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PAPR Reduction for Single Carrier FDMA LTE Systems using Frequency Domain Spectral Shaping

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Presentation Outline

- ✓ 3GPP LTE uplink transmission – Single-Carrier Frequency Division Multiple Access (SC-FDMA).
- ✓ PAPR comparison of SC-FDMA with distributed and localized subcarrier mapping schemes.
- ✓ Investigate the impact of PAPR through frequency domain spectral shaping with localized sub-carrier mapping.



Introduction

✓ Generations of Mobile Networks

- 1G, 2G, 3G → 4G (are currently in development around the world)
- Mobile phone plays an important roles – business or social networking
- ‘smartphone’

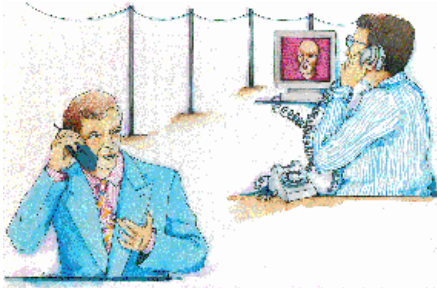
✓ Limitations – network coverage, capacity...

- **Battery life** – a key parameter that affects all mobile handsets.
- Even though the battery technology is improving
 - To ensure that mobiles phone **use as little energy as possible**



4G- Wireless & Mobile Technology

Wired communication

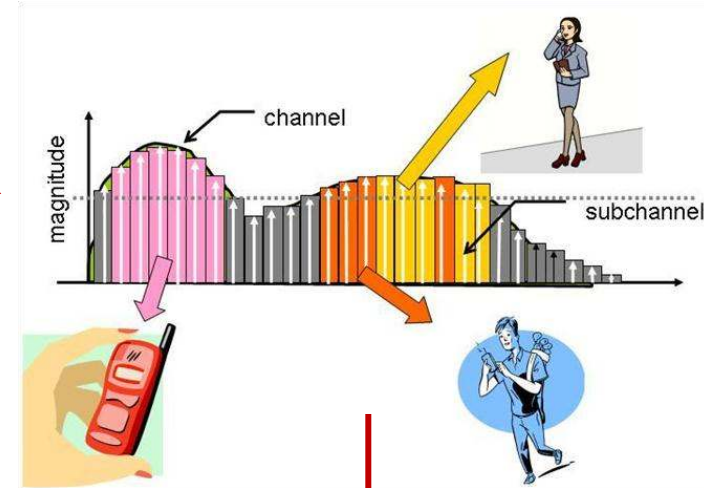


1G (Analog)

2G (Digital)
3G (W-CDMA)



Orthogonal frequency-division multiplexing (OFDM)



PAPR ???

- OFDMA
- SC-FDMA



🔥 3GPP LTE (Long-Term Evolution)

Scalable Transmission Bandwidth (MHz)

1.4, 3, 5, 10, 15 & 20

Adaptive Modulation

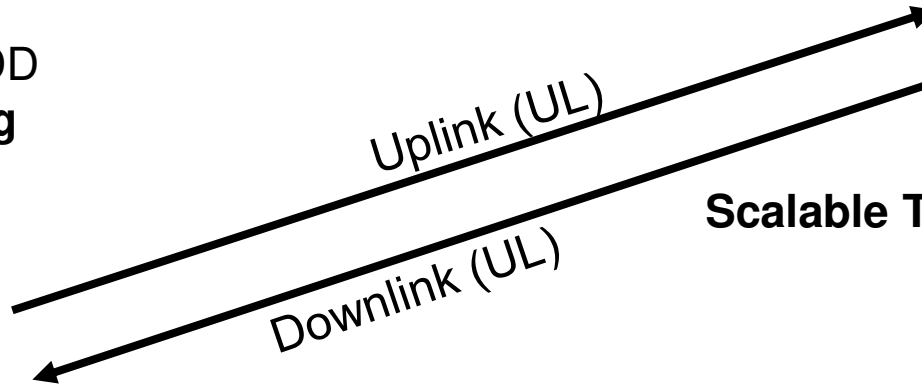
QPSK, 16QAM & 64QAM

Duplexing

FDD and TDD

Multiplexing

SC-FDMA



Scalable Transmission Bandwidth (MHz)

