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Deep Joint Source-Channel Coding for Wireless Image Transmission

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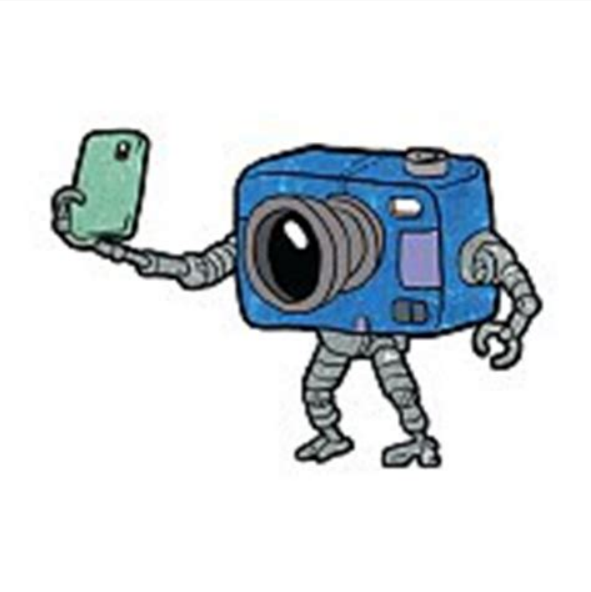
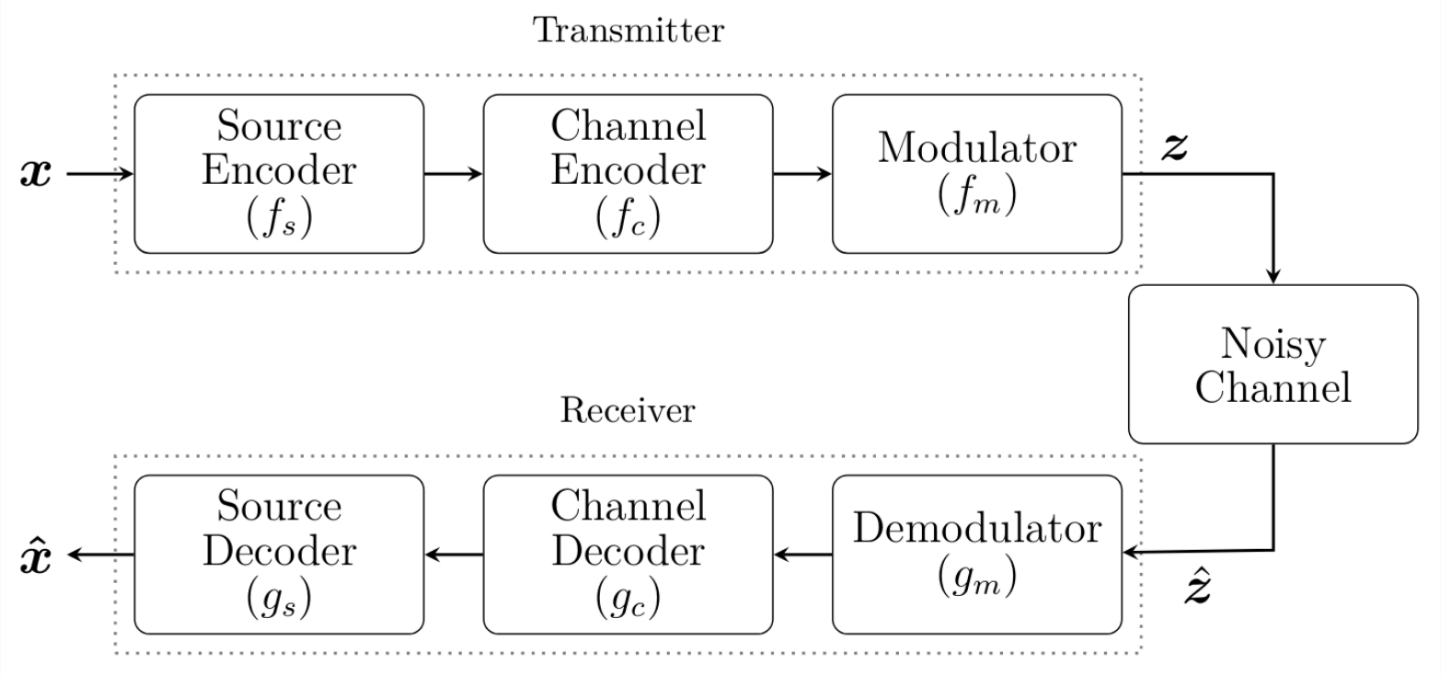
Motivation

- Increasing applications involving transmission and consumption of images in human-human, human-machine (e.g. AR, VR, telepresence) and machine-machine (e.g. pattern recognition, automation) interactions
- Particularly, how to deal with image/video transmission under extreme low latency, small bandwidth and energy constraints?



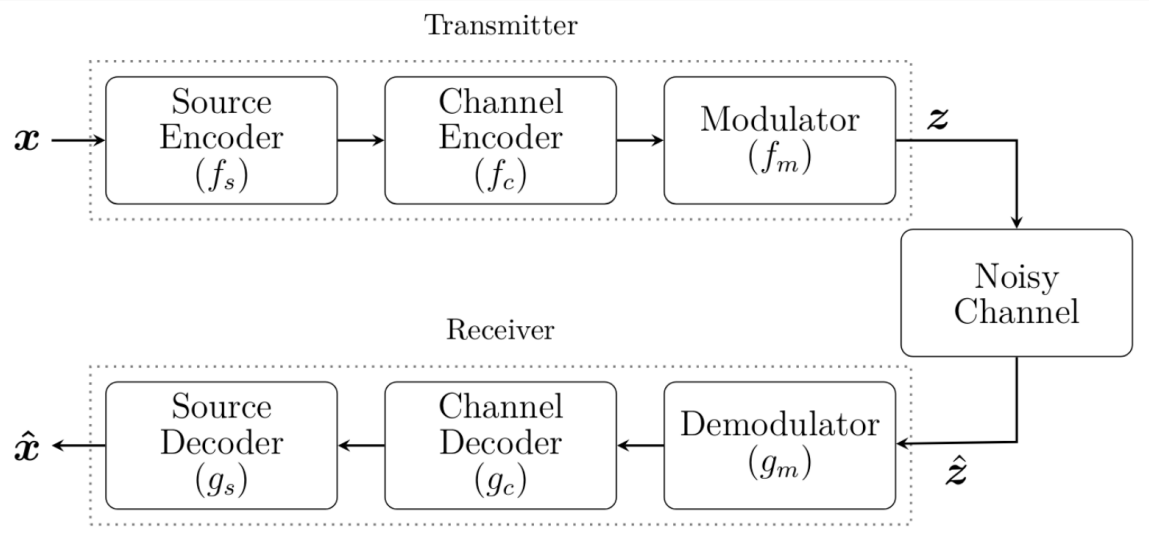
Wireless Image Transmission

How information is transmitted over a noisy channel?



- Shannon's Separation Theorem: First compress underlying source into bits; Then, transmit bits over noisy channel reliably
- Highly efficient compression algorithms (e.g. JPEG, JPEG200, WebP) and near-optimal channel codes (LDPC, Turbo codes) approach theoretical limits

Wireless Image Transmission

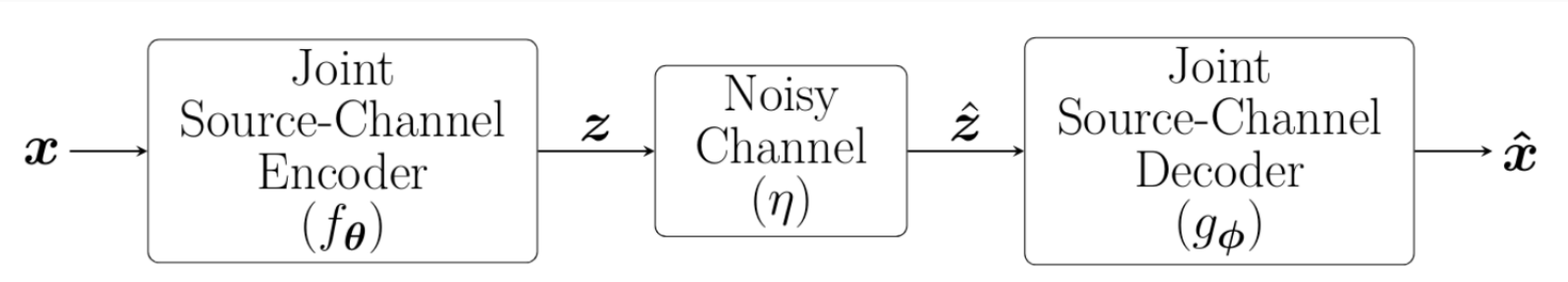


Challenges brought by modern requirements:

- Optimally holds only for infinite blocklength and complexity
- Design assumes a specific channel quality, being vulnerable to changes, variations or non-ergodic channels
- No separation theorem for multi-user networks: when broadcasting to many users, target the worst one

Proposed System - Joint Source Channel Coding

Can we learn to do better?

