Low Complexity Channel Estimation Scheme for Spectrally Efficient FDM Systems in 5G Cellular Networks

Hedaia Ghannam and Izzat Darwazeh

Department of Electronic & Electrical Engineering
University College London, UK

Agenda

- Waveform Design for 5G
- SEFDM concept
- Channel estimation challenge for SEFDM
- Existing channel estimation schemes
- Application scenario
- Results
- Conclusions

Trends in the 21st Century

More users

More data

User Demand
>>
Network Supply

More devices

More speed

More mobility

Waveform Design for 5G - 1

Characteristics:

- Aim for higher spectrum efficiency
- Time-frequency squeezing
  - Reduced frequency spacing
  - Increased pulse duration
- Non-orthogonal signals
- Pulse shaping
- Advanced detectors (soft-/sphere- decoding)

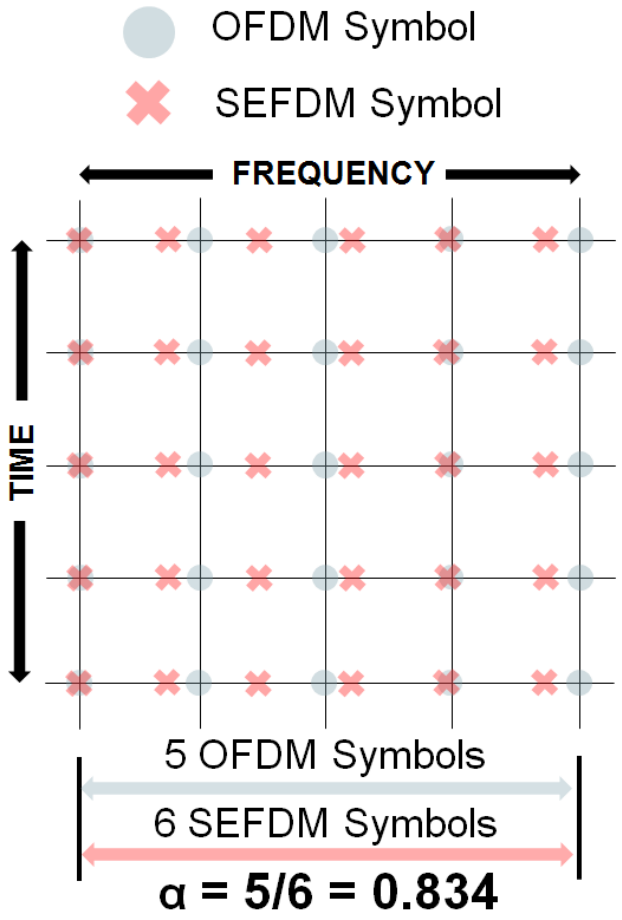
Waveform Design for 5G - 2

Research:

- SEFDM (UCL, Wireless)
- Multistream Faster-than-Nyquist (Lund, Wireless)
- Time-Frequency Packing (Parma, Optical)
- Fast OFDM (UCL and Aston University, Optical)
- Non-OFDM (nOFDM) (Oulu,Wireless)
- GFDM (Dresden, Wireless / Cognitive Radio)
- Other Contenders: FBMC, UFMC
- Projects (FP7): METIS, 5GNOW