1.4, 3, 5, 10, 15 & 20

Adaptive Modulation

QPSK, 16QAM & 64QAM

Duplexing

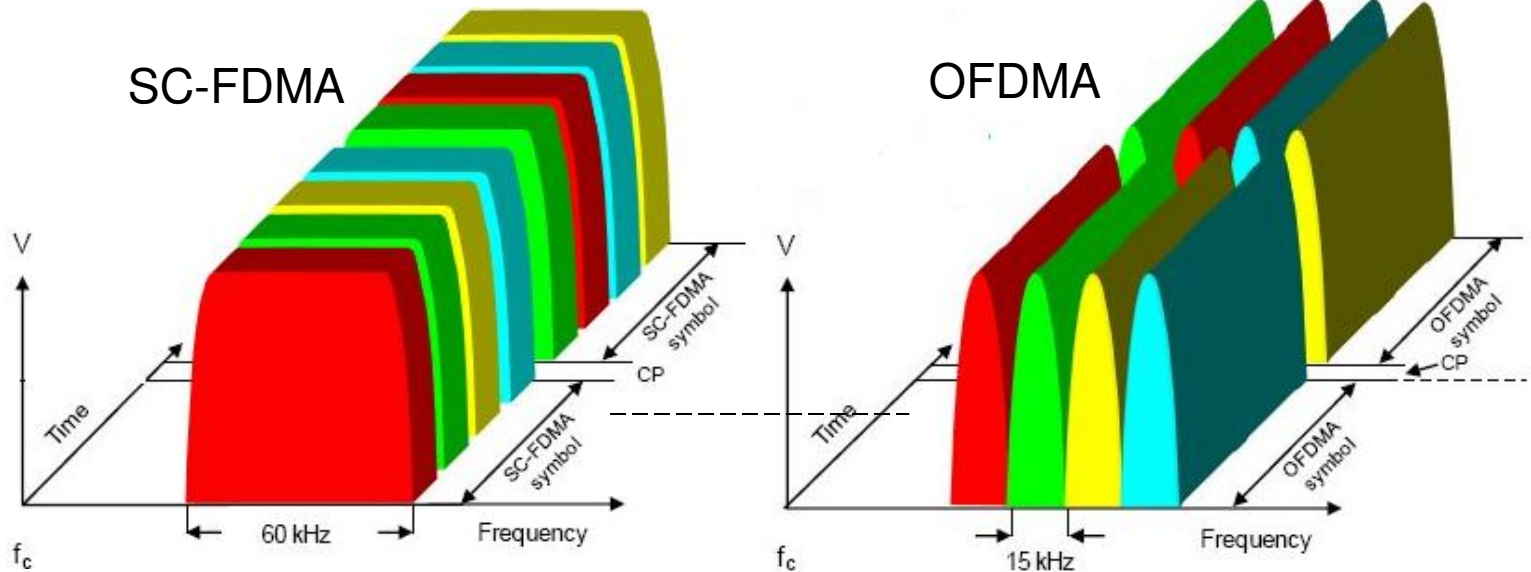
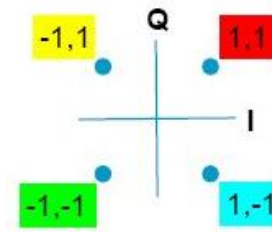
FDD and TDD