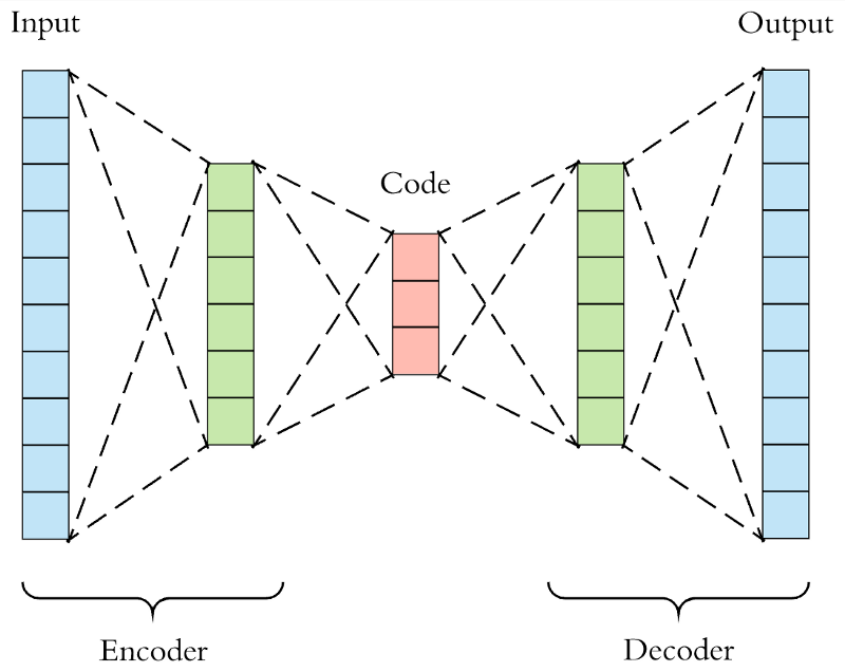


- Can we learn a direct mapping from pixel values to channel input symbols?
- Can this optimal mapping be learned directly from data, without the need of prior models?

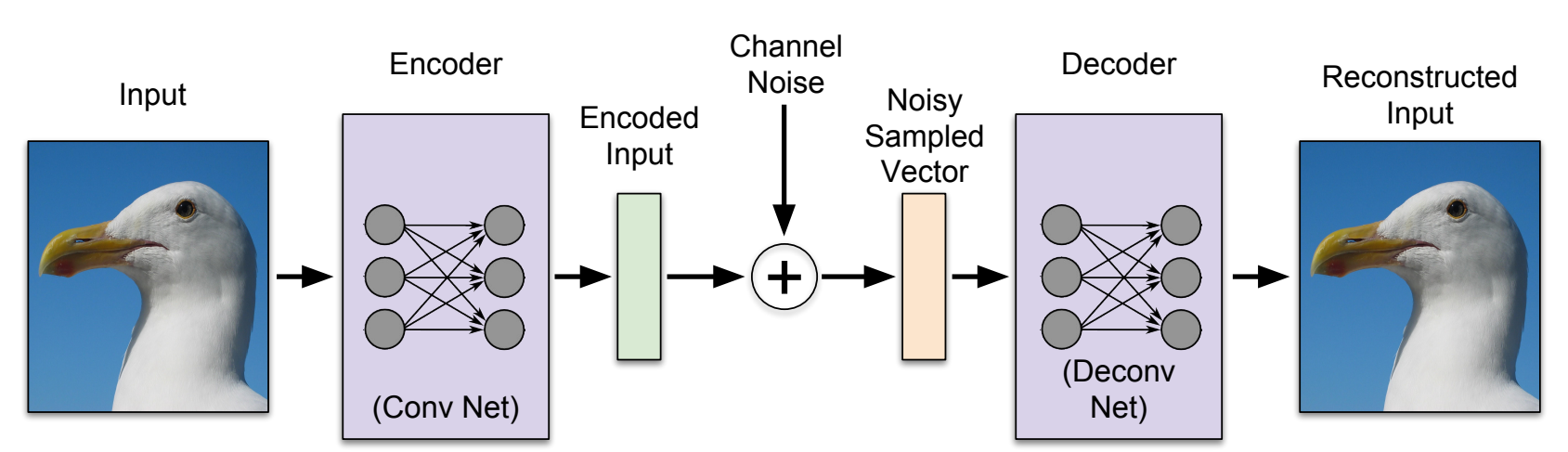
Proposed Solution

Autoencoders

- Unsupervised learning: two neural networks trained together
- Similarities to digital communication systems
- Successfully applied in compression; design of channel code; blind channel equalization; etc.

