Turbo Coded OFDM-OQAM using Hilbert Transform

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Overview

- The big picture
- OFDM
- Multicarrier communications (MC)
  - Theory
  - System model
  - Results
- Conclusions

The big picture

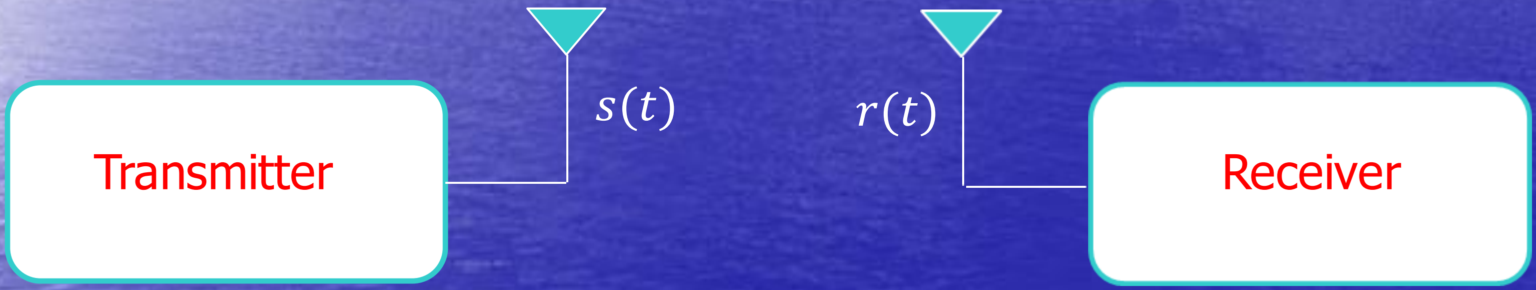
- Transmission of information signals through distorting (frequency selective) channels
- Received signal

$$r(t) = s(t) \star h(t) + w(t) \qquad (1)$$

  - $s(t)$ is the information
  - $h(t)$ is the channel, $\star$ denotes convolution
  - $w(t)$ is noise

