PLC Transmission Prototype using TDS-OFDM and MV Channel Modeling

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Outline

- Introduction
- TDS-OFDM based PLC Prototype
- Medium-Voltage Channel Modeling
- Summary and Future Plan

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- ***Introduction***
- **TDS-OFDM based PLC Prototype**
- **Medium-Voltage Channel Modeling**
- **Summary and Future Plan**

Objective

❖ Major system parameters

- Bandwidth: 20MHz (with scalability)
- Length of frame body: 4096 data symbols
- Length of frame head: 350 and 700 symbols
- Modulation: QPSK/16QAM/64QAM/256QAM
- FEC rate: 0.4/0.6

❖ Performance specifications

- Max. throughput: 160 Mbps (W/O PN)
- Max. payload: >100Mbps
- Max. multi-path delay: 25us
- Max. frequency offset: 300Hz

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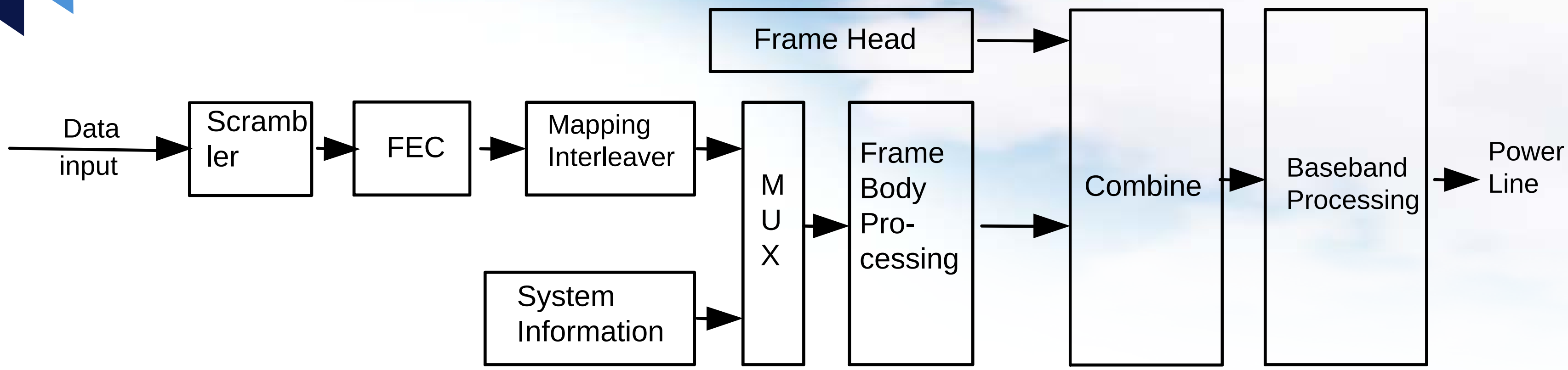
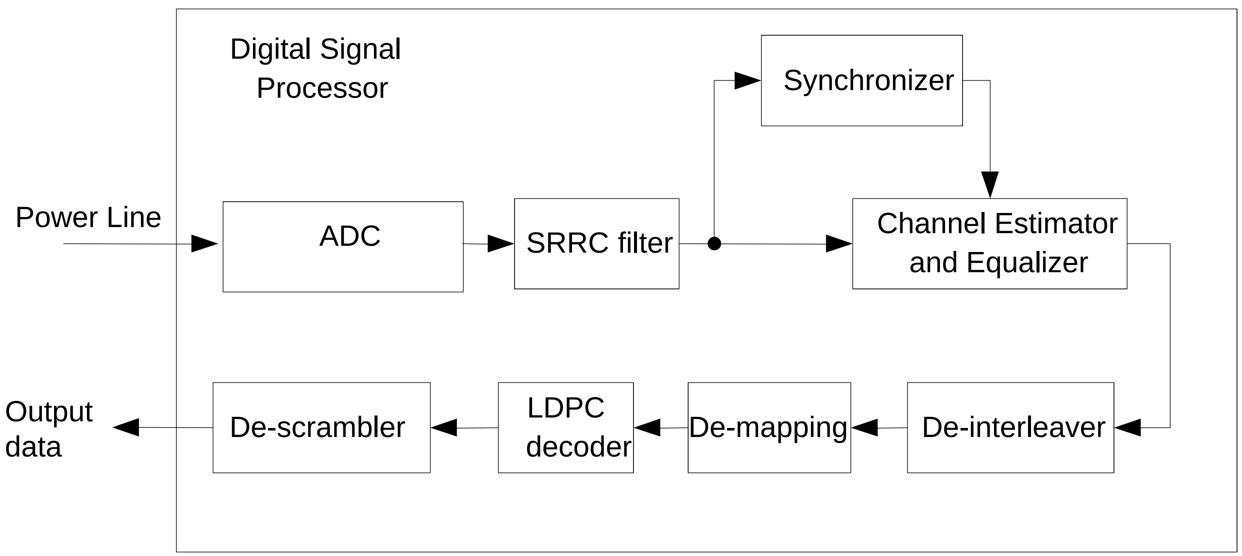
System block diagram