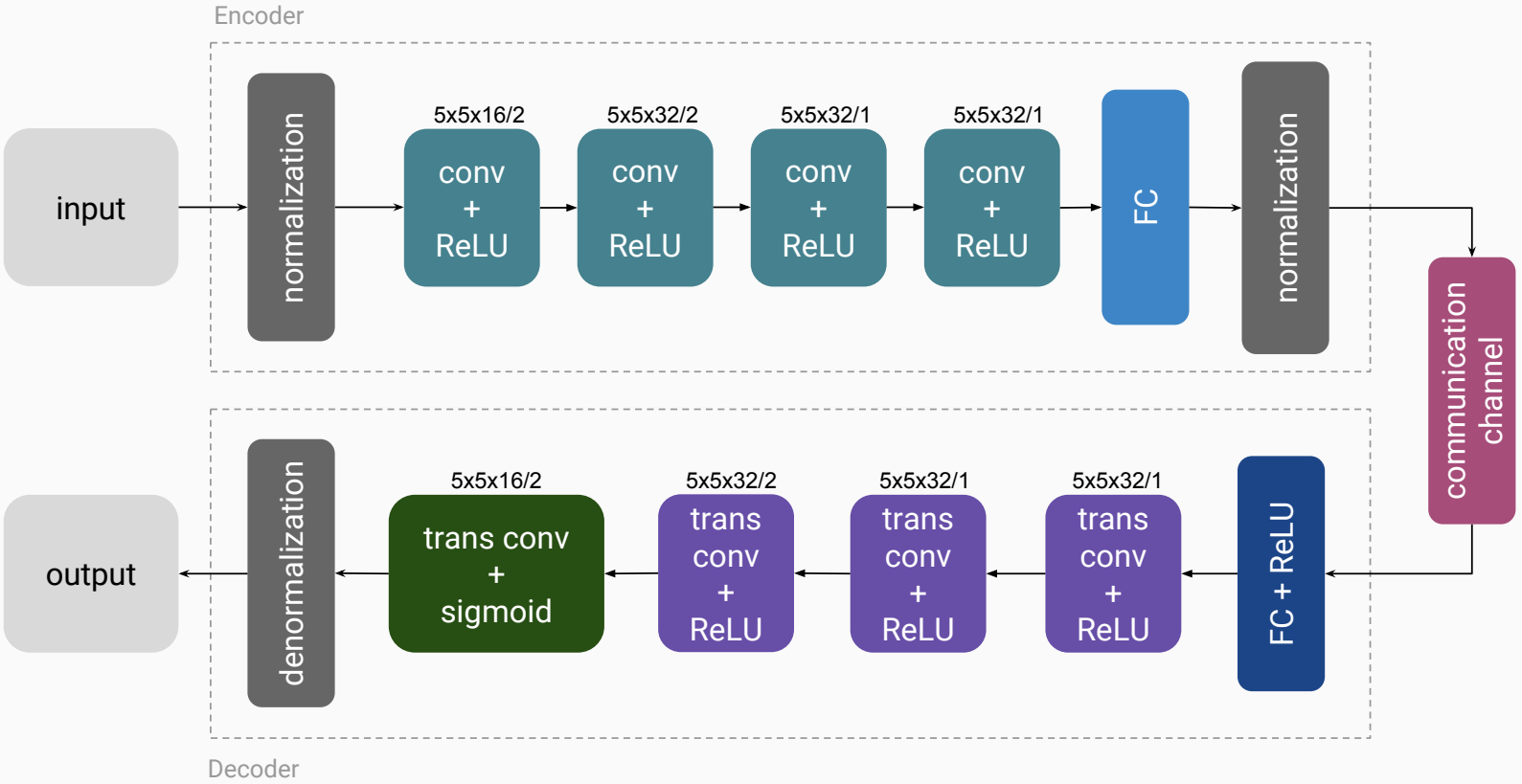


Proposed Model - Deep JSCC



- Noisy channel added as non-trainable layer
- Directly mapping to channel: no bits conversion, speeding up the process and exploiting channel coding compression
- Coherent mapping: similar content stay close to each other

