses

Capturing data. Liberating knowledge.™

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www.Aclara.com



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<http://www.aclaratech.com>



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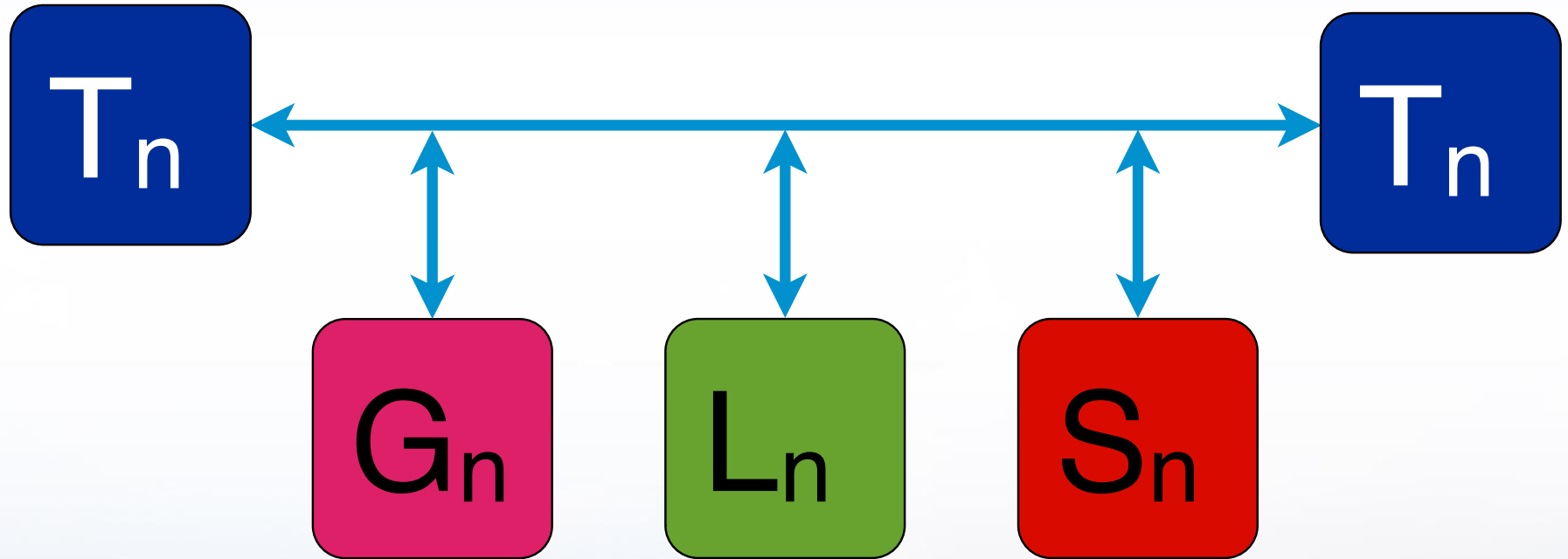


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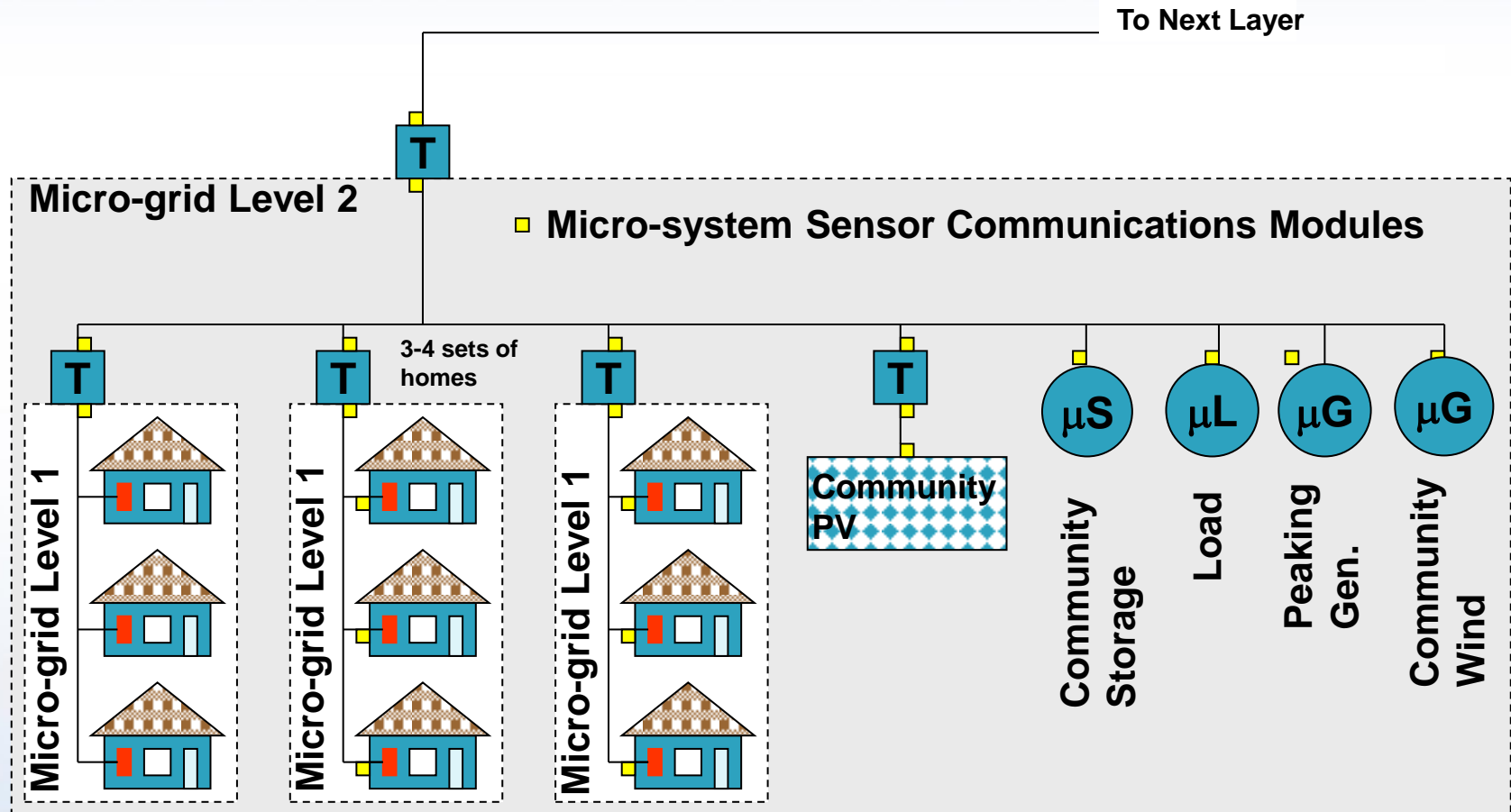