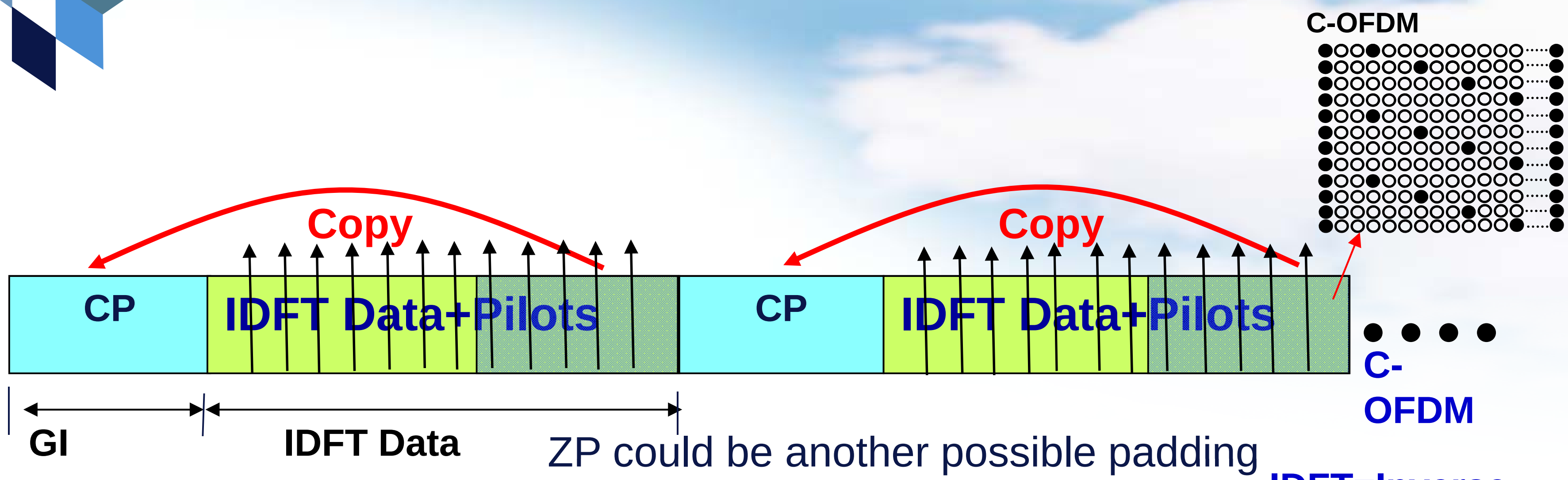




Characteristic of TDS-OFDM

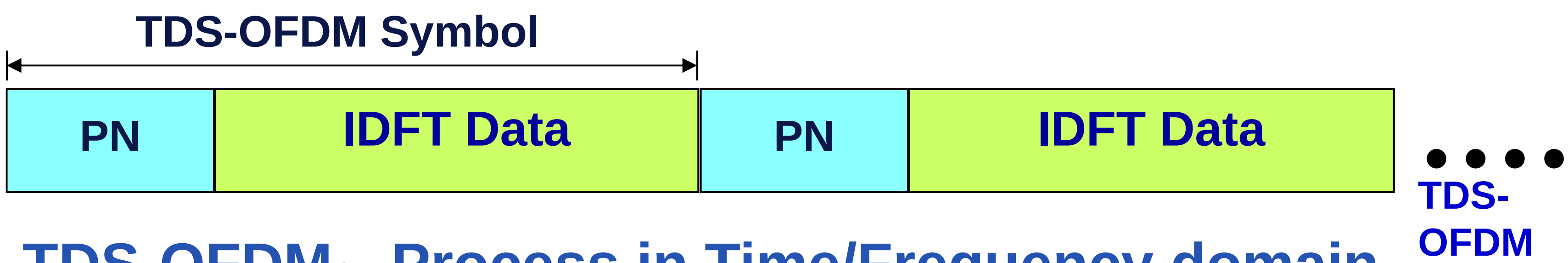
- **PN sequence is used as the guard interval, as well as the training sequence for the channel acquisition, time synchronization, and channel estimation**
- **Main feature**
  - Fast channel acquisition since this can be done directly in the time domain, robust for timing variable channel
  - High spectrum efficiency as it avoids both continuous and scattered pilot insertion into the frame body by CP-OFDM approach
  - More accurate channel estimation due mainly to the good correlation of PN sequence (spreading gain)

TDS-OFDM *vs* C-OFDM



IDFT=Inverse Discrete Fourier Transform

C-OFDM：Process in Frequency domain

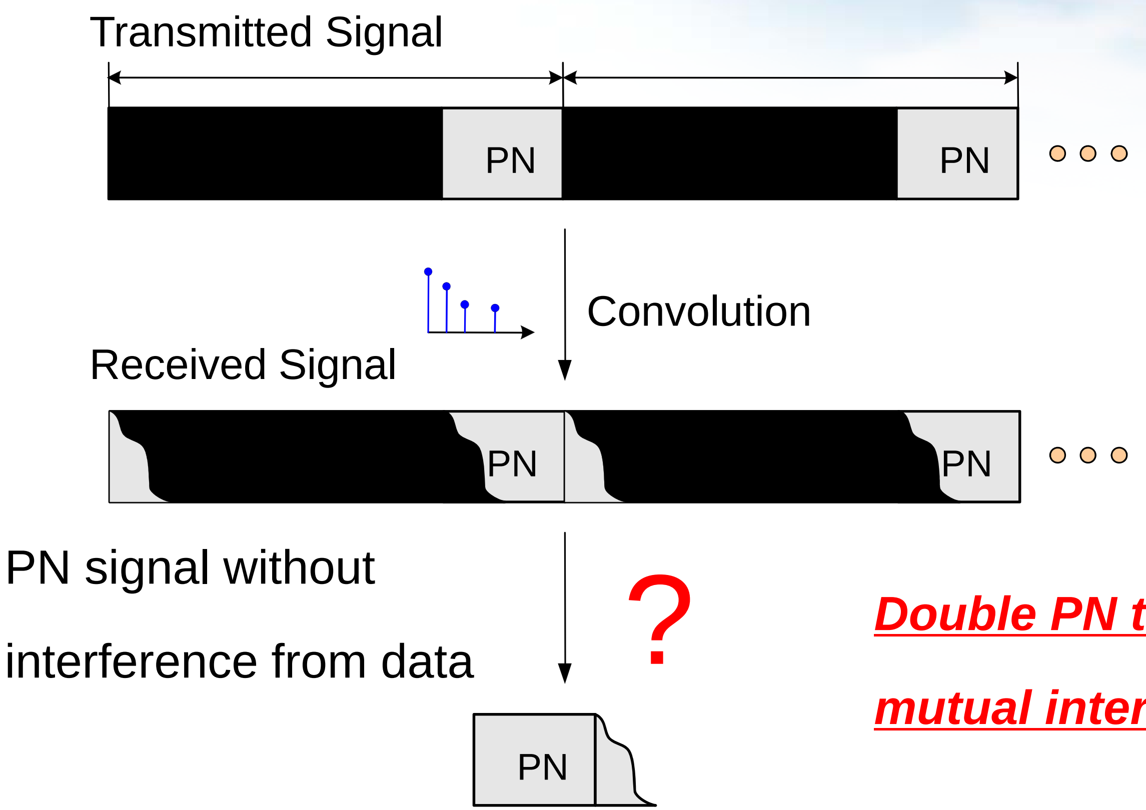


TDS-OFDM：Process in Time/Frequency domain

Interference Cancellation is NEEDED

Channel estimation is challenging

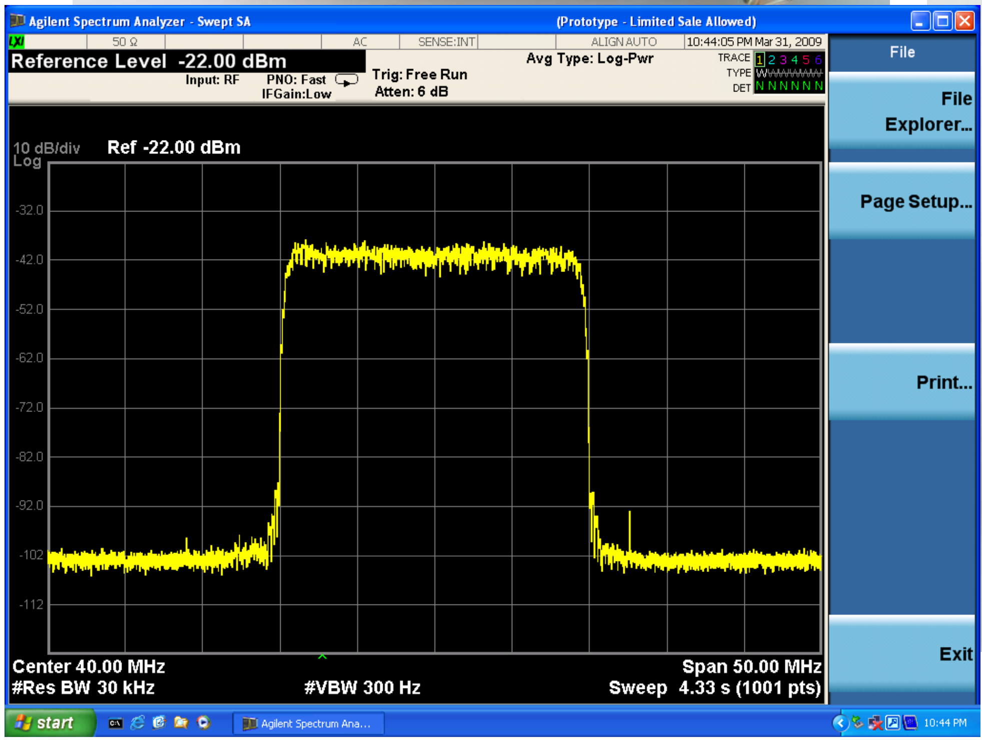
- Mutual interference between Data and PN sequence



Double PN to avoid mutual interference?