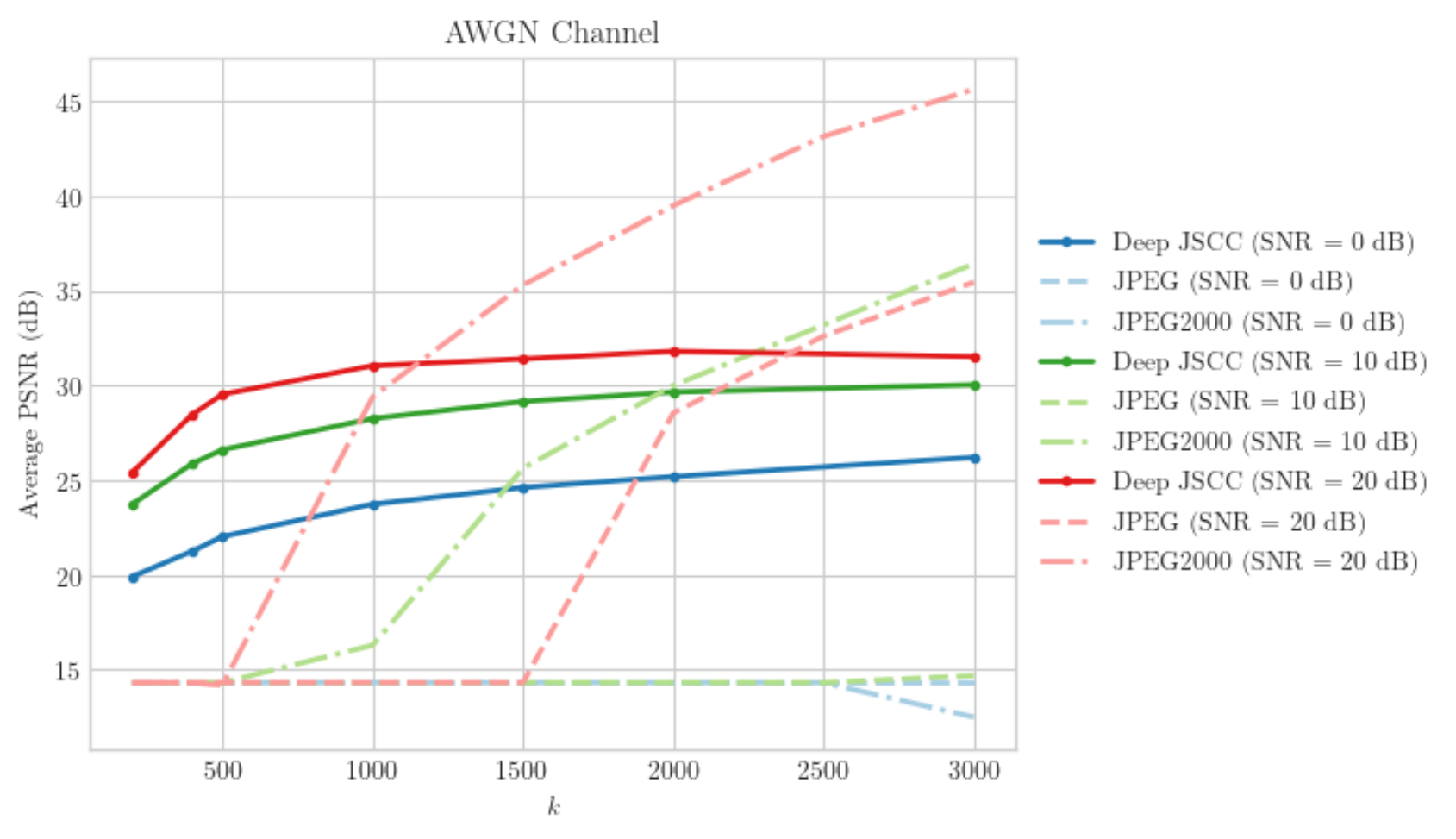
Proposed Model - Deep JSCC



- Low-delay: bandwidth compression
- Low-energy: average power constraint

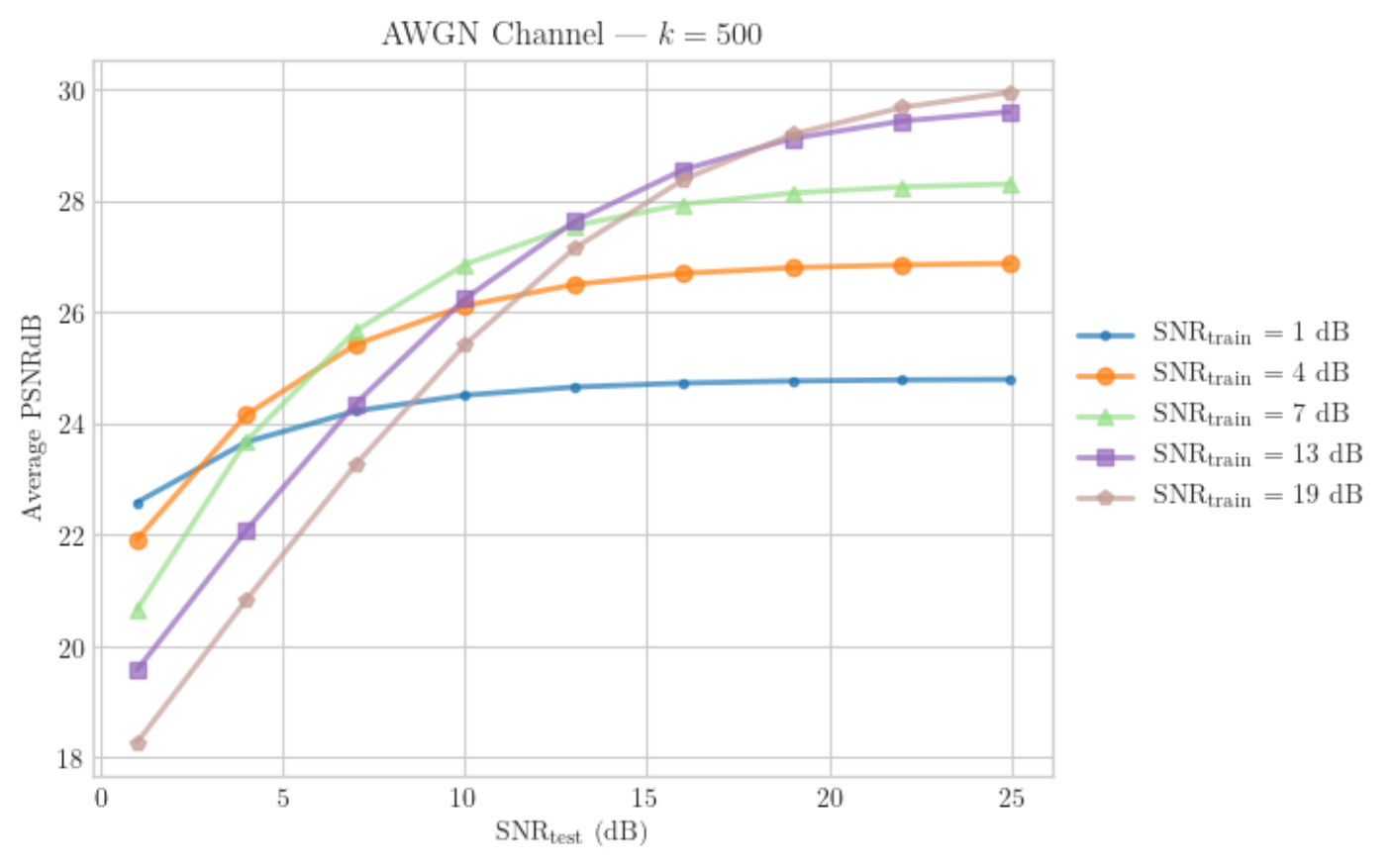
Evaluation

AWGN Channel - Performance by Bandwidth



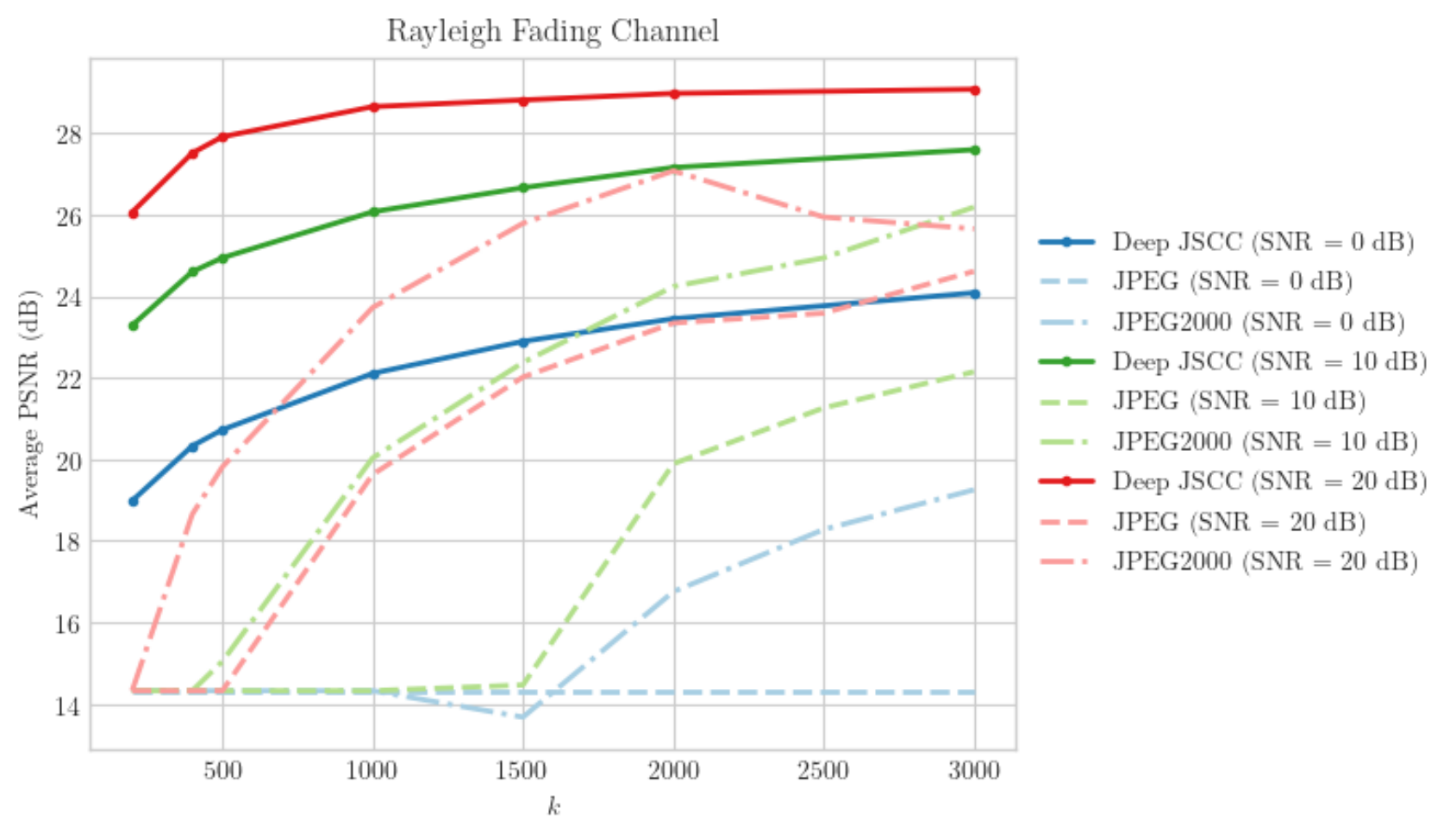
- Significant improvement to separation-based digital transmission for low SNR and low channel bandwidth

AWGN Channel - Performance by Channel SNR



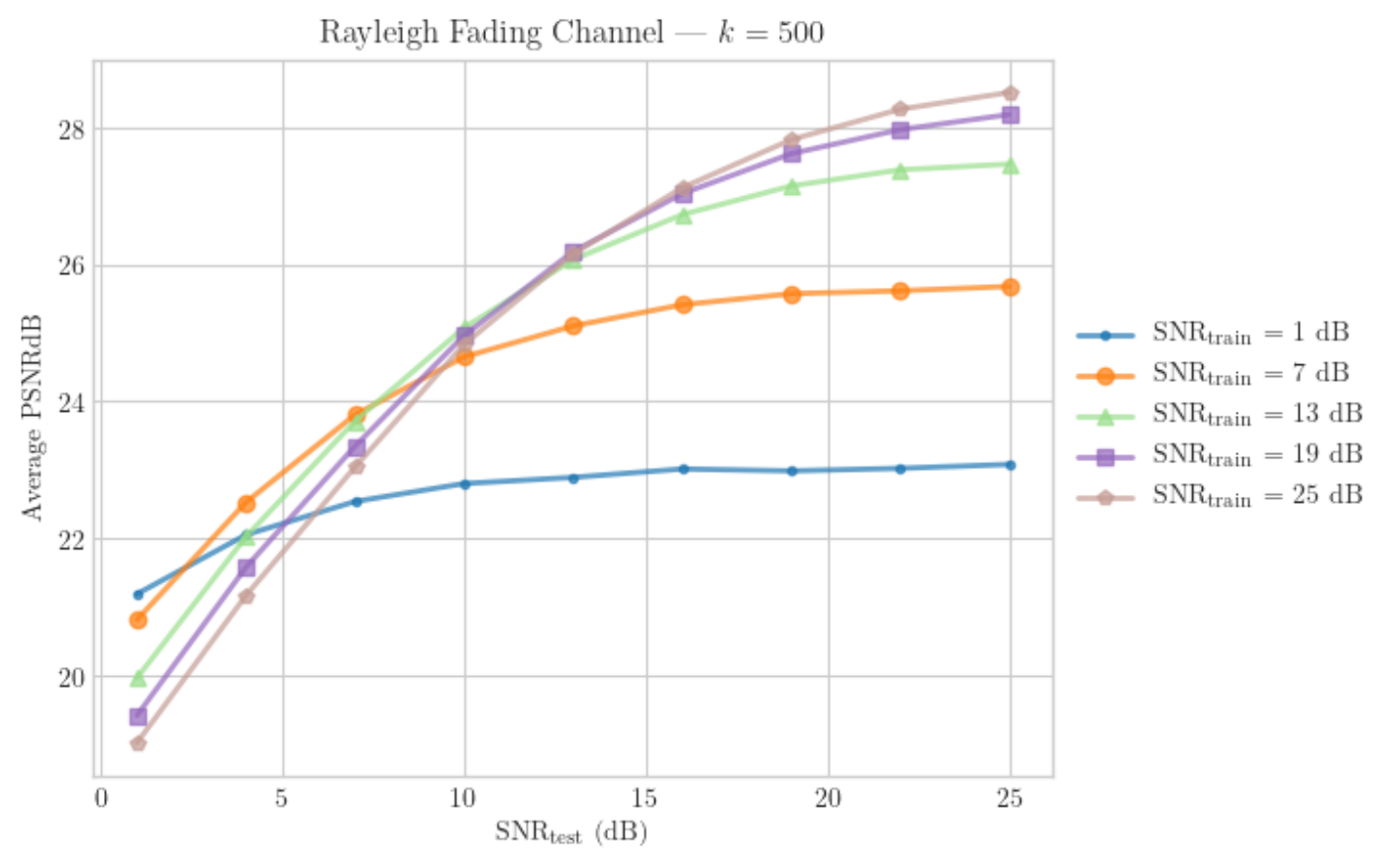
- Optimise for one SNR, deploy to different channel conditions
- Not affected by the “cliff effect”: graceful degradation
- More like analog communications than digital!