μ Grid Multiagent Architecture



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

Interconnected μ Grid



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



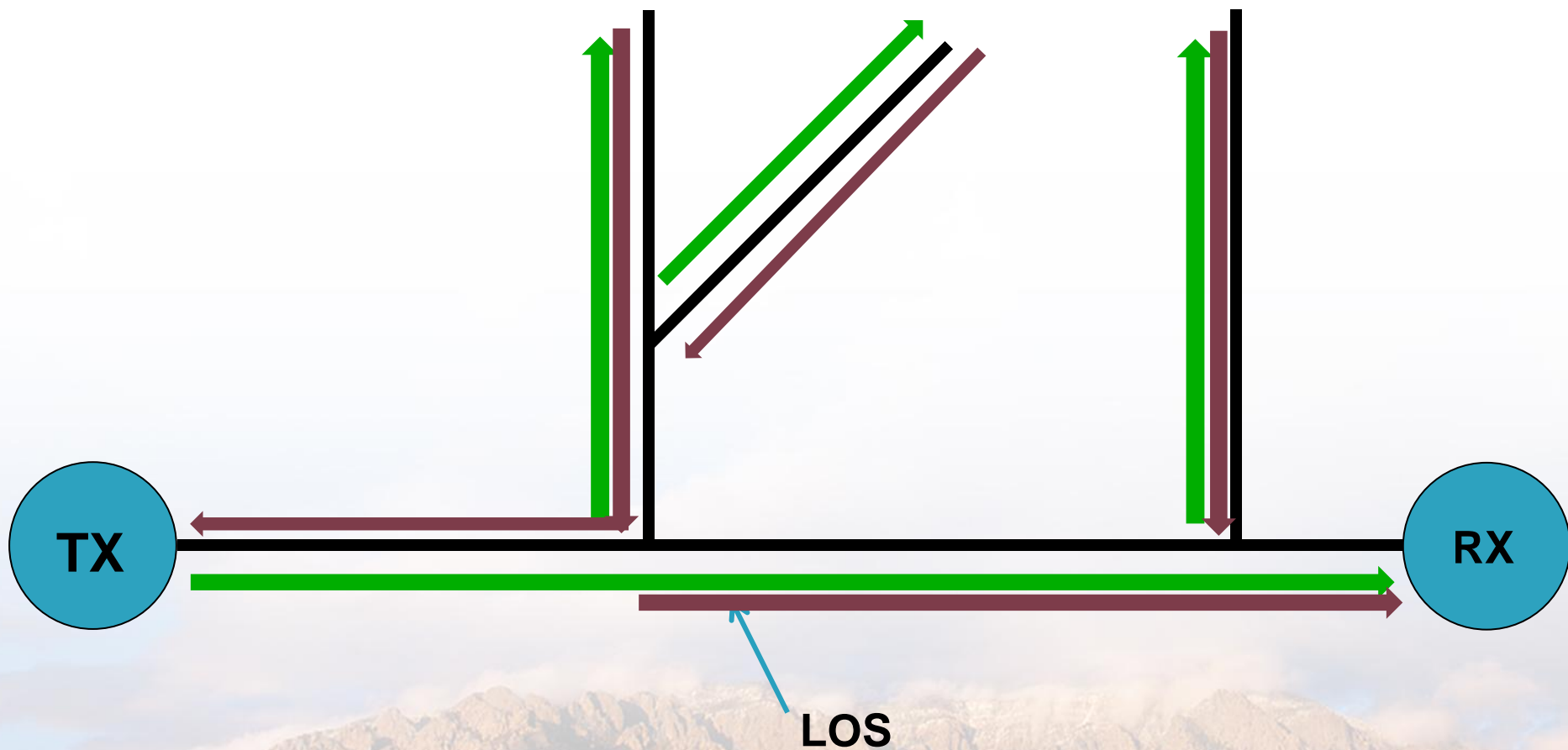


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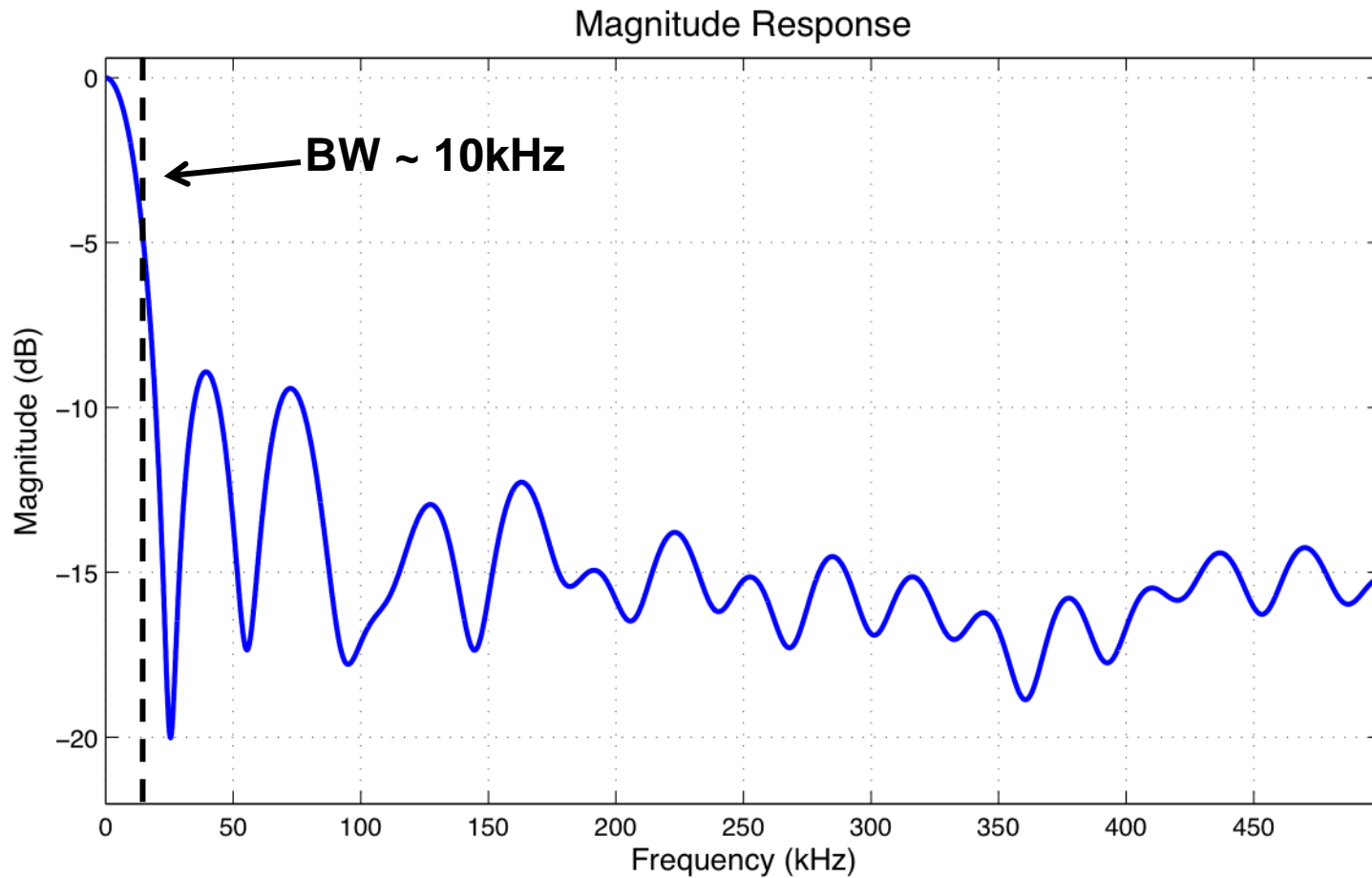
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Multipath Source in PLC