The big picture

Fig 1



$$r(t) = \int h(\alpha) s(t-\alpha) \; d\alpha + w(t)$$

System model

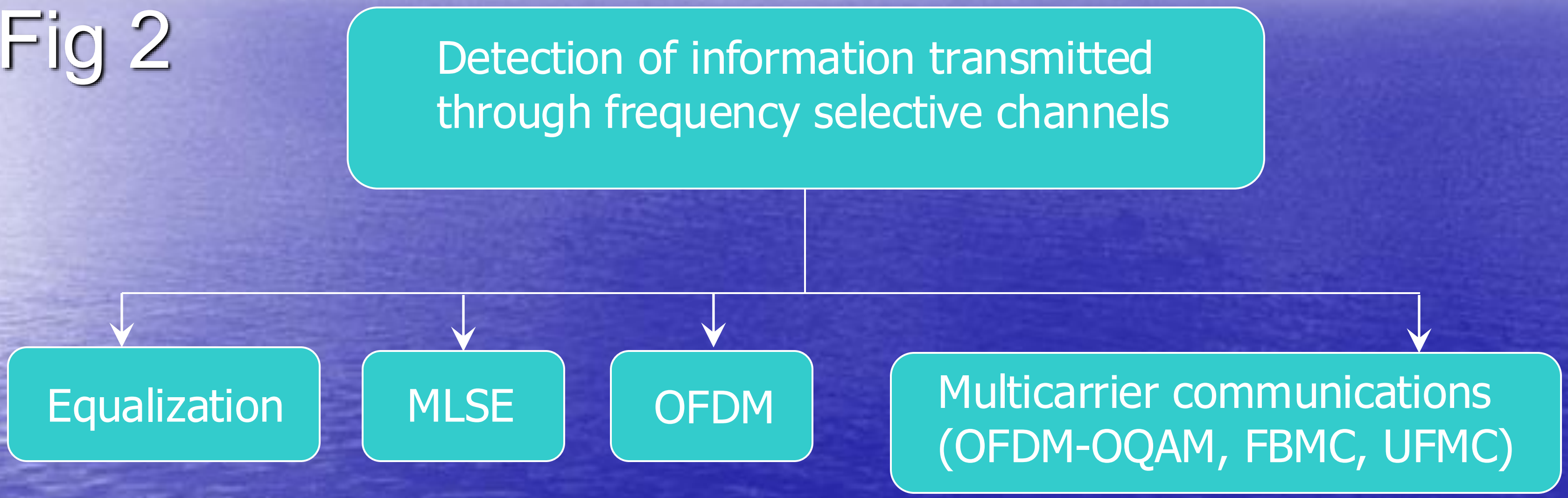
The big picture

Problem statement:

Find $s(t)$ given $r(t)$.

The big picture

Fig 2



Solutions

OFDM

- Convolution in the time domain results in multiplication in the frequency domain
- Eliminates inter symbol interference (ISI)
- Received signal

$$r_n = h_n \star s_n + w_n \qquad (2)$$

OFDM

Fig 3

$$r_n = \sum_l h_l s_{n-l} + w_n$$

$$R_k = H_k S_k + W_k$$

System model

OFDM

Problem

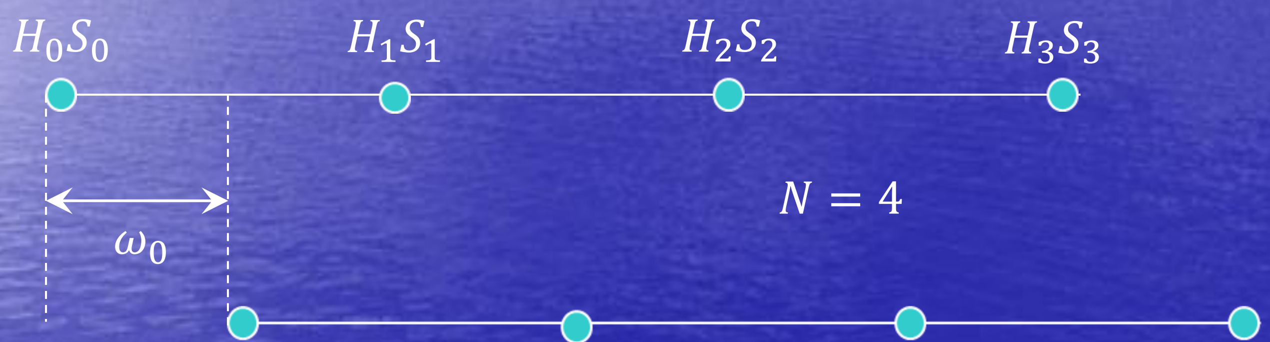
- Frequency offset
  - Due to relative motion between transmitter and receiver
  - Received signal

$$r_n = (h_n \circledast_N s_n)e^{\mathrm{j}\omega_0 n} + w_n \qquad (3)$$

  - ω_0 is the frequency offset
  - $\circledast_N$ denotes $N-$ point circular convolution