Fading Channel - Performance by Bandwidth



- Time-varying channel or multiple receivers scenarios
- Significantly outperforms separation-based digital communication at all SNR and channel bandwidth values

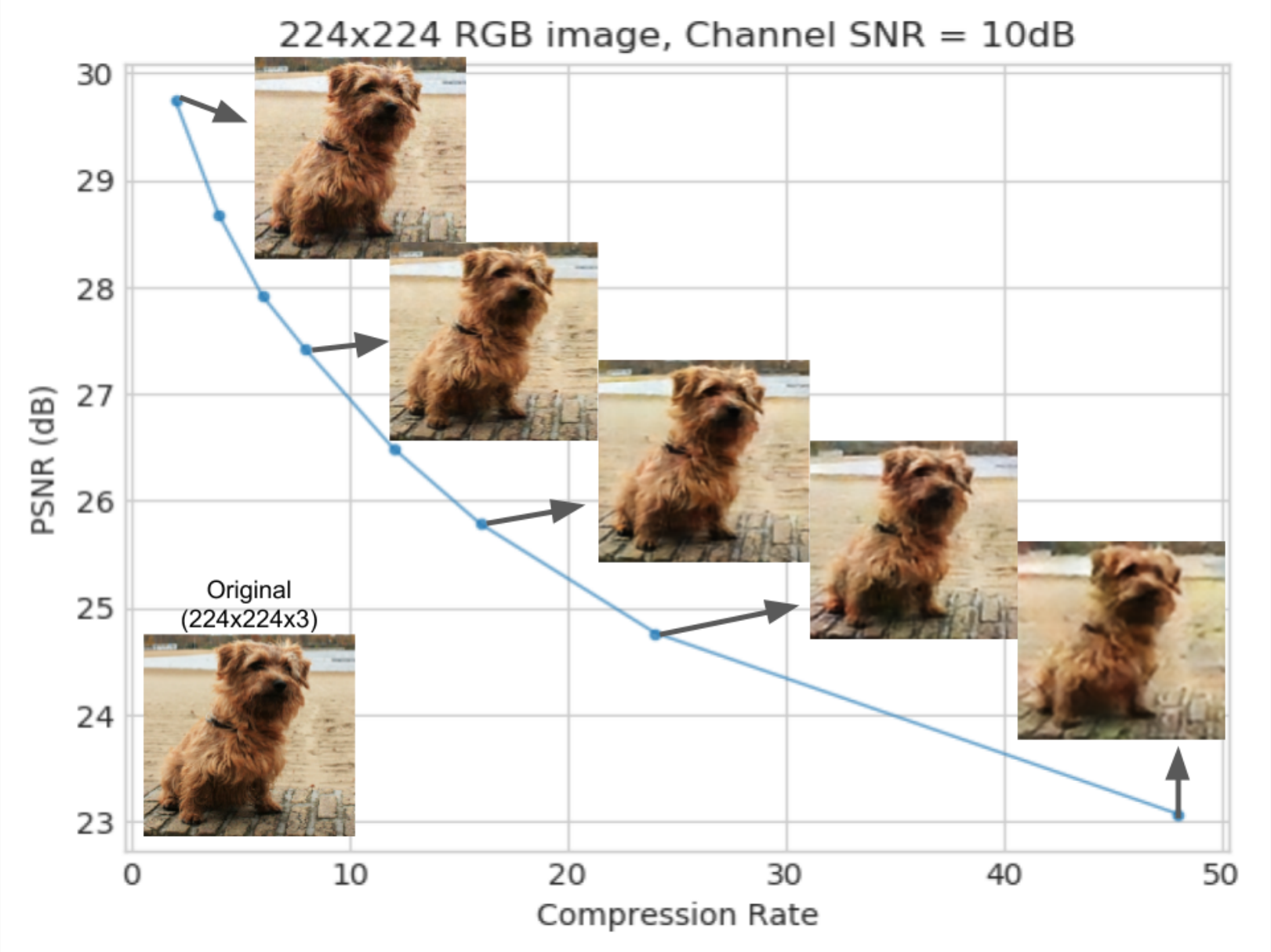
Fading Channel - Performance by channel SNR



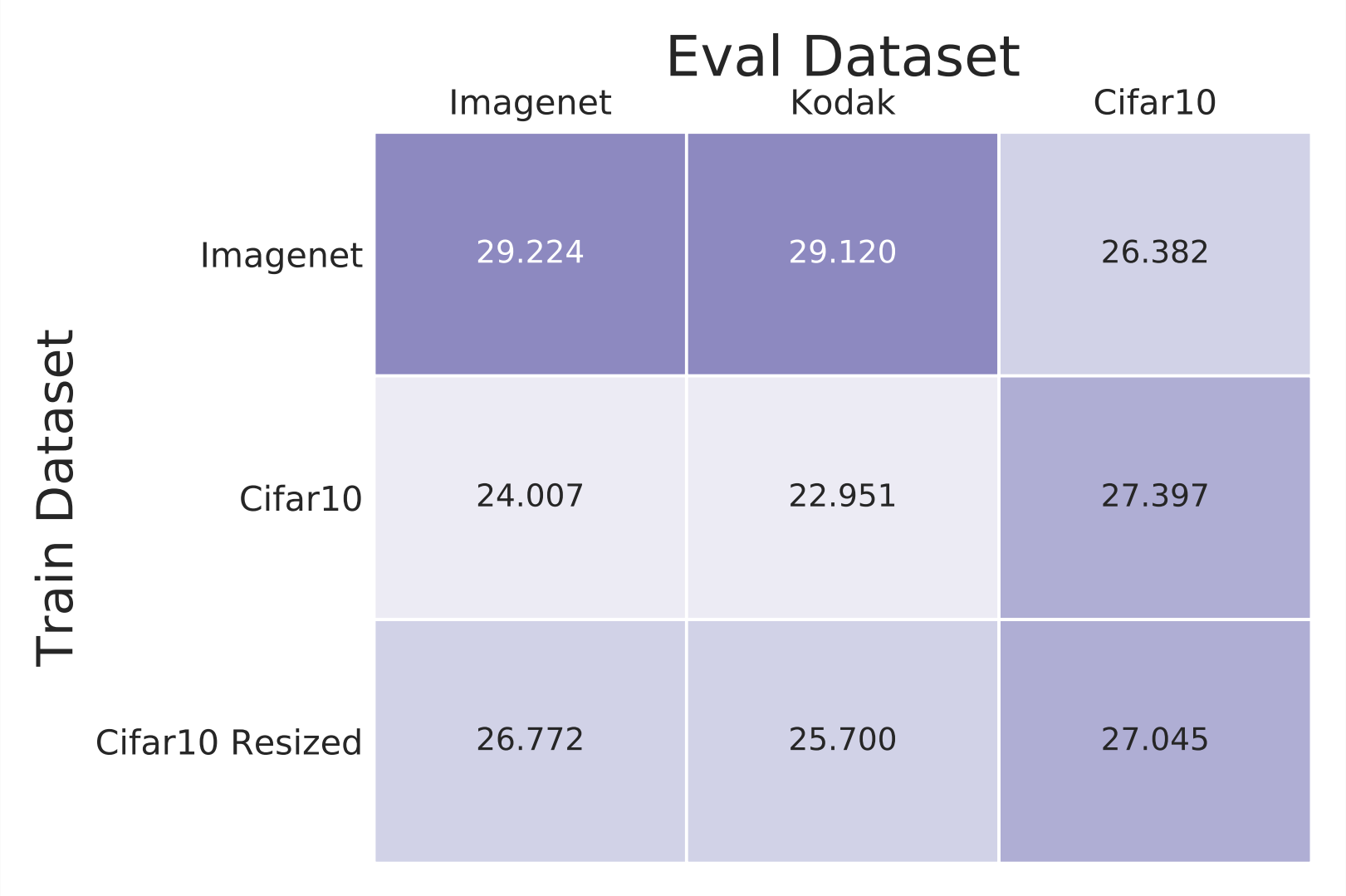
- No pilot signal or explicit channel estimation!