Frequency Response



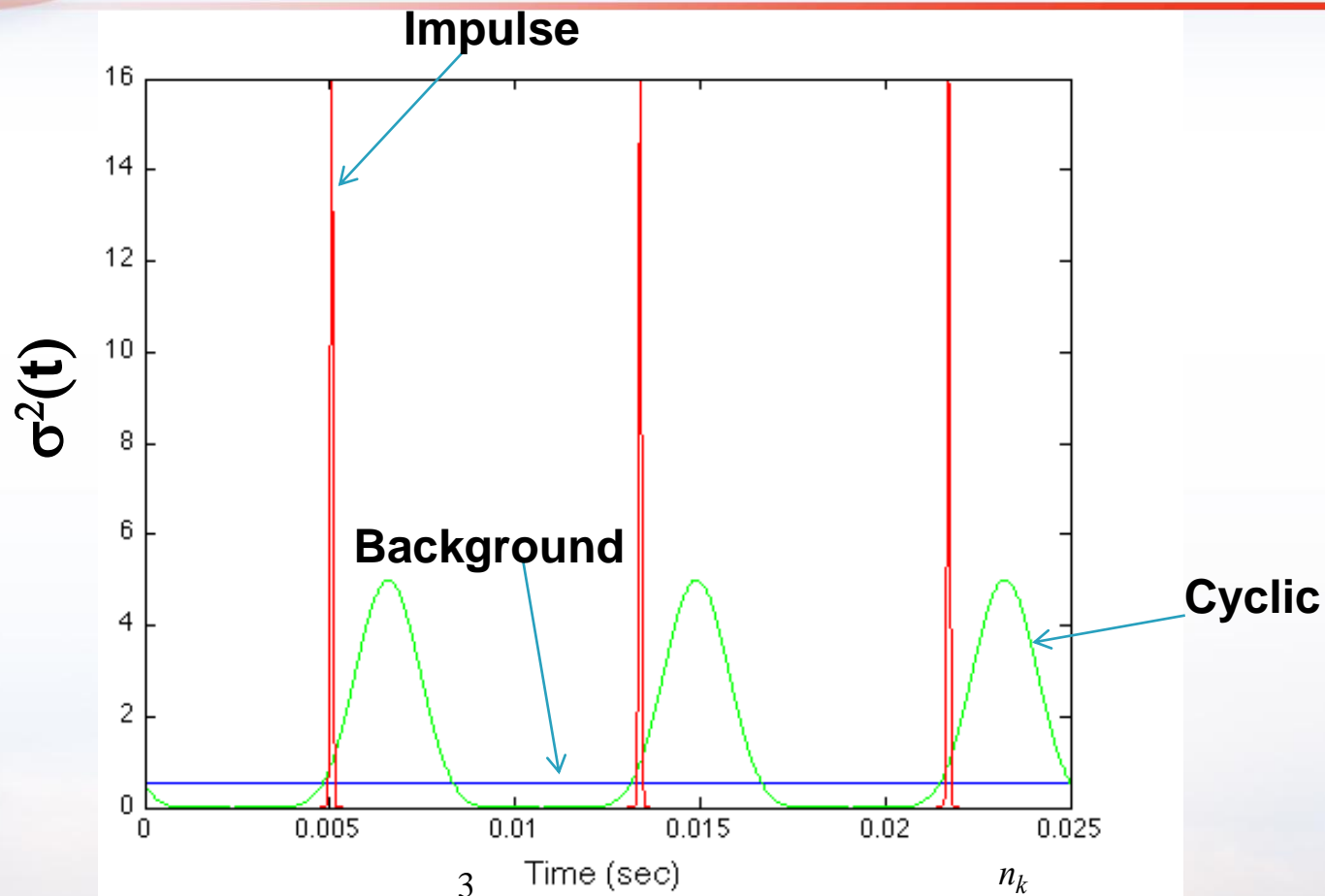


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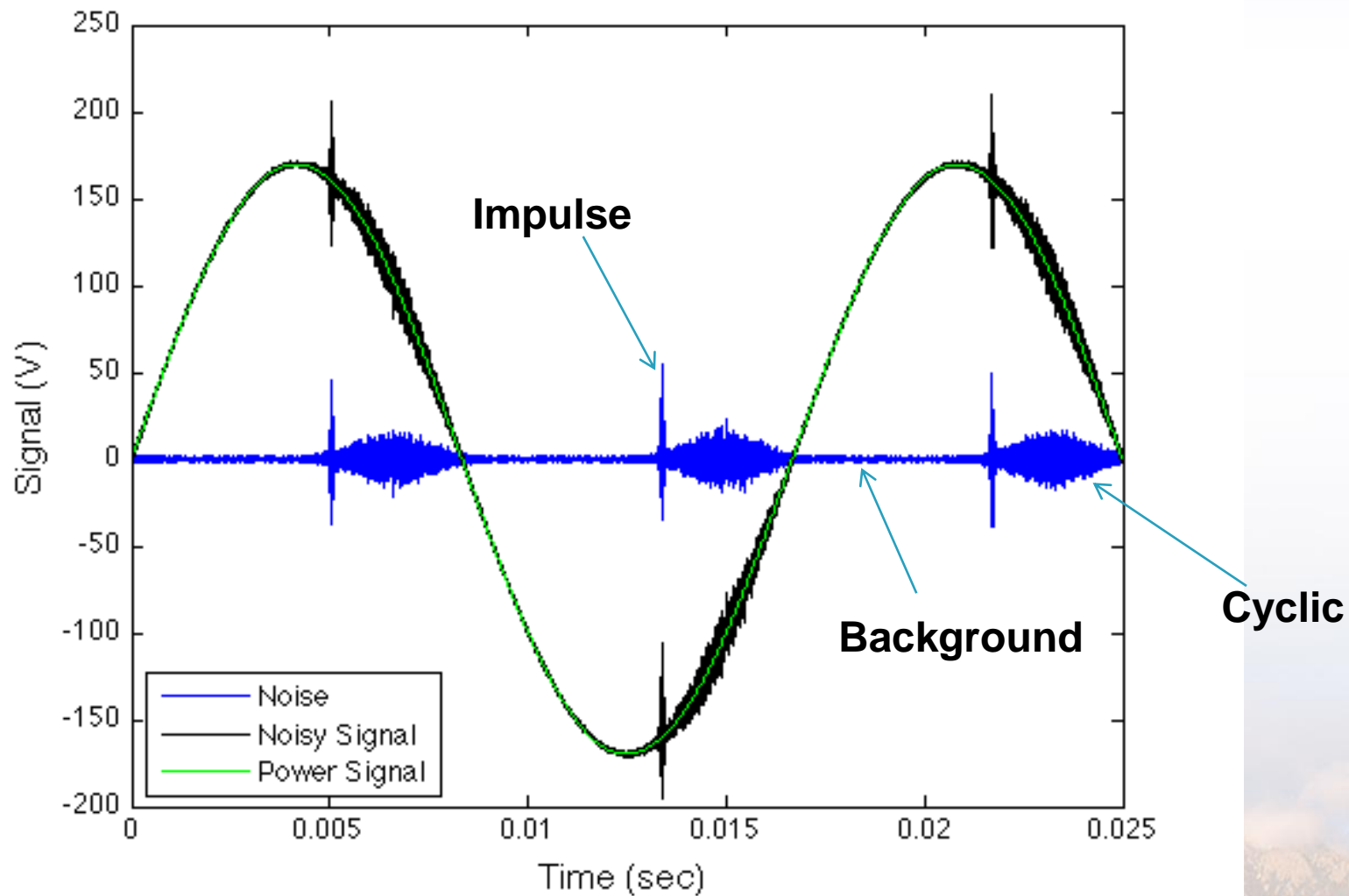
Cyclostationary Noise