Hardware Platform

The highest payload data throughput is 104 Mbps within 20MHz by using 256-QAM and LDPC rate of 0.6



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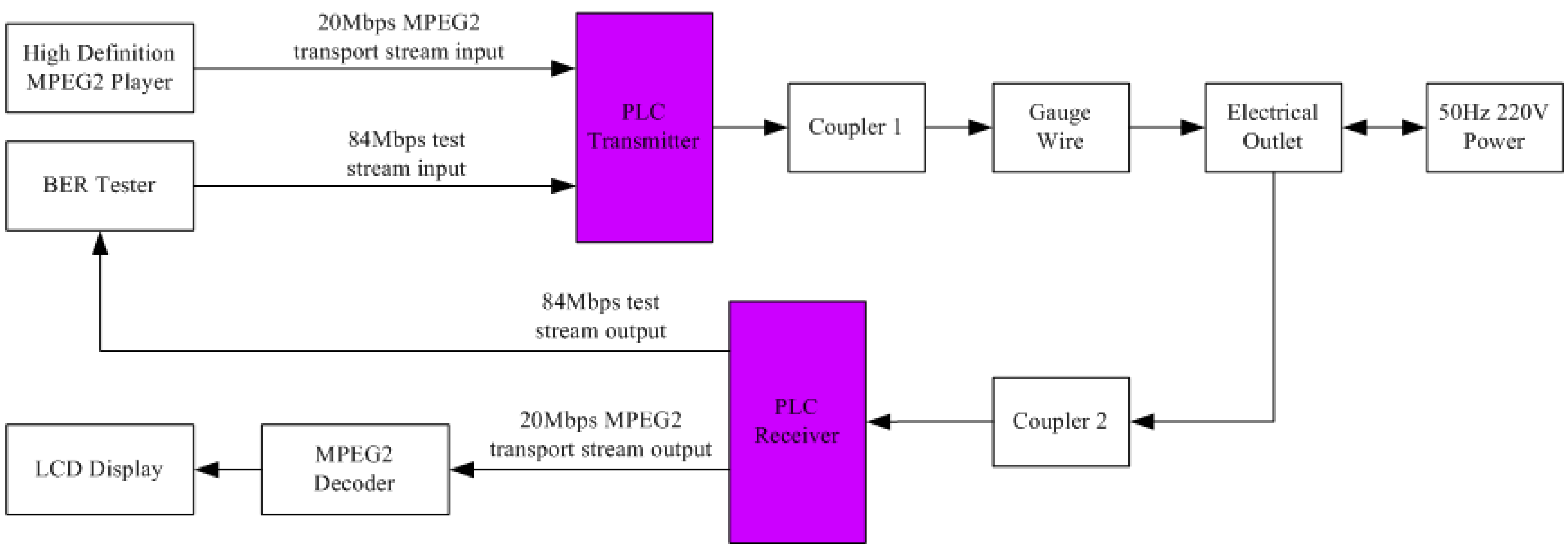
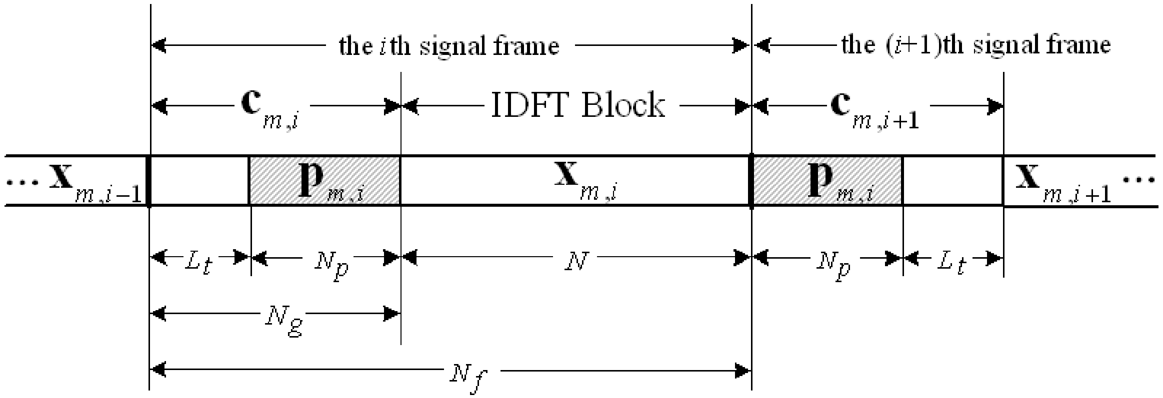
Prototype Setup