Extensions

Fully Convolutional Network

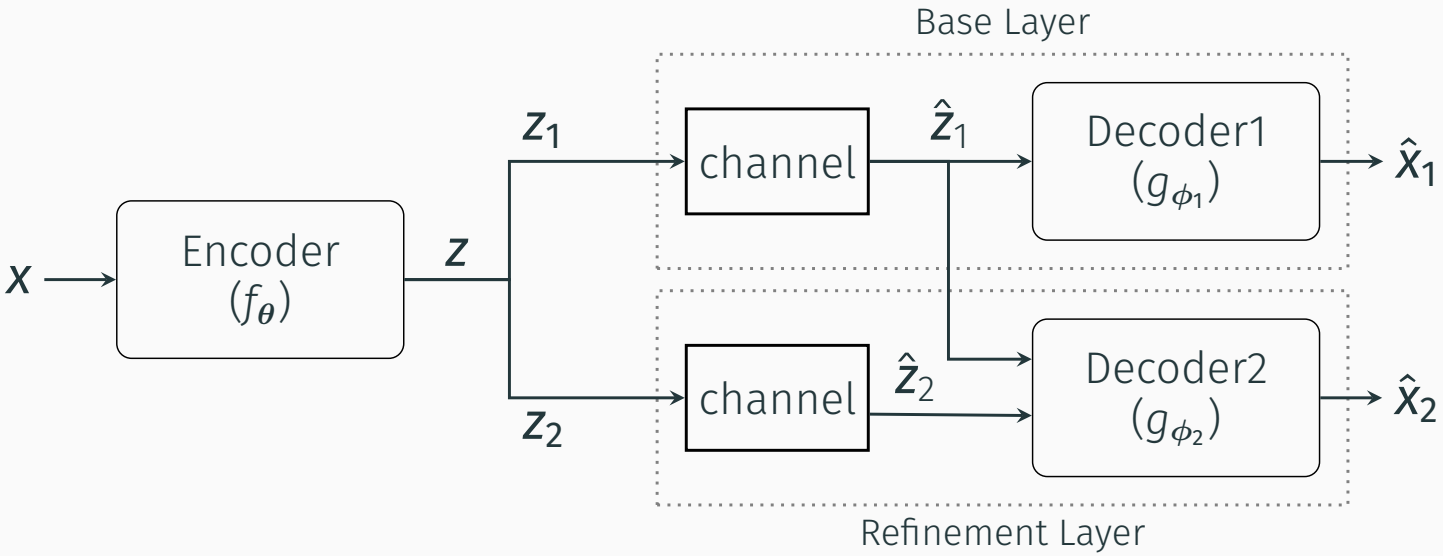


Generalisation Capacity

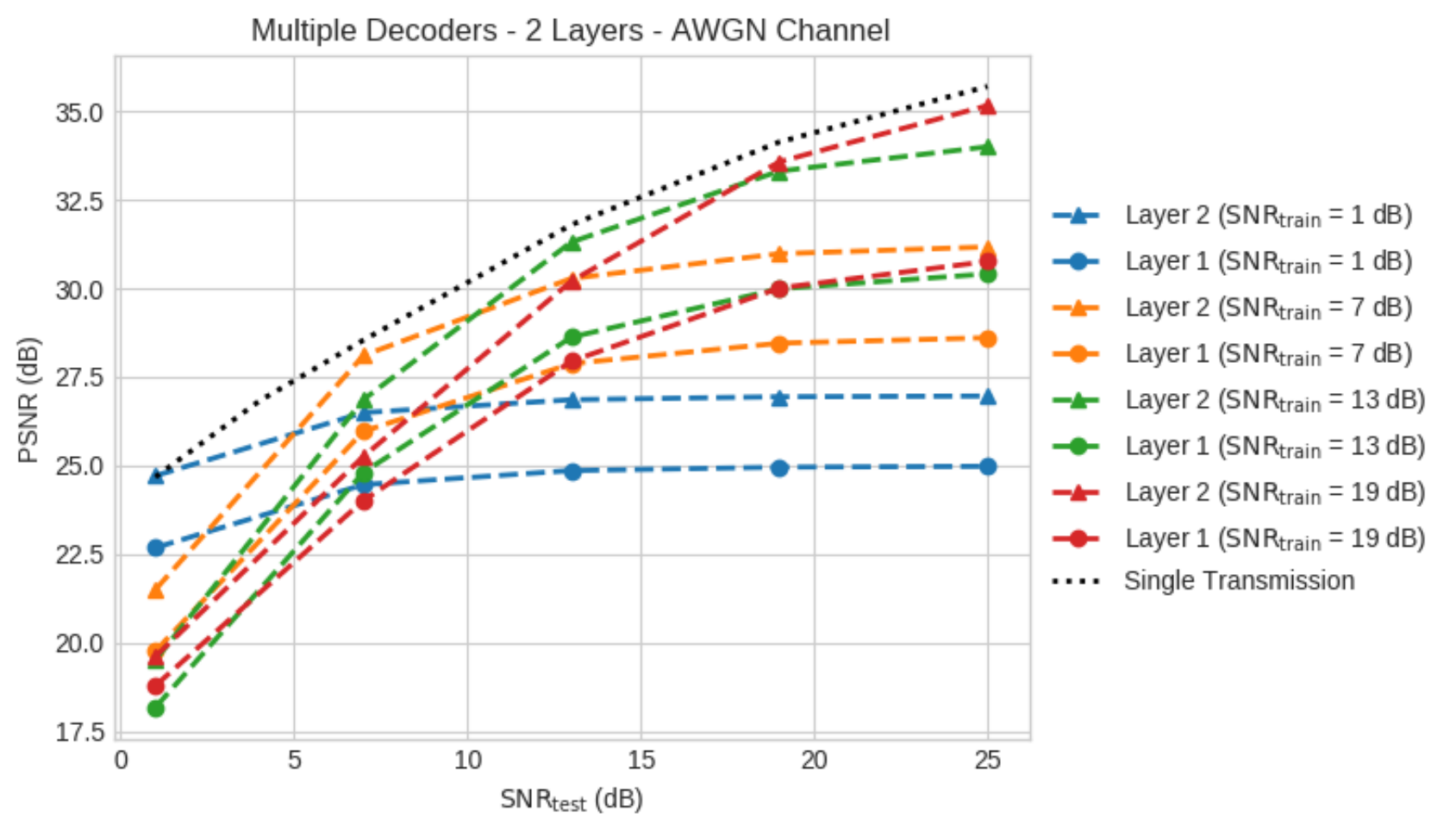


(Compresion Rate = 3; SNRtr = SNRts = 7dB)