$$s^2(t) = \sum_{k=1}^3 \dot{a} A_k |\sin(2pF_{AC}t + q_k)|$$



Noise Manifestation



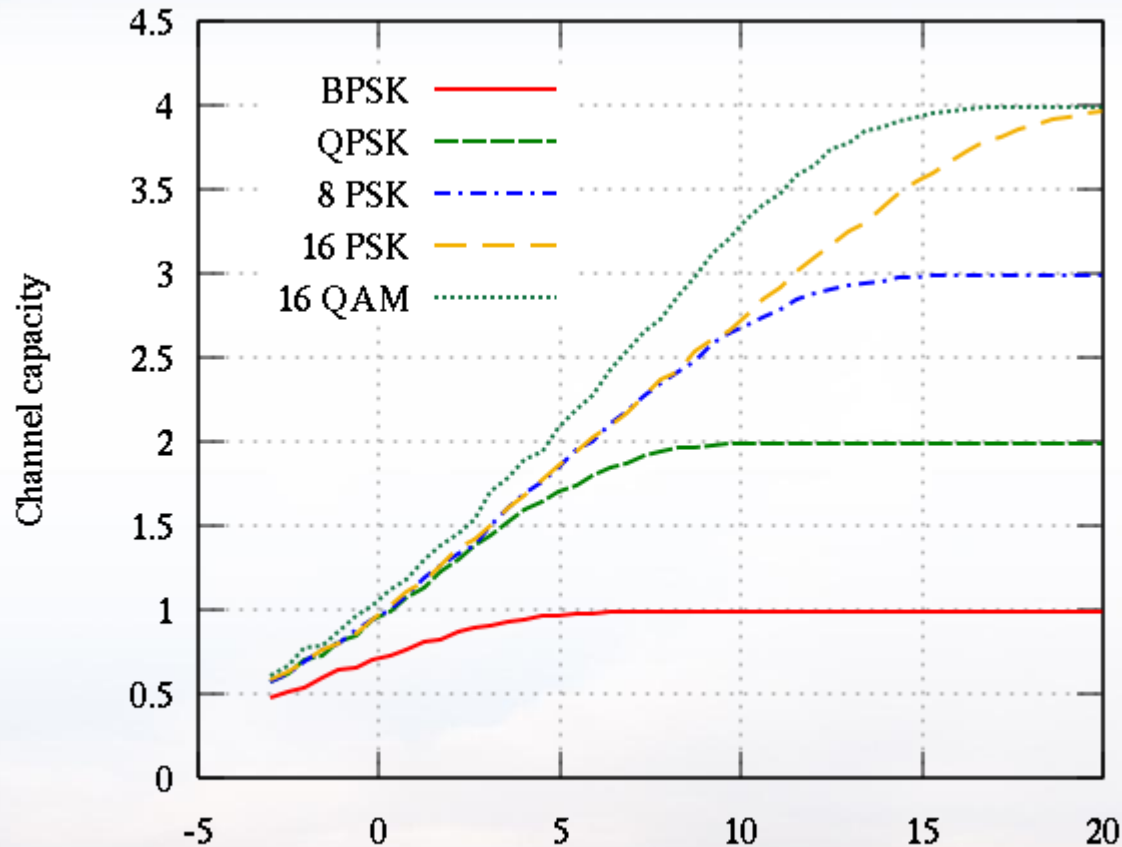


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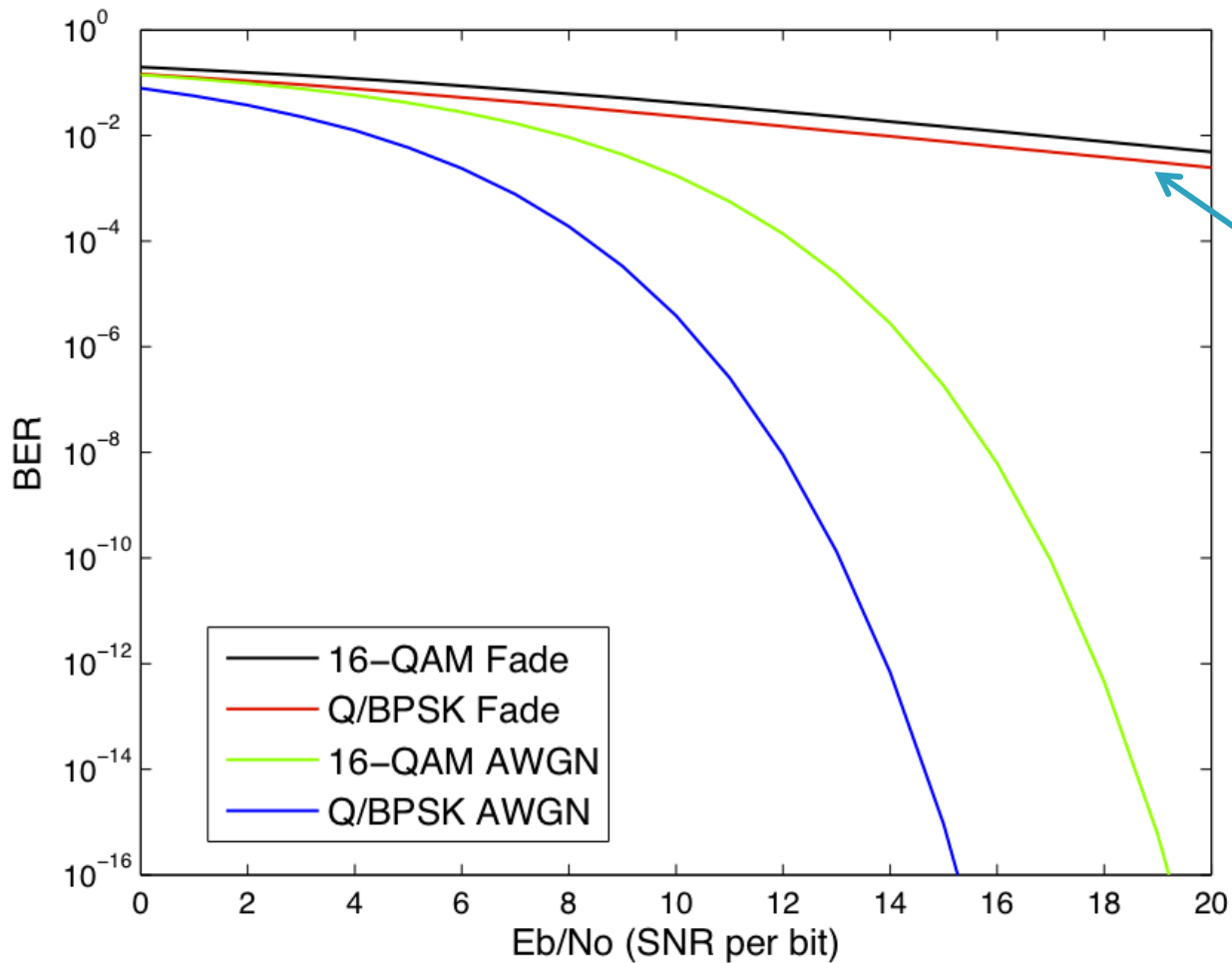
Throughput Performance