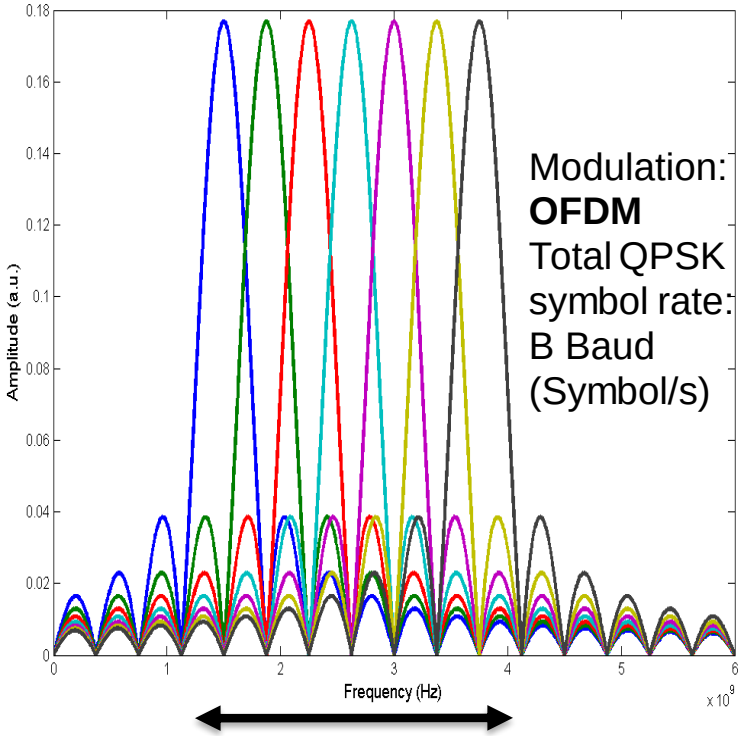
SEFDM

(M. Rodrigues and I. Darwazeh, "A spectrally efficient frequency division multiplexing based communications system," in Proc. 8th Int. OFDM Workshop, Hamburg, 2003, pp. 48 – 49.)

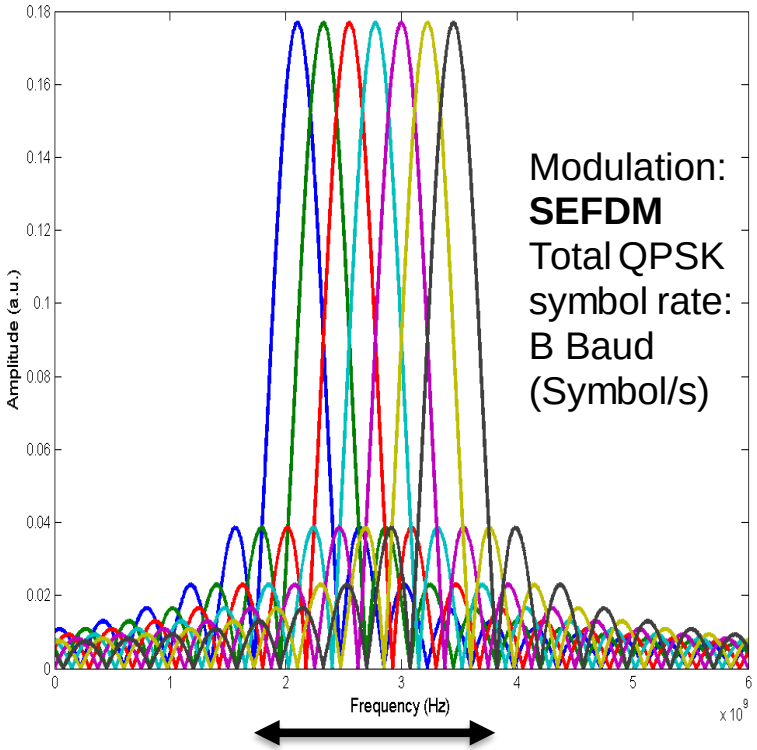


SEFDM: increase spectral efficiency by reducing the spacing between adjacent sub-carriers

Bandwidth Saving vs. ICI



Bandwidth ≈ B Hz
No ICI



Bandwidth ≈ α·B Hz, 0<α<1
With ICI

- Multiple subcarrier modulation format
- Enables tunable bandwidth "compression"
- Think of OFDM but with less than orthogonal subcarrier spacing

Spectrally Efficient Frequency Division Multiplexing (SEFDM)

- The subcarriers separation Δf is only a fraction of the inverse of the FDM symbol period T.
- the bandwidth gain achieved is $(1-\alpha)\times 100\%$.
- $z_{k,n}$ is a complex M-level modulated signal on the n^{th} subcarrier of the k^{th} symbol and α is the compression factor.

$$x[k] = \frac{1}{\sqrt{N}} \sum_{k=-\infty}^{\infty} \sum_{n=0}^{N-1} z_{k,n} \exp\left(\frac{j2\pi\alpha kn}{N}\right)$$

$$\alpha = \Delta f \times T, where\ \alpha \leq 1$$

SEFDM over Multipath Channel

$$\mathbf{y} = \mathbf{H}\boldsymbol{\Lambda}\mathbf{z} + \mathbf{w}$$

ill-conditioned matrix

$\mathbf{y}$: demodulated symbols after FFT

$\mathbf{H}$: channel matrix

$\boldsymbol{\Lambda}$: Correlation matrix

$\mathbf{z}$: Transmitted complex symbols

$\mathbf{w}$: white noise (AWGN)

How to estimate the channel effect??