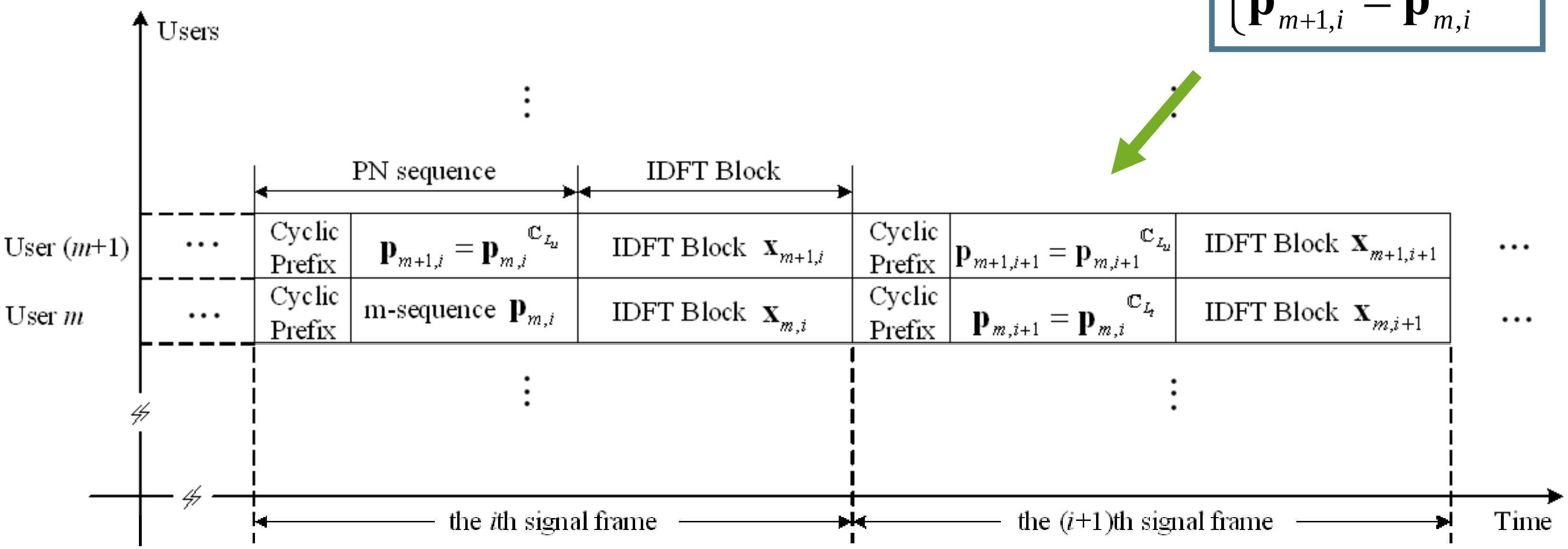
Power Line Communication Demo



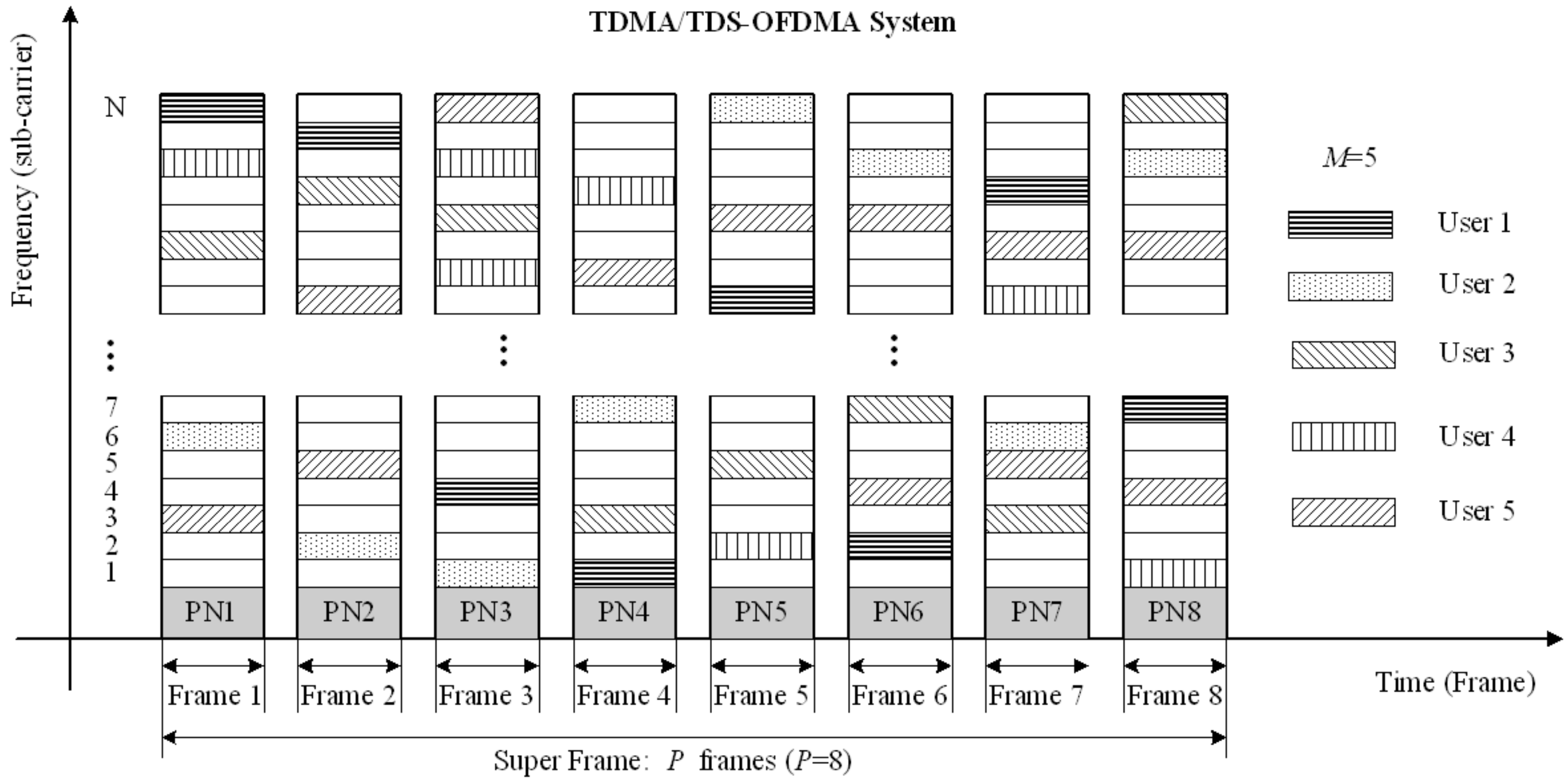
Frame Structure Design



$$\begin{cases} \mathbf{p}_{m,i+1} = \mathbf{p}_{m,i}^{\square\, L_t} \\ \mathbf{p}_{m+1,i} = \mathbf{p}_{m,i}^{\square\, L_u} \end{cases}$$



Multiple Access



Scalable TDMA + TDS-OFDMA

Adaptive Bit Loading

- Bit-loading algorithms for multi-rate LDPC coded OFDM system
- Optimization over
  - QPSK/16QAM/64QAM/256QAM
  - LDPC 0.4/0.6
- Adapt the Constellation & coding mode according to the SNR estimation on each sub-carrier and SNR threshold for each code rate and constellation

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Channel modeling

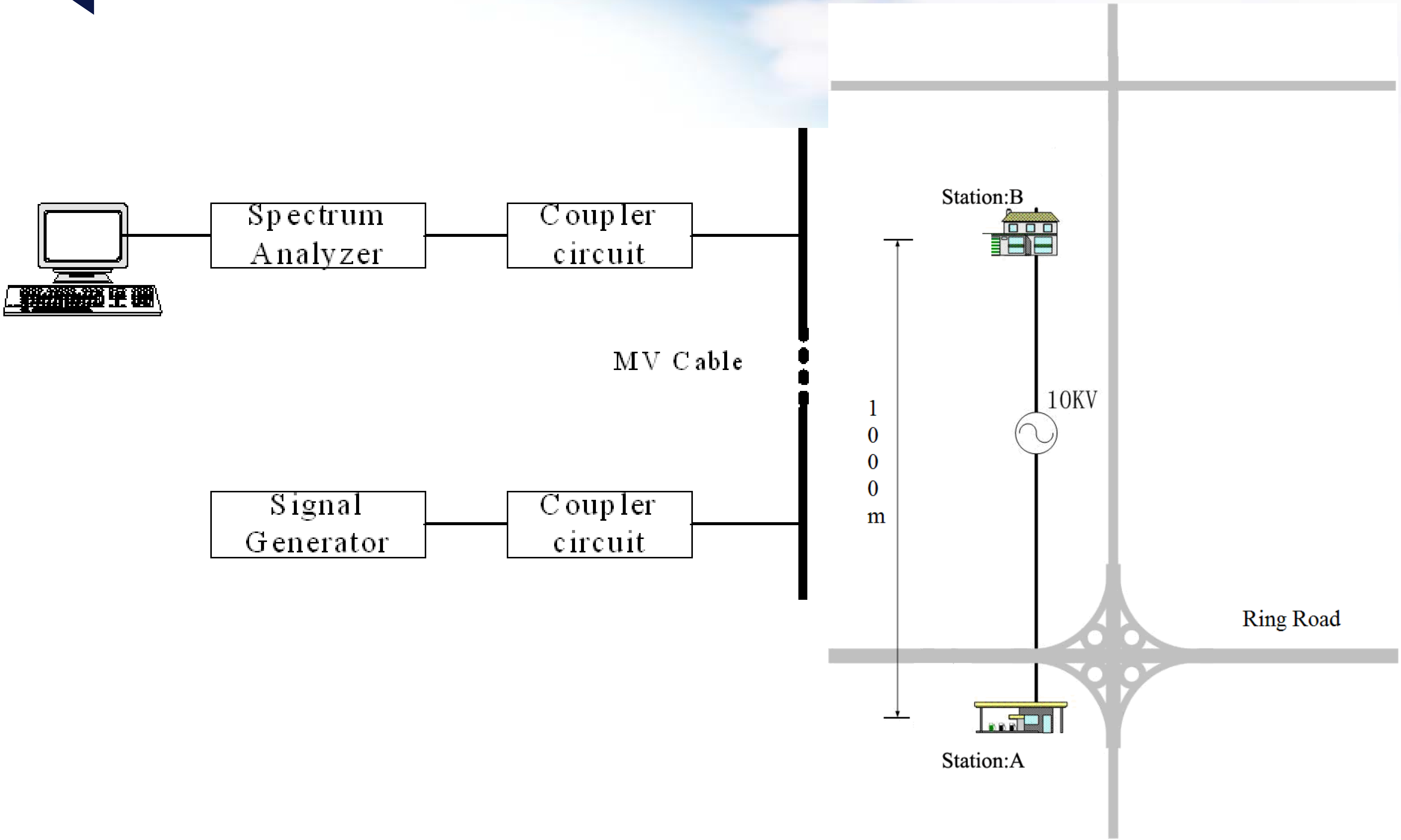
Approximation by the echo model:

$$H(f) = \sum_{i=1}^{N} \underbrace{g_i}_{\text{weighting factor}} \cdot \underbrace{e^{-\left(a_0 + a_1 f^k\right)d_i}}_{\text{attenuation portion}} \cdot \underbrace{e^{-j2\pi f\left(d_i / v_p\right)}}_{\text{delay portion}}$$

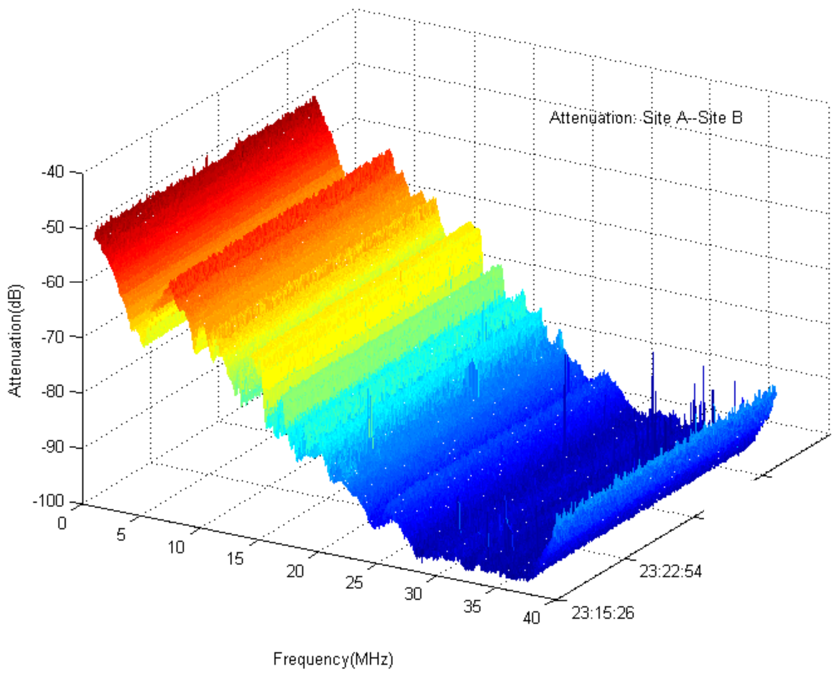
Error definition:

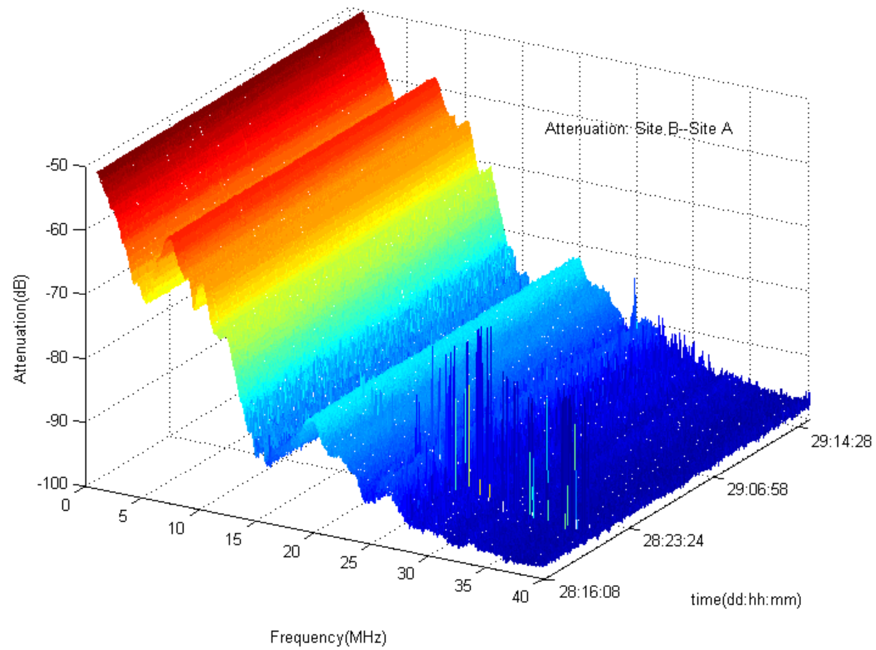
$$ERR = \frac{1}{M}\sum_{i=1}^{M}\left|H_i - y_i\right|$$