$$SNR_{dB} = 20 \log_{10} \frac{\text{signal}}{\text{noise}}$$



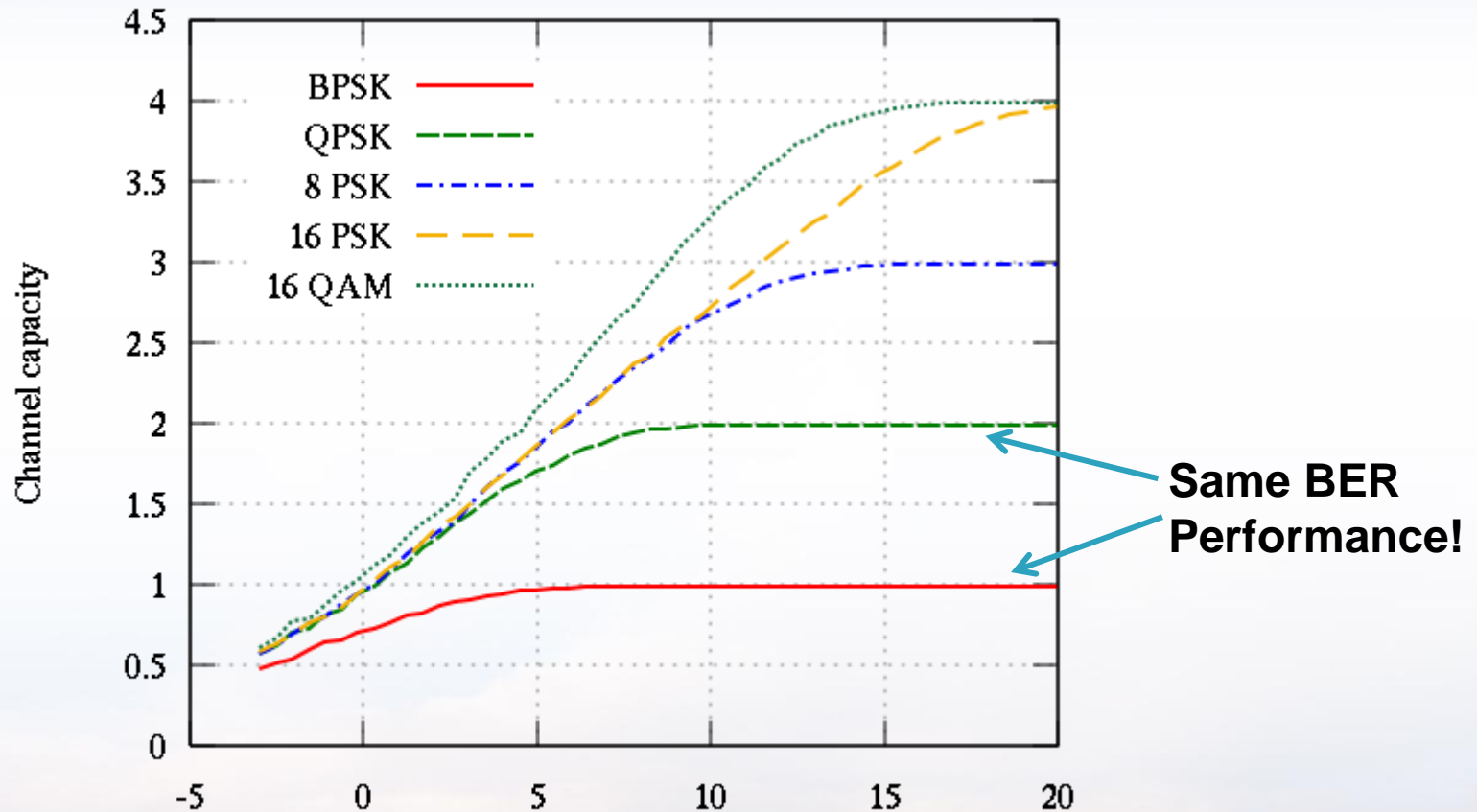
BER Performance



You are here