OFDM

Fig 4



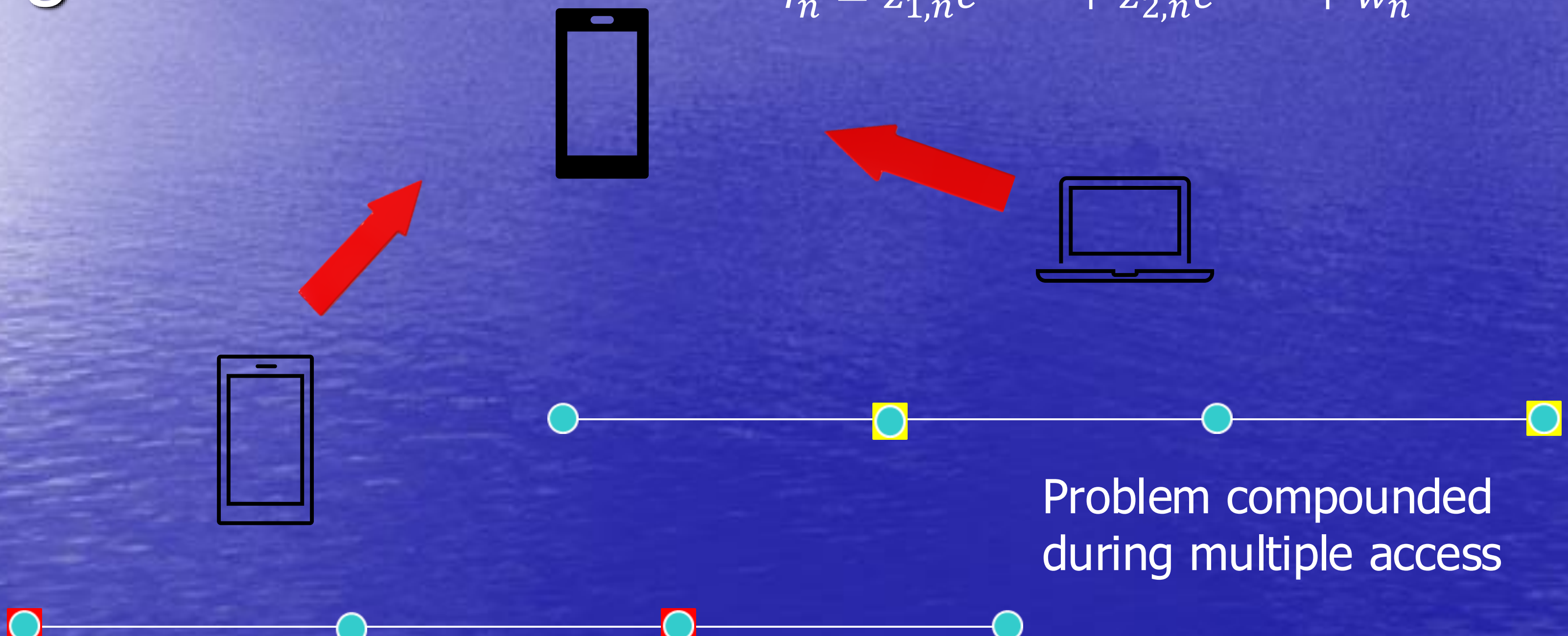
$$Z_{k,\omega_0} = \sum_{n=0}^{N-1} z_n \, e^{\mathrm{j}\omega_0 n} e^{-\mathrm{j}2\pi kn/N} \neq H_k S_k$$

$$z_n = h_n \circledast_N s_n$$

OFDMA

Fig 5

$$r_n = z_{1,n} e^{\mathrm{j}\omega_1 n} + z_{2,n} e^{\mathrm{j}\omega_2 n} + w_n$$



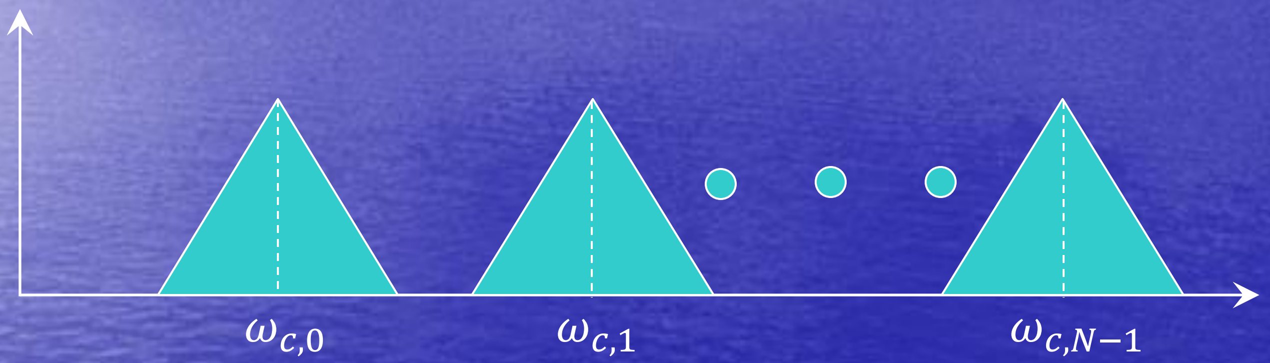
User 1 subcarrier   User 2 subcarrier

OFDMA

- ✓ Can be used if the frequency offset is cancelled at the transmitter
- ✓ Frequency offset information needs to be sent from receiver to transmitter