Successive Refinement



Succesive Refinement



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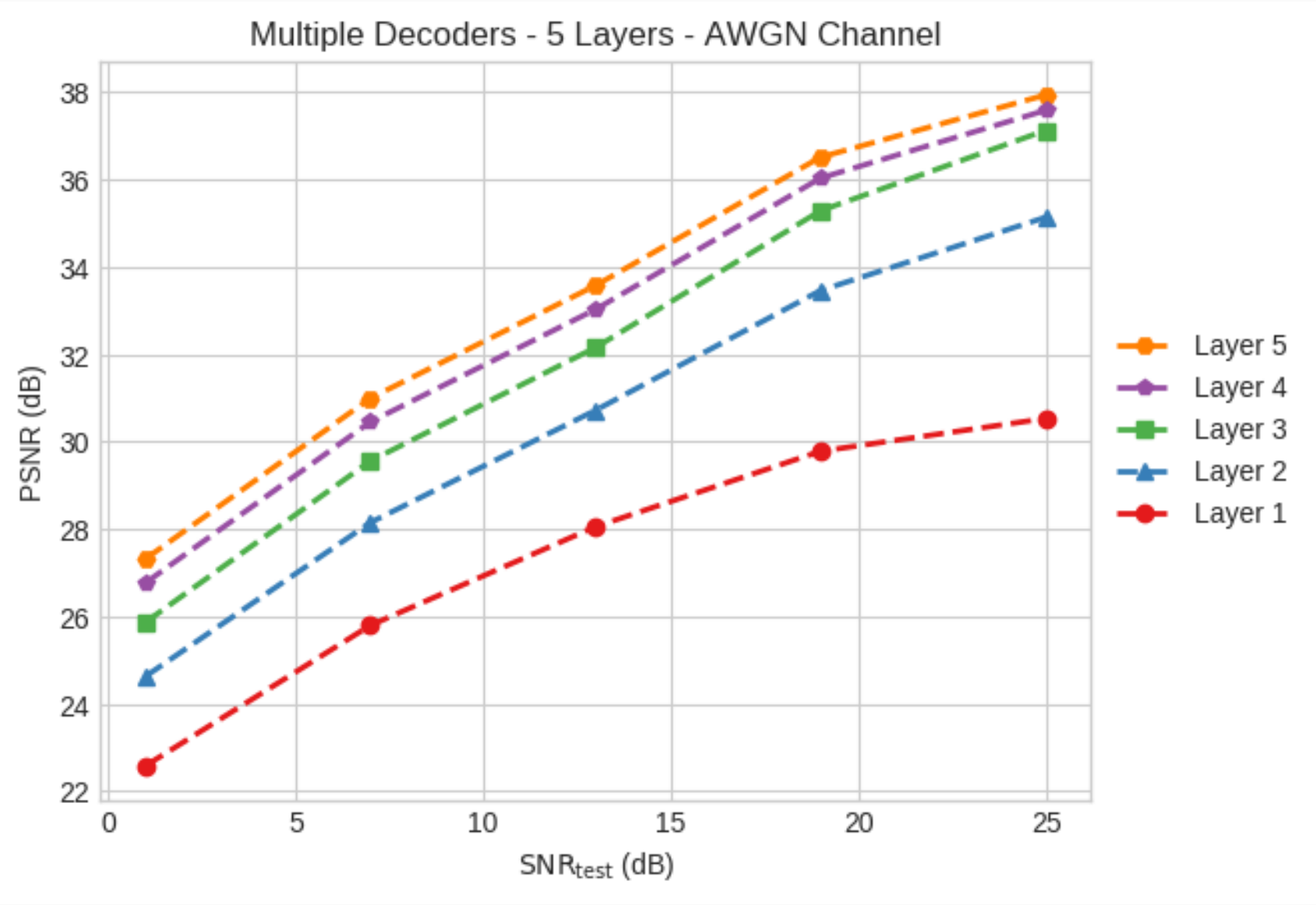

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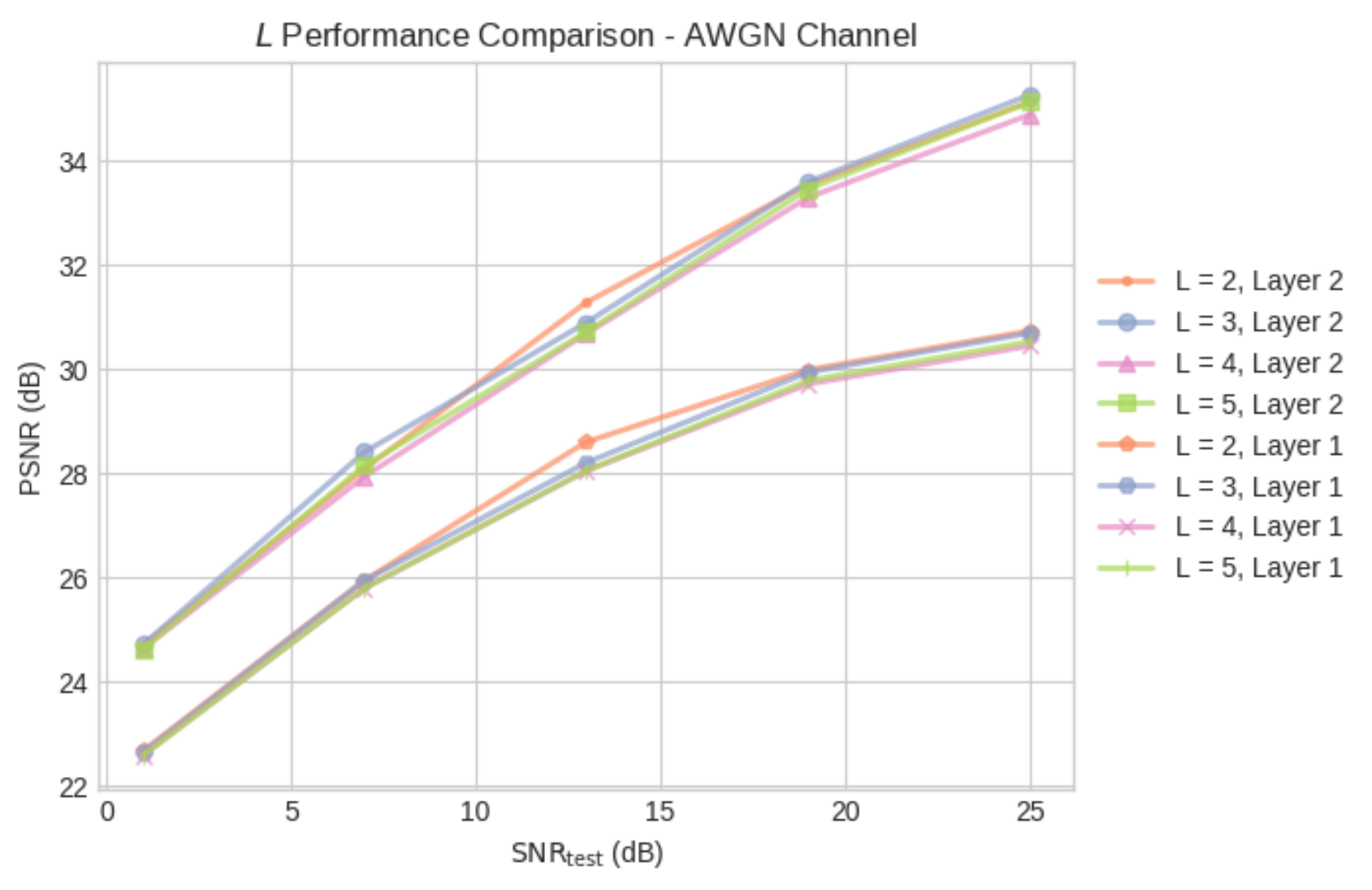