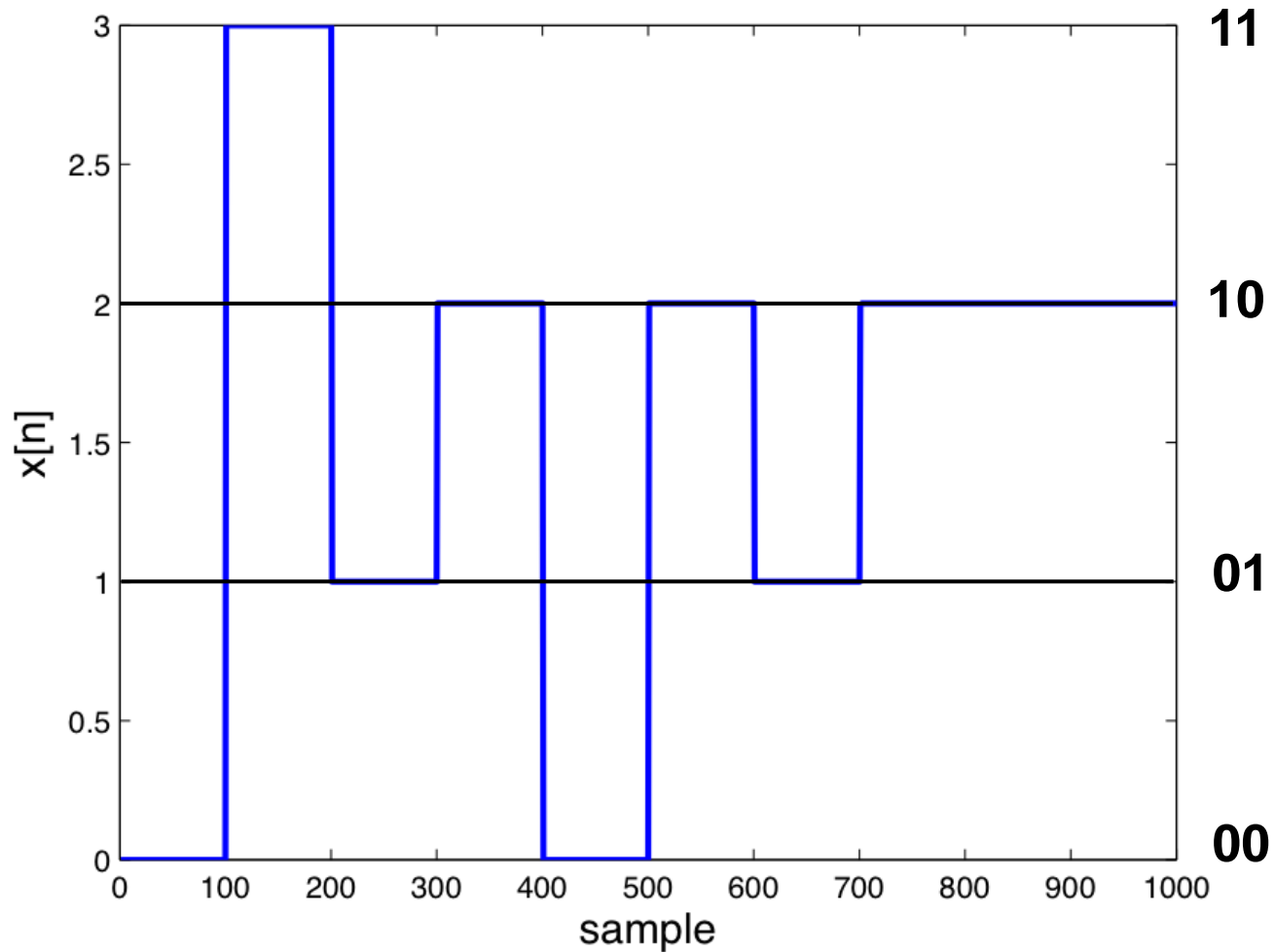
Throughput Performance



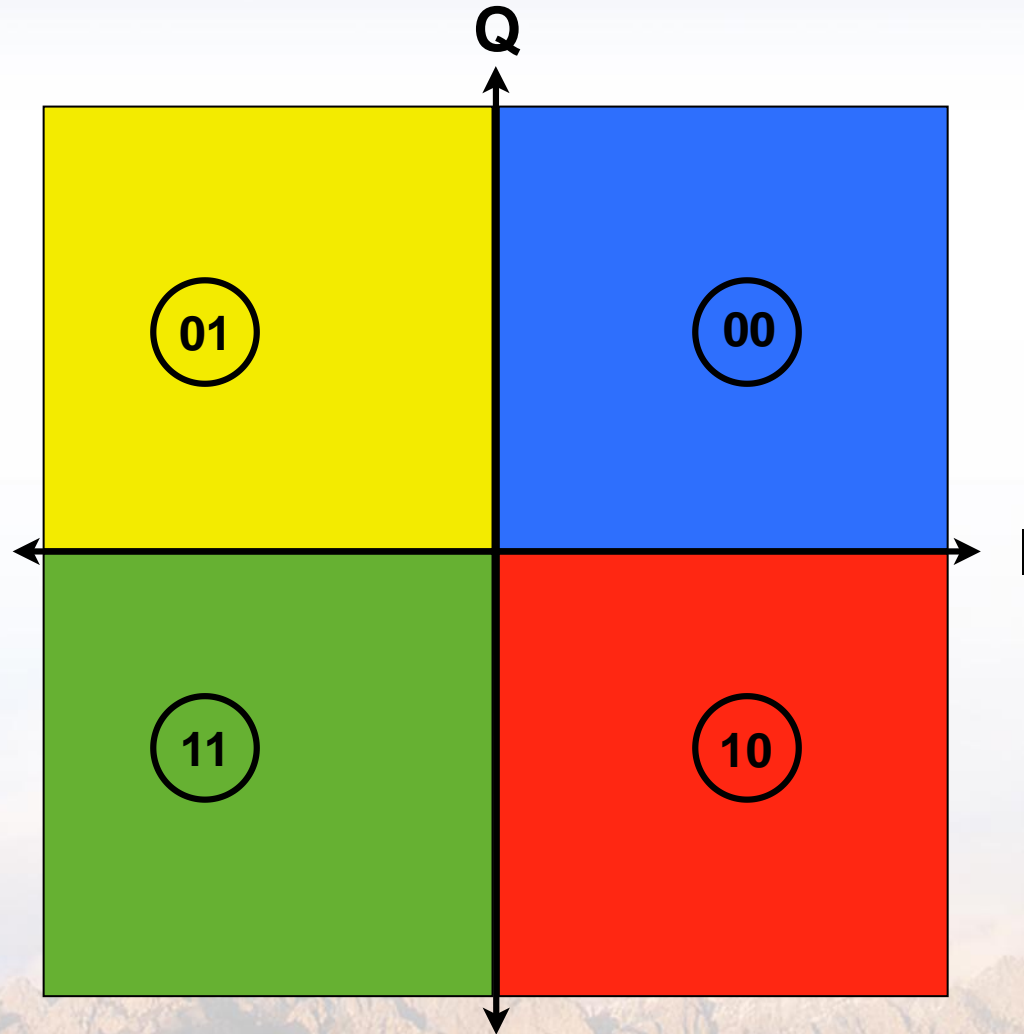
$$SNR_{dB} = 20 \log_{10} \frac{\text{signal}}{\text{noise}}$$