Channel measurement

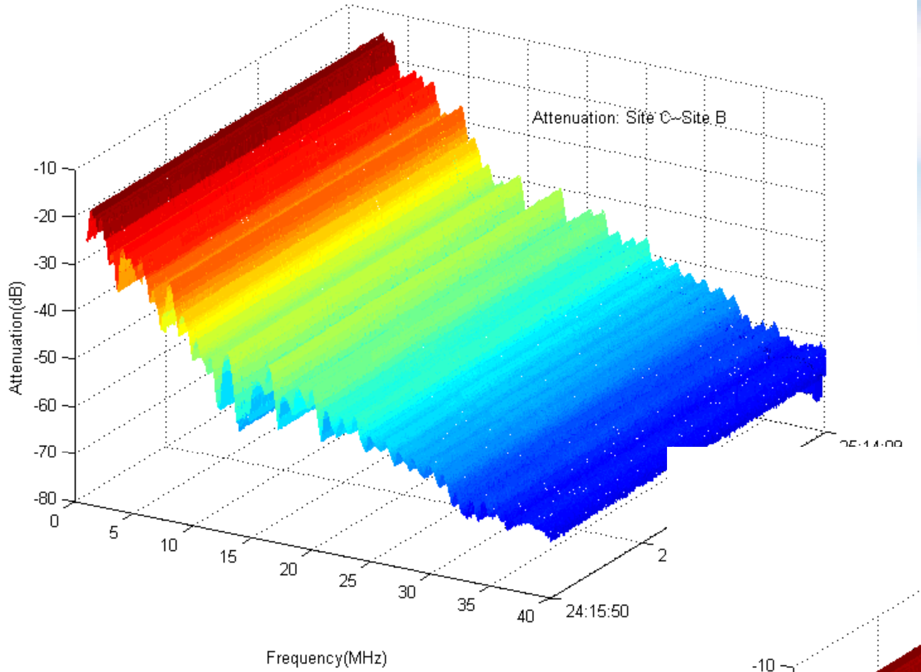


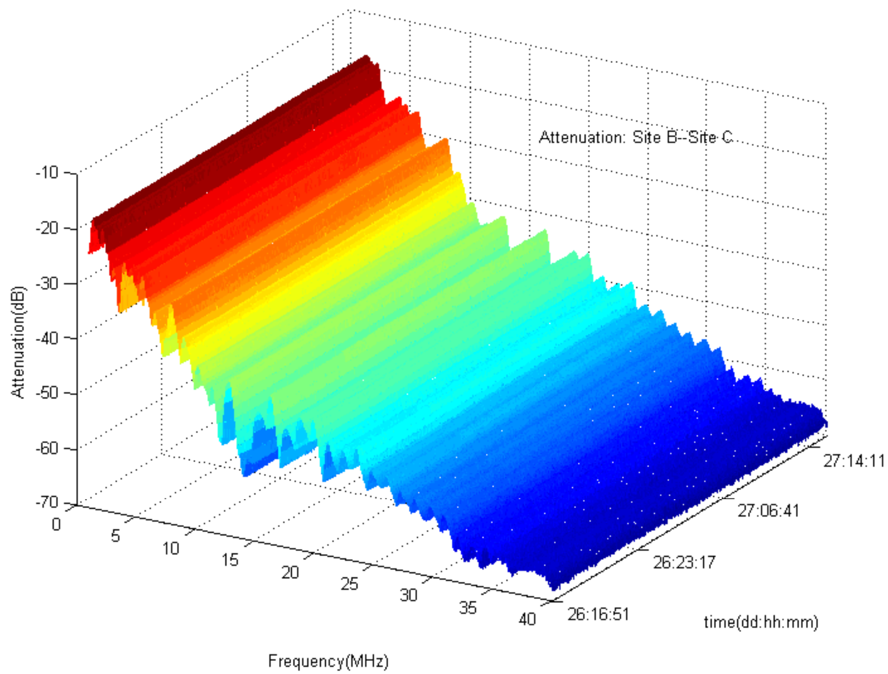
MV-Measurements



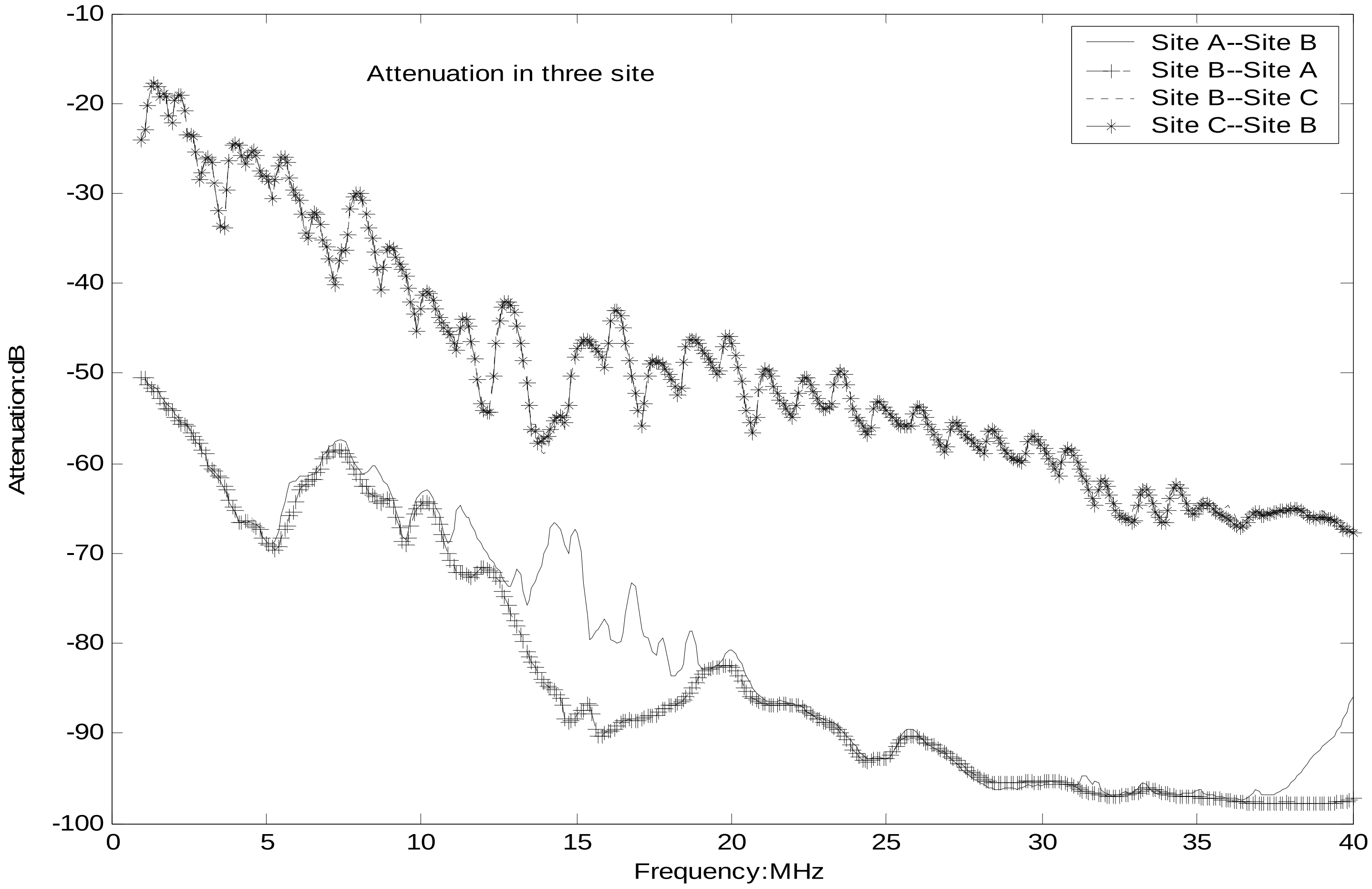


MV-Measurements (cont'd)