MC - Theory

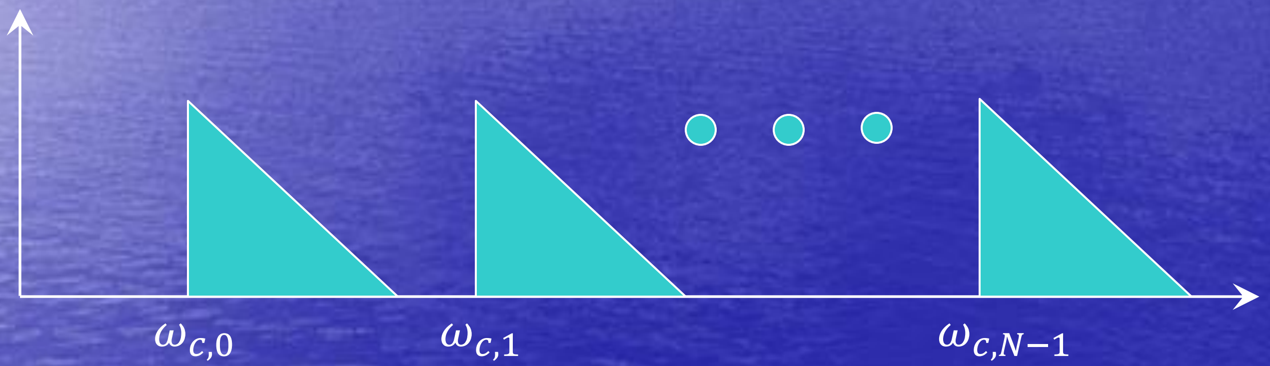
Fig 6



Solution - Use frequency division multiplexing for multiple access (multicarrier communications): OFDM-OQAM/FBMC/UFMC

MC - Theory

Fig 7



Use single sideband modulation for bandwidth efficiency

MC - Theory

- Let $p(t)$ denote the transmit filter
- Let $P(f)$ denote its Fourier transform
  - $p(t) \rightleftharpoons P(f)$
- Signal spectrum $\propto |P(f)|^2$
- Transmit filter can be complex-valued
  - $\tilde{p}(t) = p(t) + \mathrm{j}\hat{p}(t)$
  - $\hat{p}(t)$ is the Hilbert transform of $p(t)$