Bit Stream



QPSK Constellation



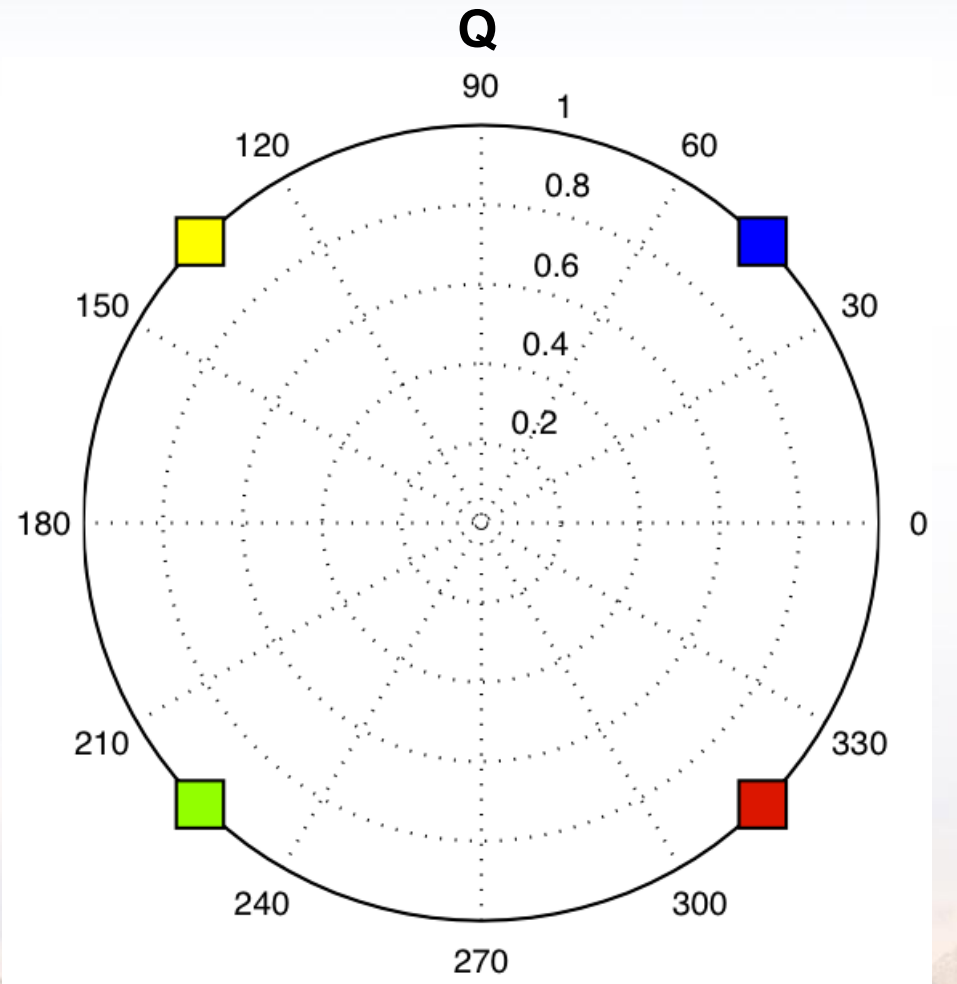


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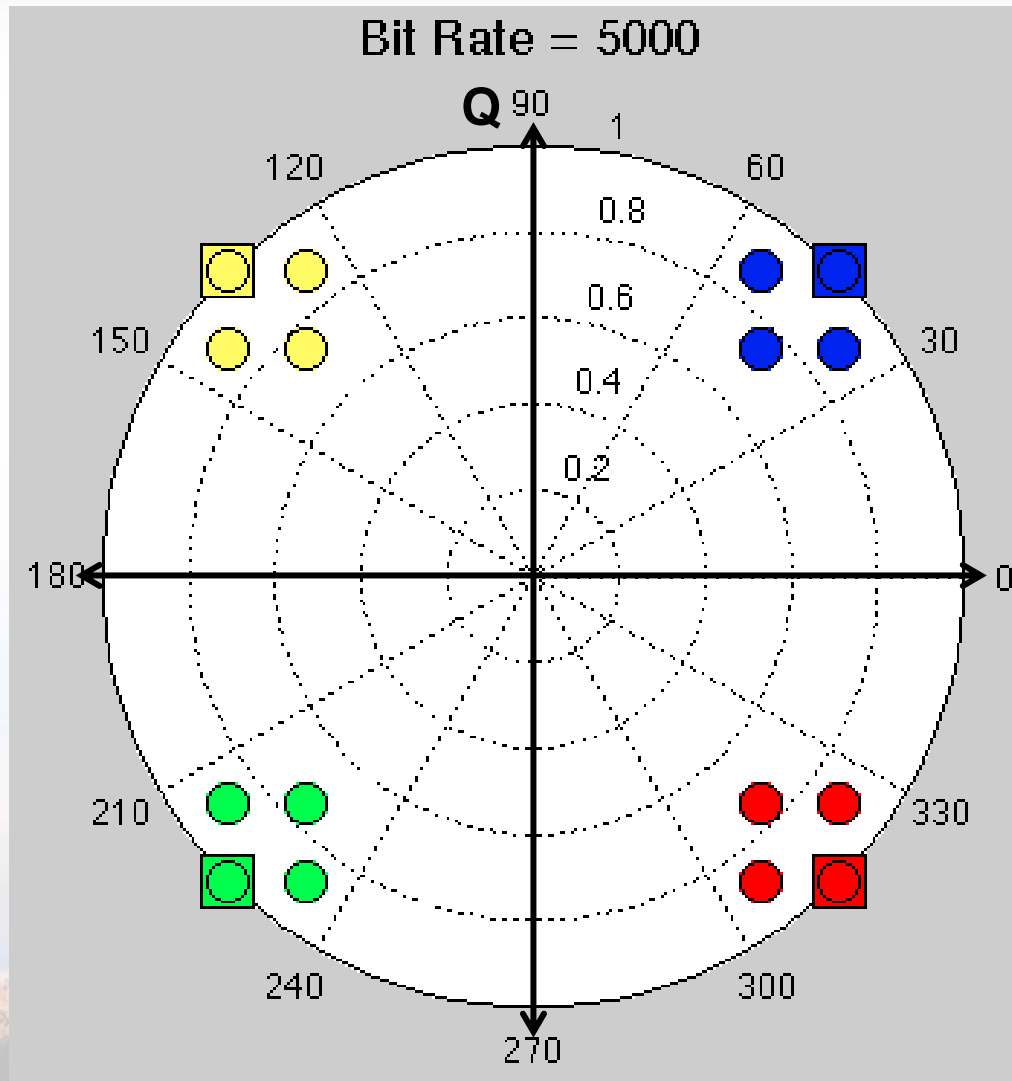
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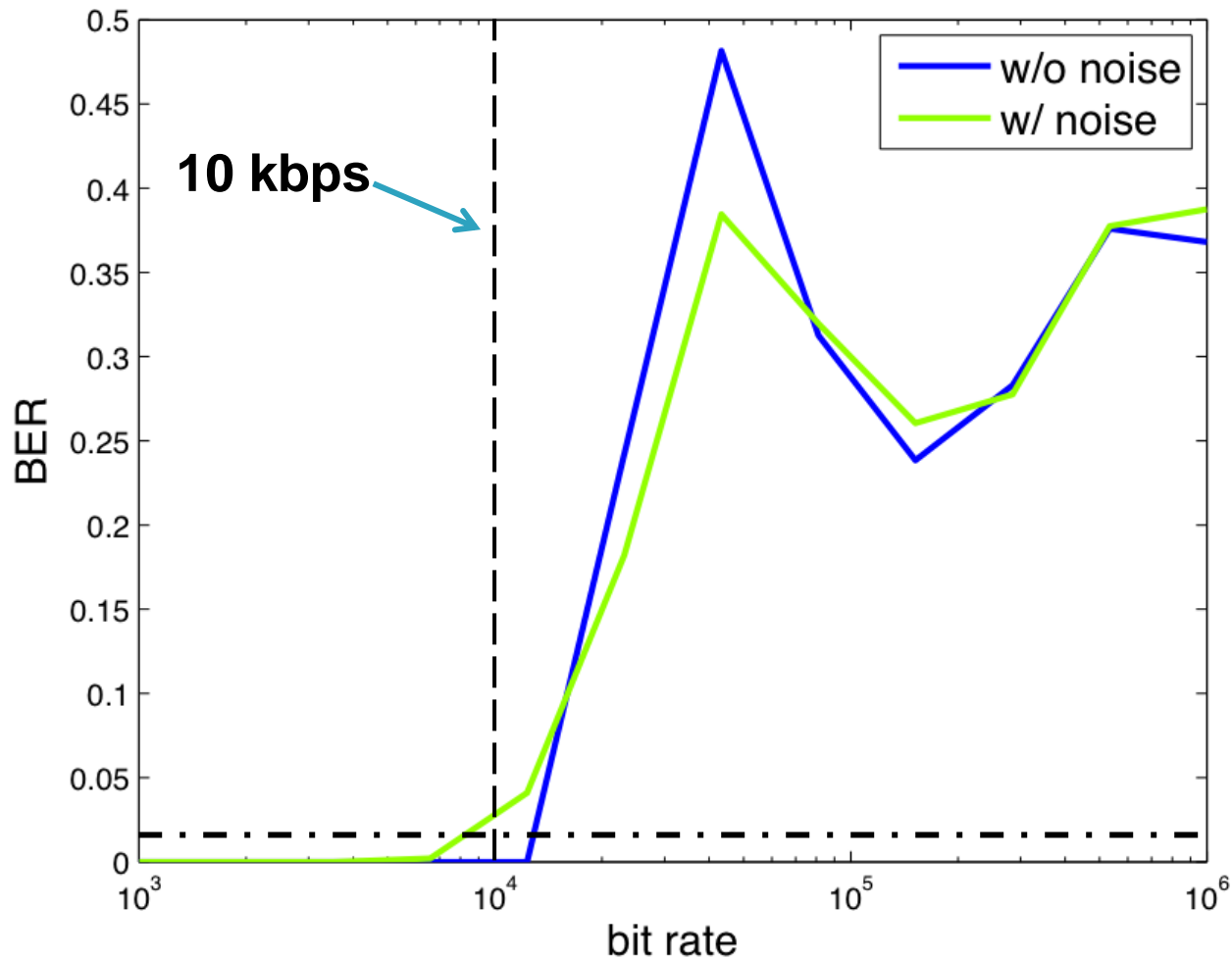
Ideal Constellation



Constellation with Multipath and Noise



Bit Error Rate Performance





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Conclusions

- **This model shows a bandwidth of $\sim 10\text{kHz}$**
- **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 μ Grid to improve accuracy**
- **Real distribution of loads/generators in μ Grid**
- **Investigate communication requirements for stability in low inertial systems**
- **Is it up to the inverter?**
- **Isolate stochastic generation with storage?**



Questions?