Channel Estimation Schemes for SEFDM

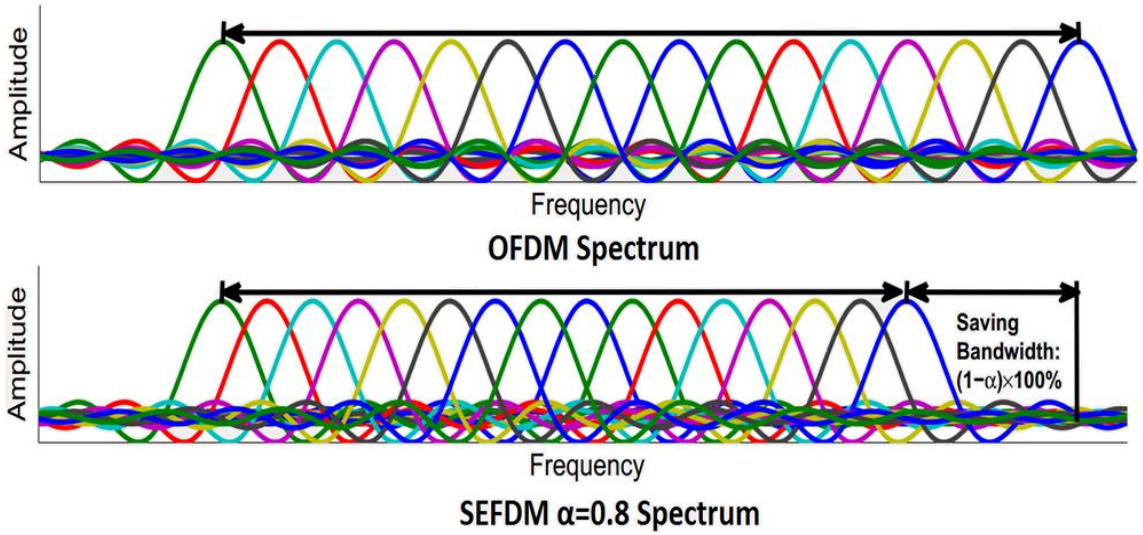
1) **Time domain**

2) **Frequency domain**

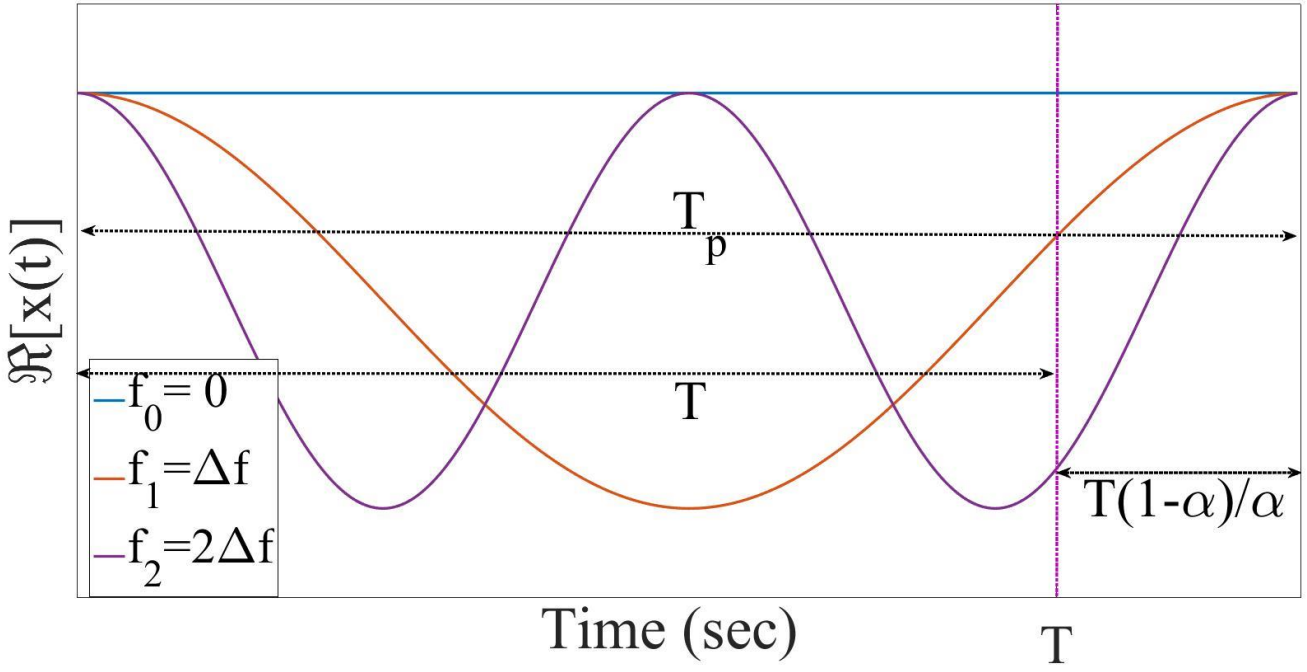
I: Partial channel estimation

II: OFDM with interpolation

III: OFDM without interpolation



OFDM pilot/ SEFDM Transmission Symbols (Time Domain)