Conclusion

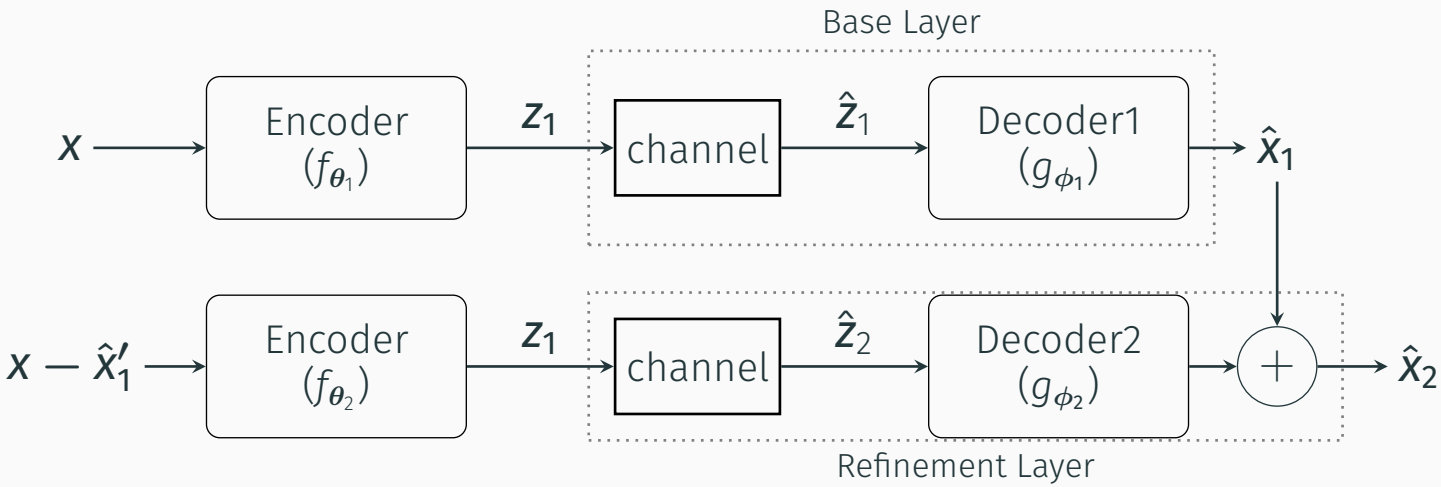
Final Remarks

- Novel deep JSCC architecture for image transmission over wireless channels under low latency, bandwidth and energy
- Proposed model outperforms state-of-the-art separation-based transmission schemes, especially for limited channel bandwidth and SNR
- Absence of cliff effect and graceful degradation of the reconstruction quality with channel SNR
- Ability to communicate without explicit channel estimation

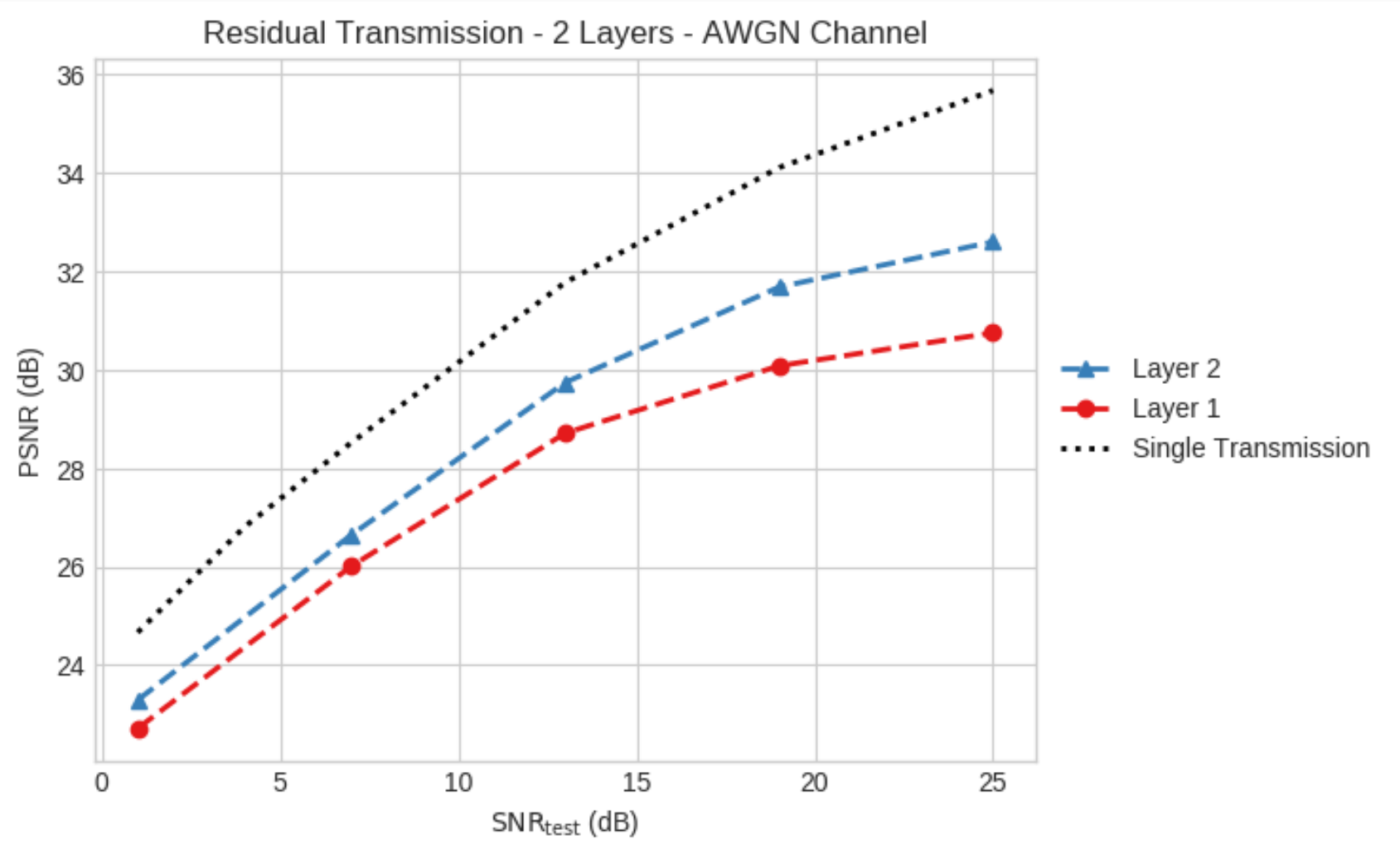
Thank you!

Appendix

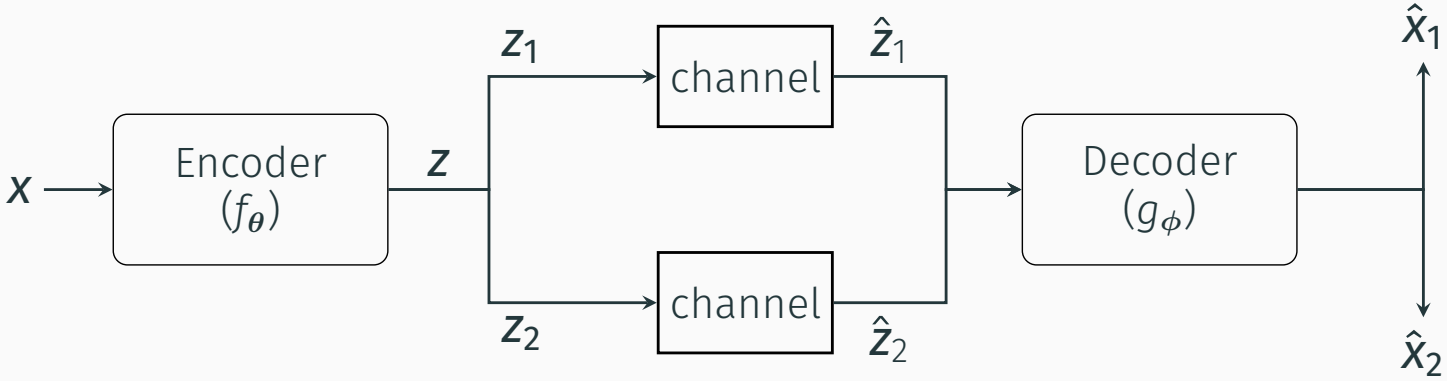
Successive Refinement - Residual Transmission



Successive Refinement - Residual Transmission



Successive Refinement - Single Decoder



Successive Refinement - Single Decoder