MC - Theory

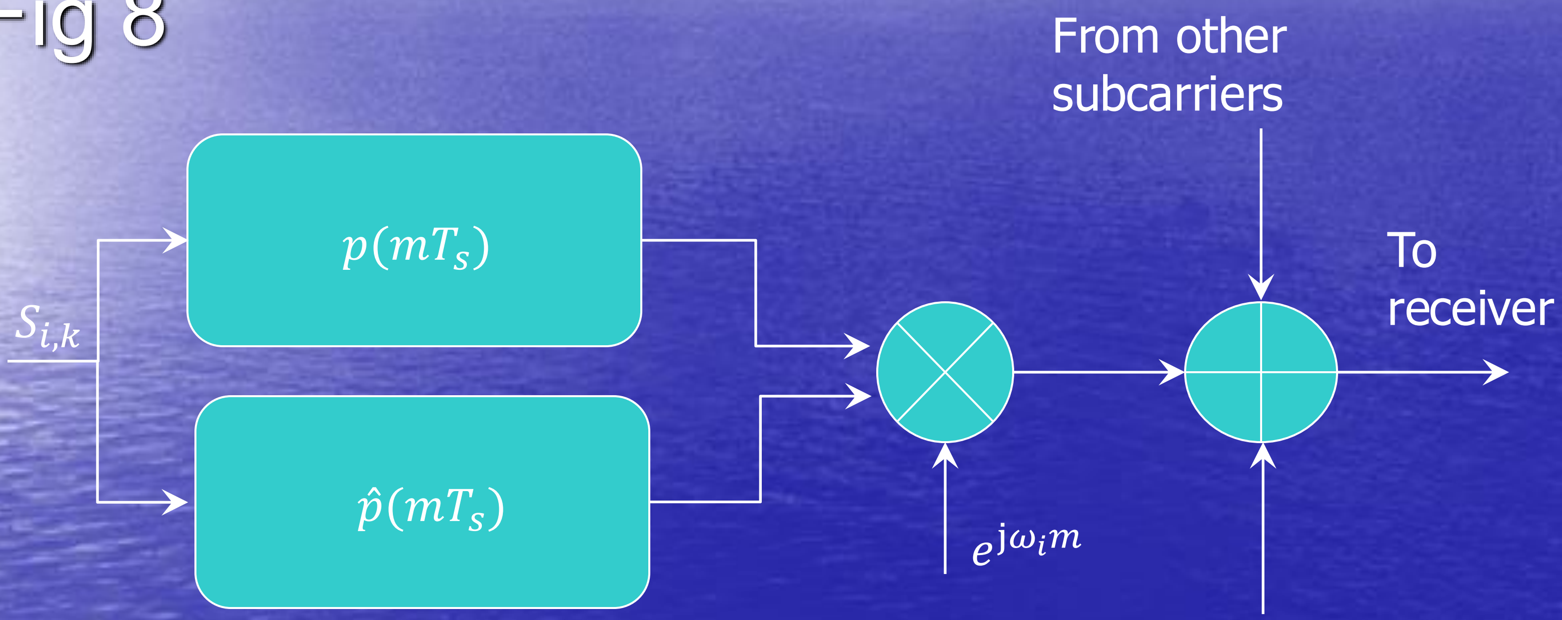
- Let $\tilde{p}(t) \rightleftharpoons \tilde{P}(f)$
- Then

$$\tilde{P}(f) = P(f) + \mathrm{j}(-\mathrm{j})\,\mathrm{sgn}(f)\,P(f)$$

$$\Rightarrow \tilde{P}(f) = \begin{cases} 2P(f) & \text{for } f > 0 \\ P(0) & \text{for } f = 0 \\ 0 & \text{for } f < 0 \end{cases} \qquad (4)$$