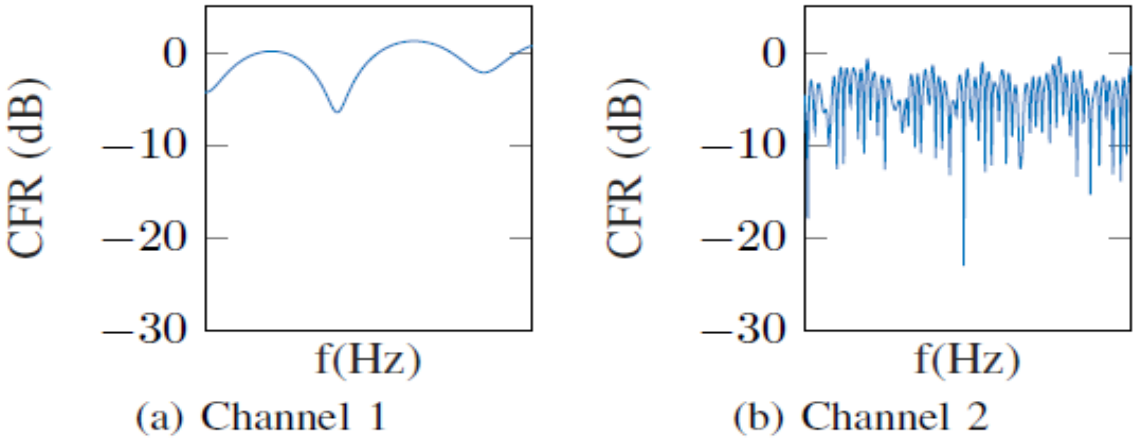


The real part of the pilot and data signals in the time domain

The mobile channel is time varying and frequency dependent

- **Channel 1:**

$$h(t) = 0.8765\delta(t) - 0.2279\delta(t - T_s) + 0.1315\delta(t - 5T_s) - 0.4032\exp(\frac{i\pi}{2})\delta(t - 7T_s)$$