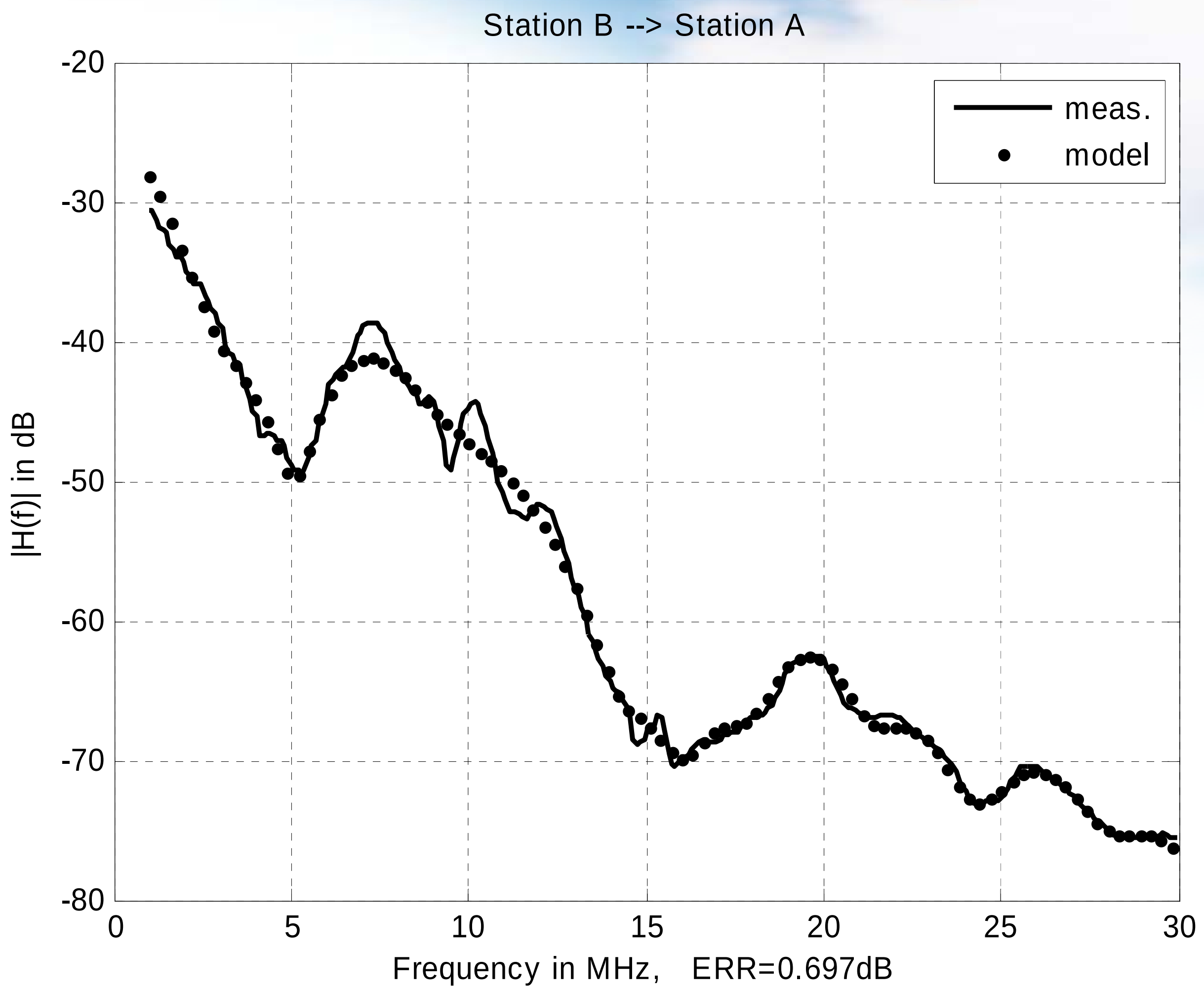


Average Attenuation

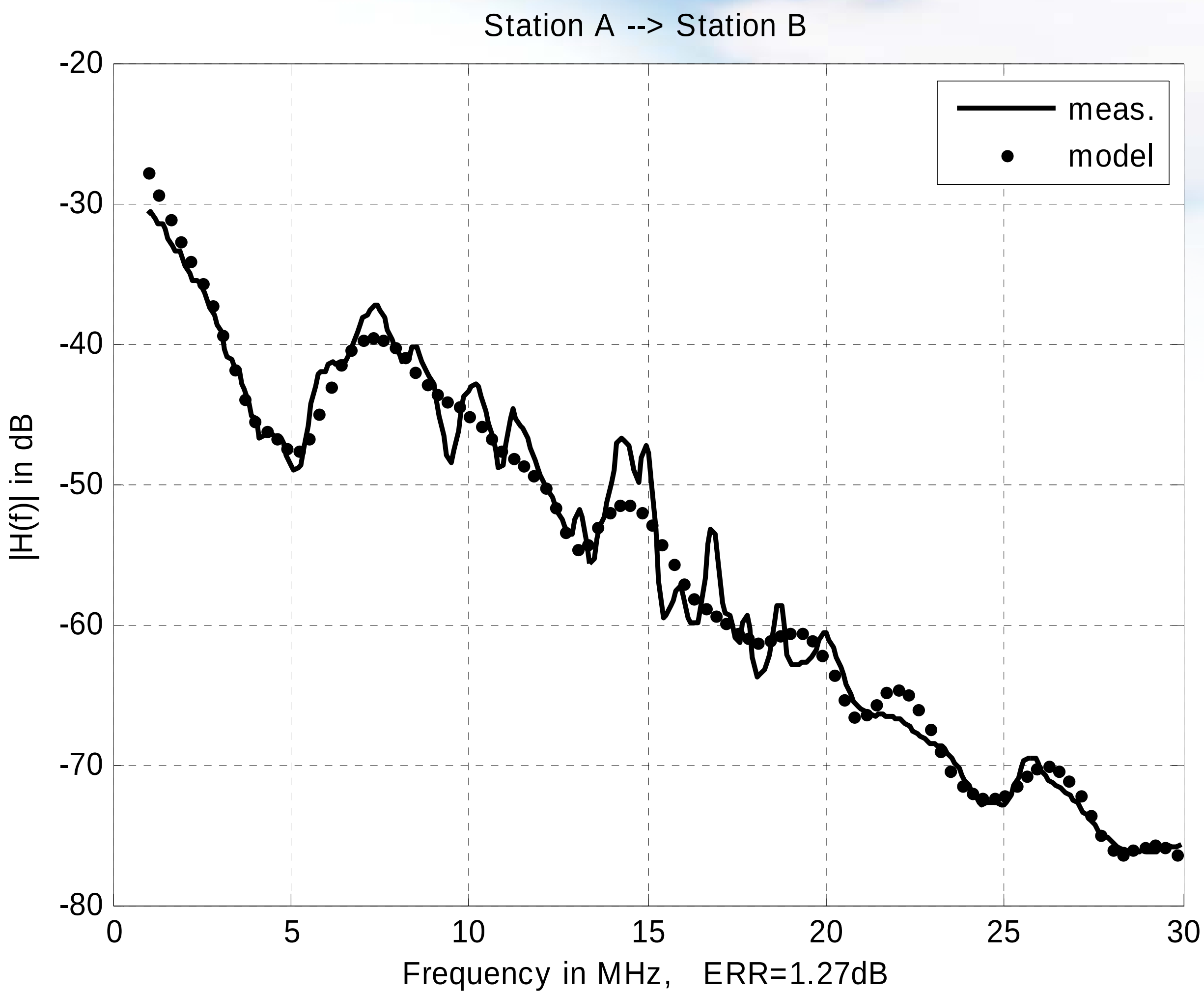


Frequency (MHz)

Measurement (site B-> site A)



Measurement (site A-> site B)



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Summary

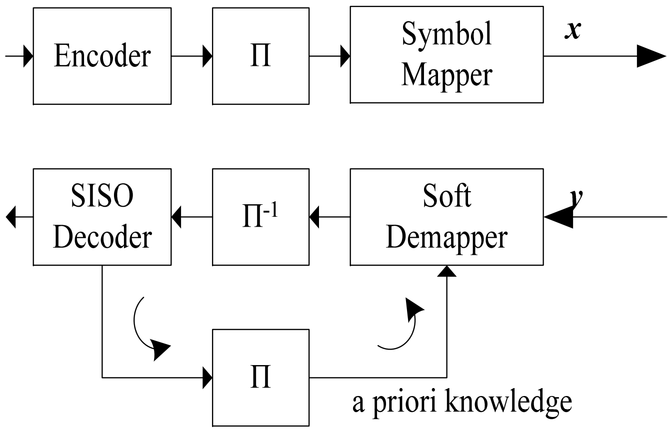
- TDS-OFDM technology is feasible to be adopted by the powerline communication systems with potentially
  - high spectrum efficiency
  - better capability to track the channel variation