MC – System Model

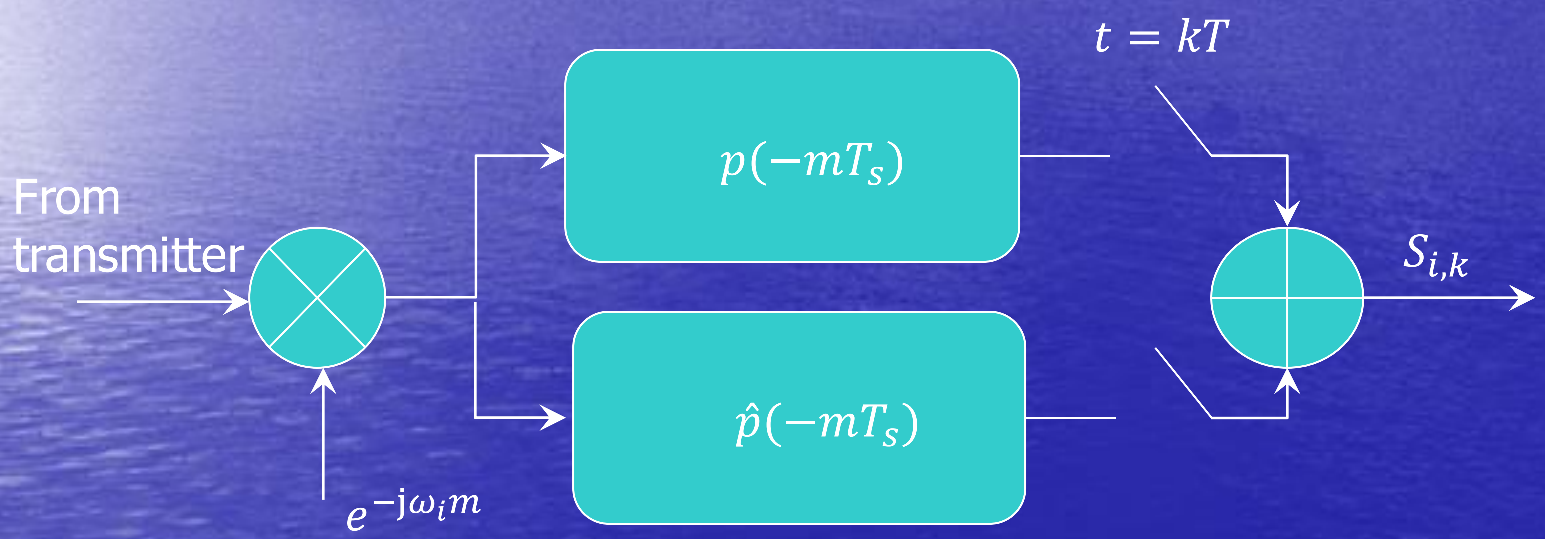
Fig 8



Transmitter block diagram for i^{th} subcarrier

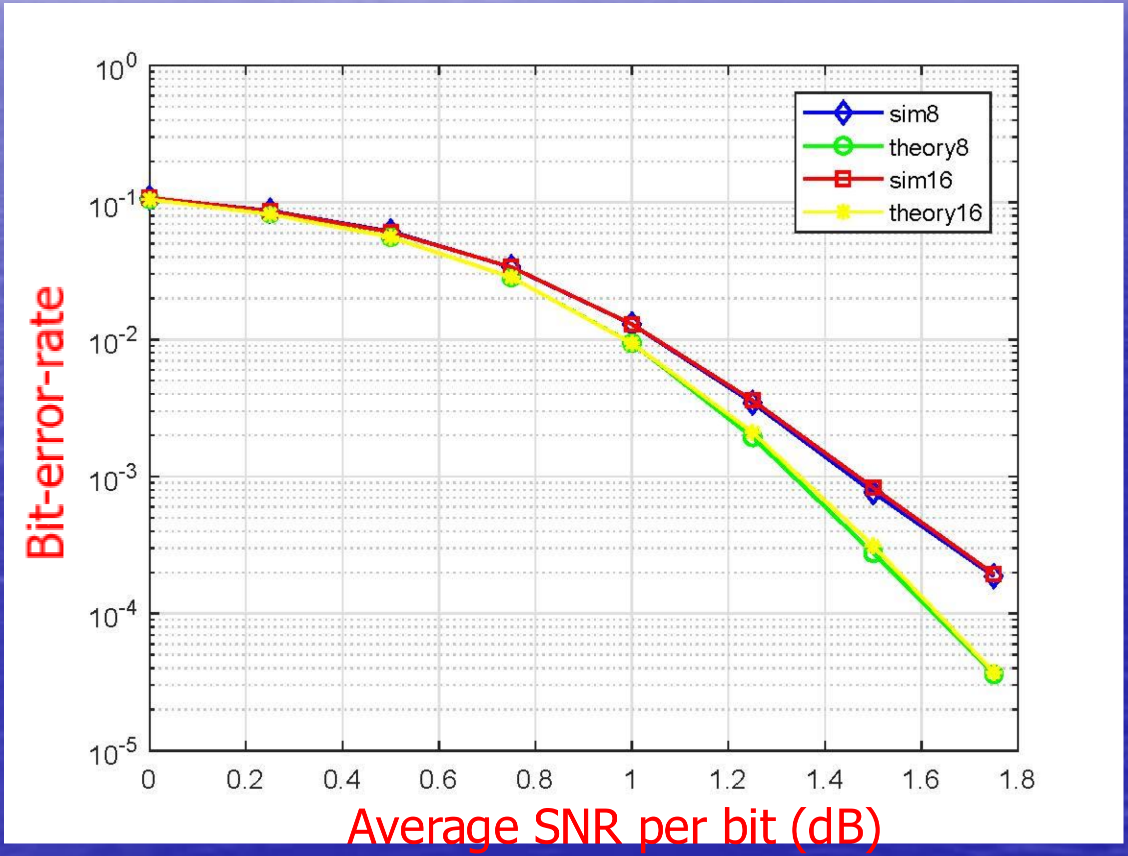
MC – System Model

Fig 9



MC - Results

Fig 10

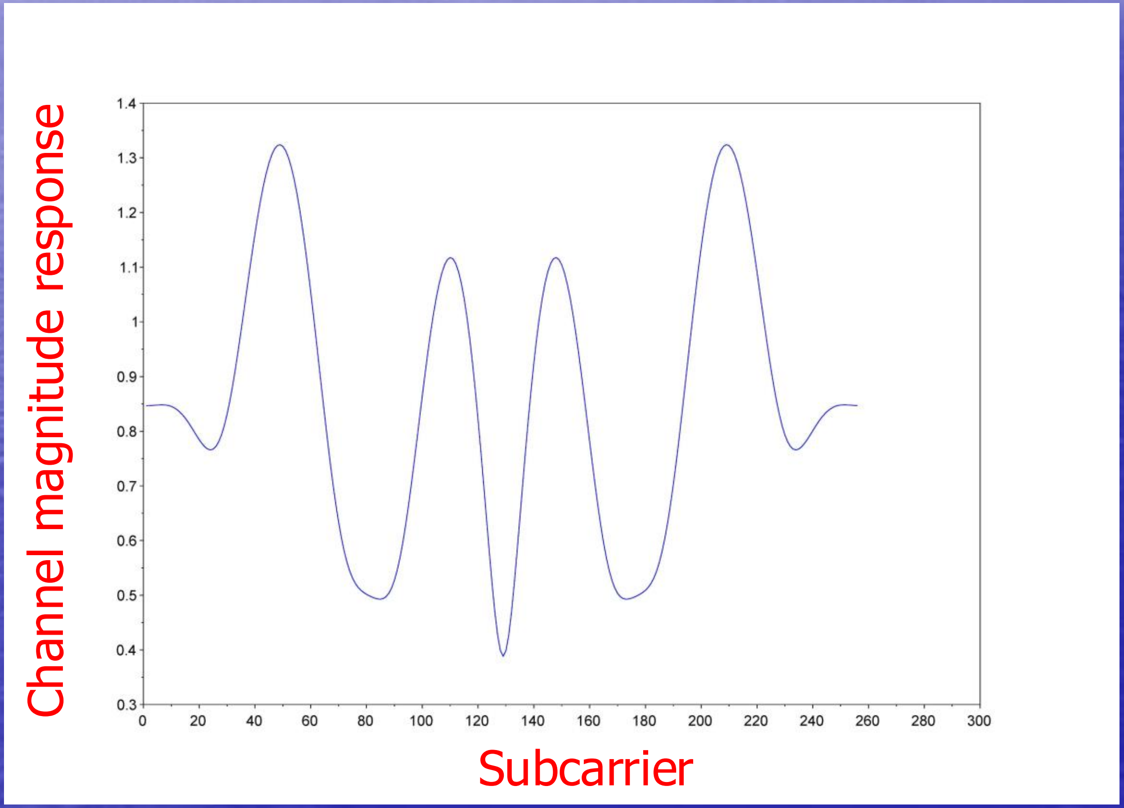


Fading Channels

- Rayleigh fading
  - Some subcarriers undergo deep fade at certain times
  - Receiver has to send this information to transmitter for re-transmission of the frame
  - Transmitter waits for some time and re-transmits the frame or use another subcarrier – increases latency