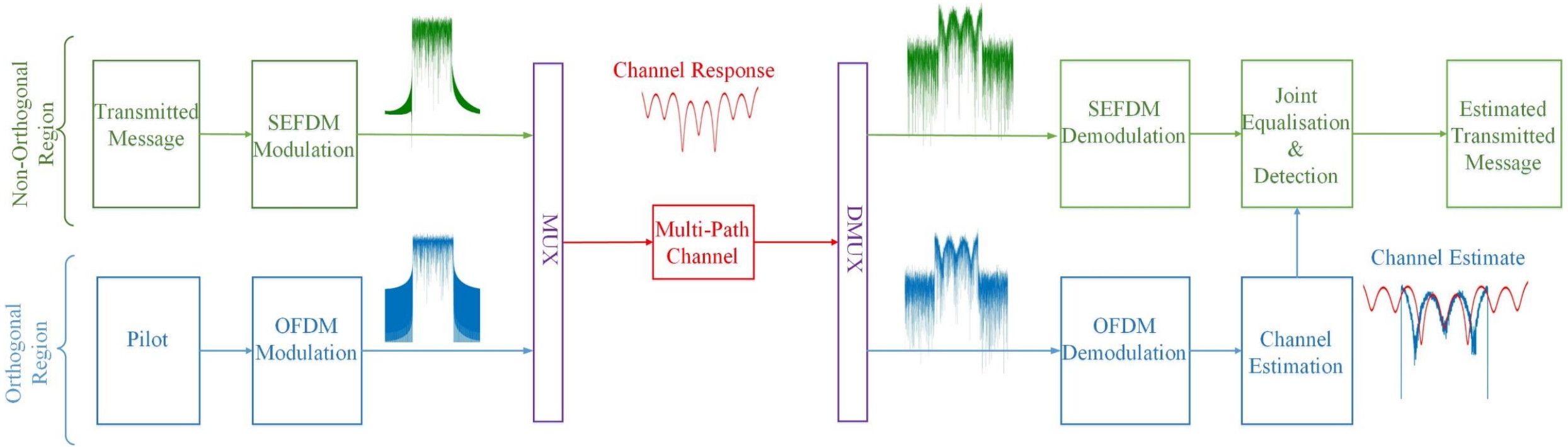


(a) Channel 1 (b) Channel 2

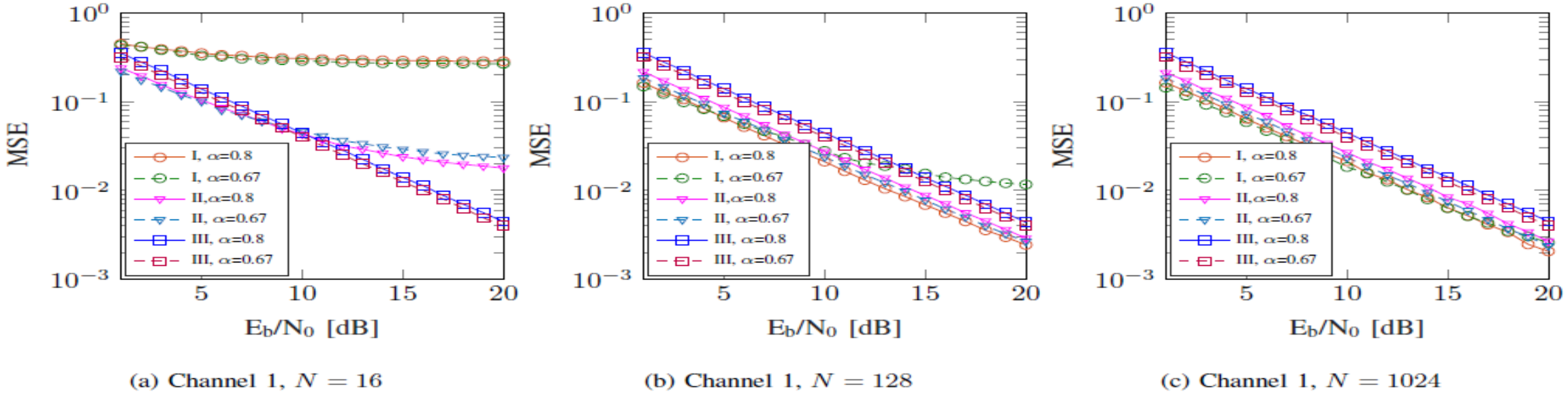
- **Channel 2:**

Rayleigh Channel (quasi-static)

Transceiver Block Diagram



Results



(a) Channel 1, $N = 16$ (b) Channel 1, $N = 128$ (c) Channel 1, $N = 1024$

(d) Channel 2, $N = 16$ (e) Channel 2, $N = 128$ (f) Channel 2, $N = 1024$

Conclusions

- Spectral efficiency → Key requirement in future systems.
- SEFDM can
  - Improve spectral efficiency
    - Improve data rate
    - Save bandwidth
- Channel estimation challenge
- A frequency domain channel estimation scheme is proposed.
- Simulation results and demonstrated for different channel scenarios.

Questions