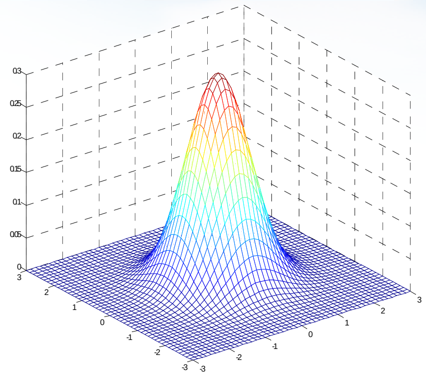
- Medium voltage channel is different from the low-voltage with the clear large scale effect

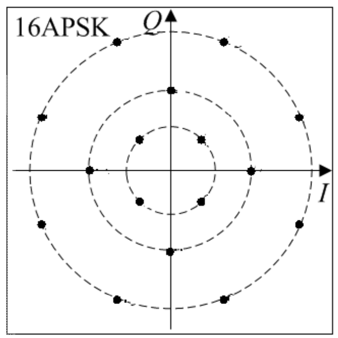
- Research on power allocation algorithm can be conducted based on good channel modeling

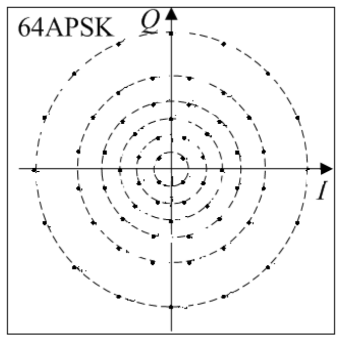
Future Work

- Training sequence in frequency domain helping remove the noise enhancement effect for the channel estimation
- BICM-ID for better error correction performance



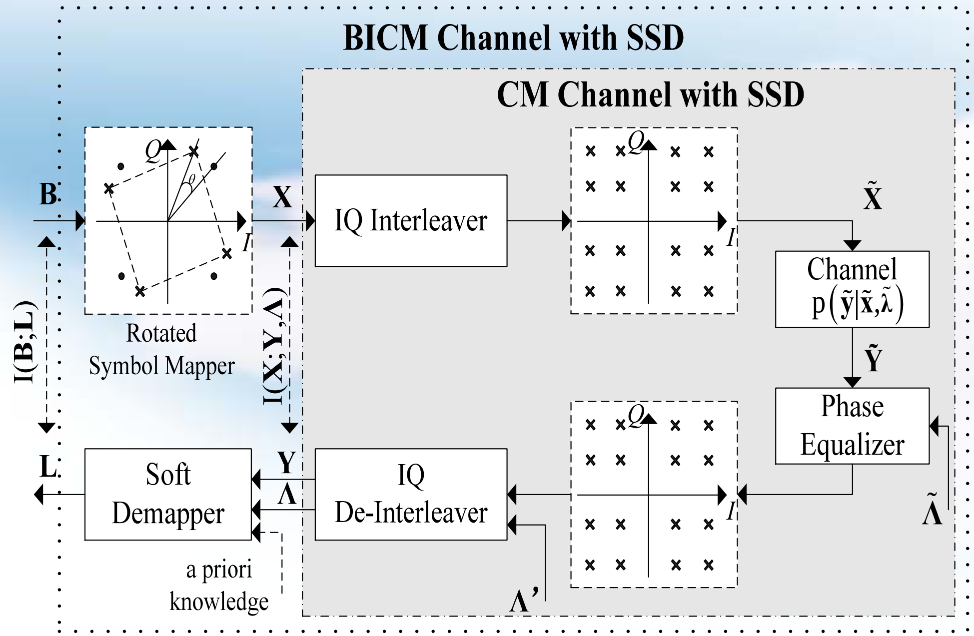


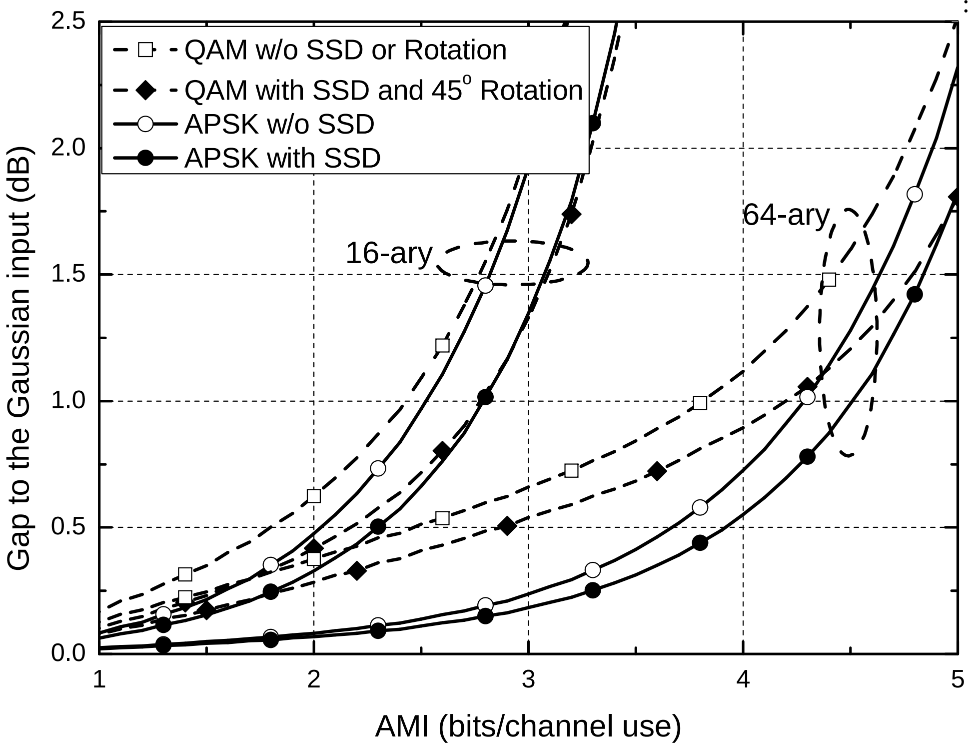




Only Gaussian inputs achieve the AWGN channel capacity. circular APSK rather than square QAM constellations seem closer to Gaussian inputs.

Future work





Gaps between the DCMC capacity and the channel capacity. **APSK plus Signal Space Diversity (SSD)** over i.i.d. Rayleigh fading channels.

References

1. H. Liu, et al., “Channel Study for Medium-voltage Power Network”, IEEE International Symposium on PowerLine Communications and its Applications 2006, P.245-250, Florida, USA.
2. J. Song, et al., “Field Trial of Digital Video Transmission over Medium-Voltage Powerline with Time Domain Synchronous Orthogonal Frequency Division Multiplexing Technology”, IEEE International Symposium on PowerLine Communications and its Applications 2007, pp.559-564, Pisa, Italy
3. Z. Yang, et al., “Labeling optimization for BICM-ID systems,” *IEEE Commun. Letters*, vol. 14, no. 11, pp. 1047–1049, Nov. 2010.
4. H. Zhang, et al., “A Hughes-hartogs algorithm based bit loading algorithm for OFDM systems”, ICC 2010, Cape Town, South Africa.
5. Dai LingLong, et al., “A Novel Time Domain Synchronous Orthogonal Frequency Division Multiple Access Scheme”, IEEE Globecom 2009.

Thank you for your attention!

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