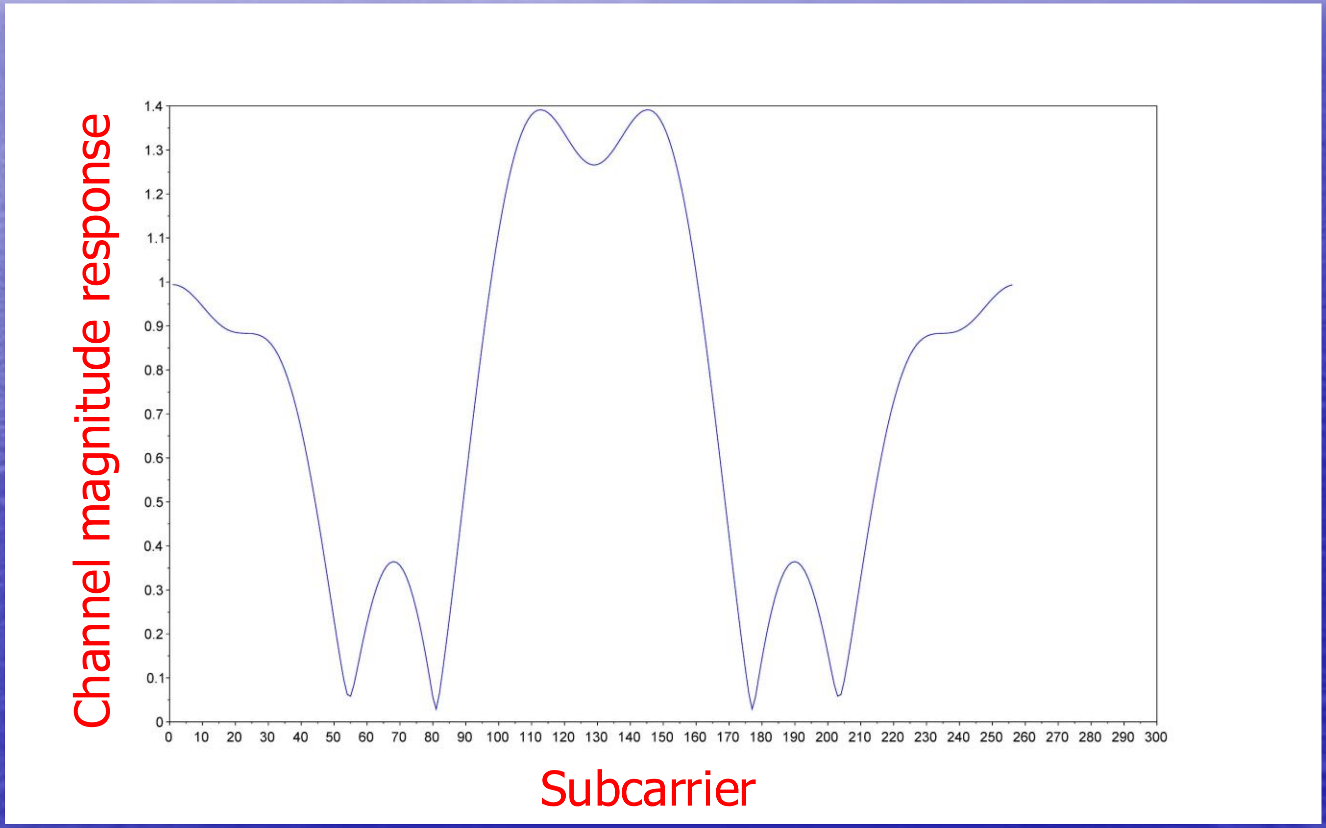
Fading Channels

Fig 11



Fading Channels

Fig 12



Conclusions

- OFDM-OQAM/FBMC/UFMC is a variation of single sideband (SSB) modulation
- Hilbert transform has been used to implement OFDM-OQAM
- Future work would be to introduce frequency offsets and frequency selective fading channel

Publications

- Kasturi Vasudevan, Surendra Kota, Lov Kumar, Himanshu Bhusan Mishra, “Turbo Coded OFDM-OQAM Using Hilbert Transform”, SIPS 2023, 27th Nov – 1st Dec, Panama. Also available at https://arxiv.org/abs/2309.09620