Multiplexing

OFDMA



SC-FDMA vs OFDMA

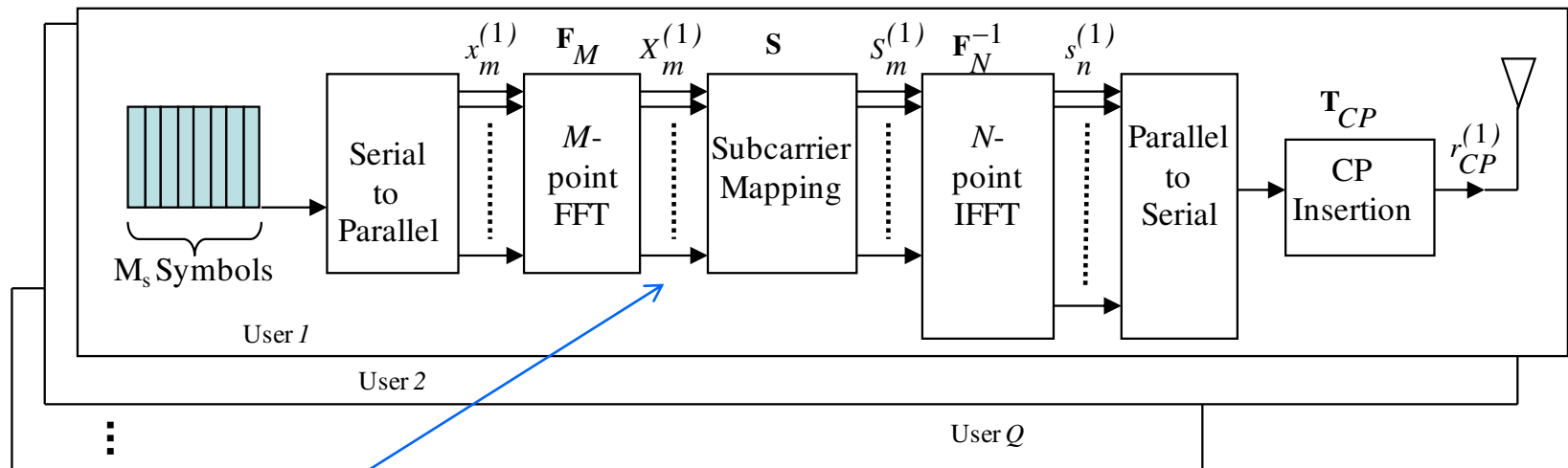


Data symbols occupy $M \cdot 15$ kHz for $1/M$ SC-FDMA symbol periods

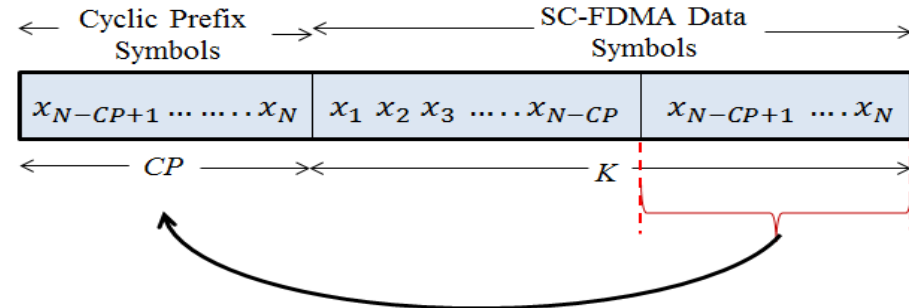
Data symbols occupy 15 kHz for one OFDMA symbol period

- ✓ shows how a sequence of eight QPSK symbols is presented in frequency and time domain

SC-FDMA Transmitter System



$$\text{FFT} \{x_m\} = X_m^{(k)} = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} x_m e^{-j \frac{2\pi}{M} nm}$$



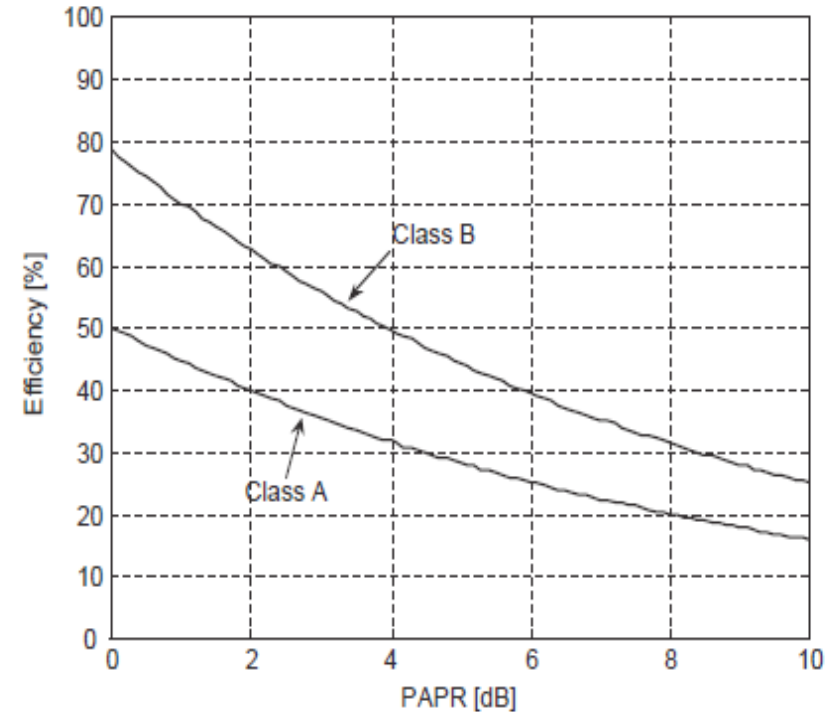
PAPR and Power Amplifier Constraints

- Peak-to-average power ratio (**PAPR**) problems occur in broadband communications causing **power amplifier distortion** issues.
- It also results in received errors as well as **reducing power efficiency** and **battery life**.
- Amplifiers must be specifically designed to cope with this problem, and this **increases their cost**.



PAPR

- ✓ Peak-to-average-power ratio (PAPR) is a performance measurement to indicate the power efficiency of the transmitter.
- ✓ Figure shows the theoretical efficiency limits of linear amplifier.
- ✓ **High PAPR** degrades the transmit power efficiency performance.

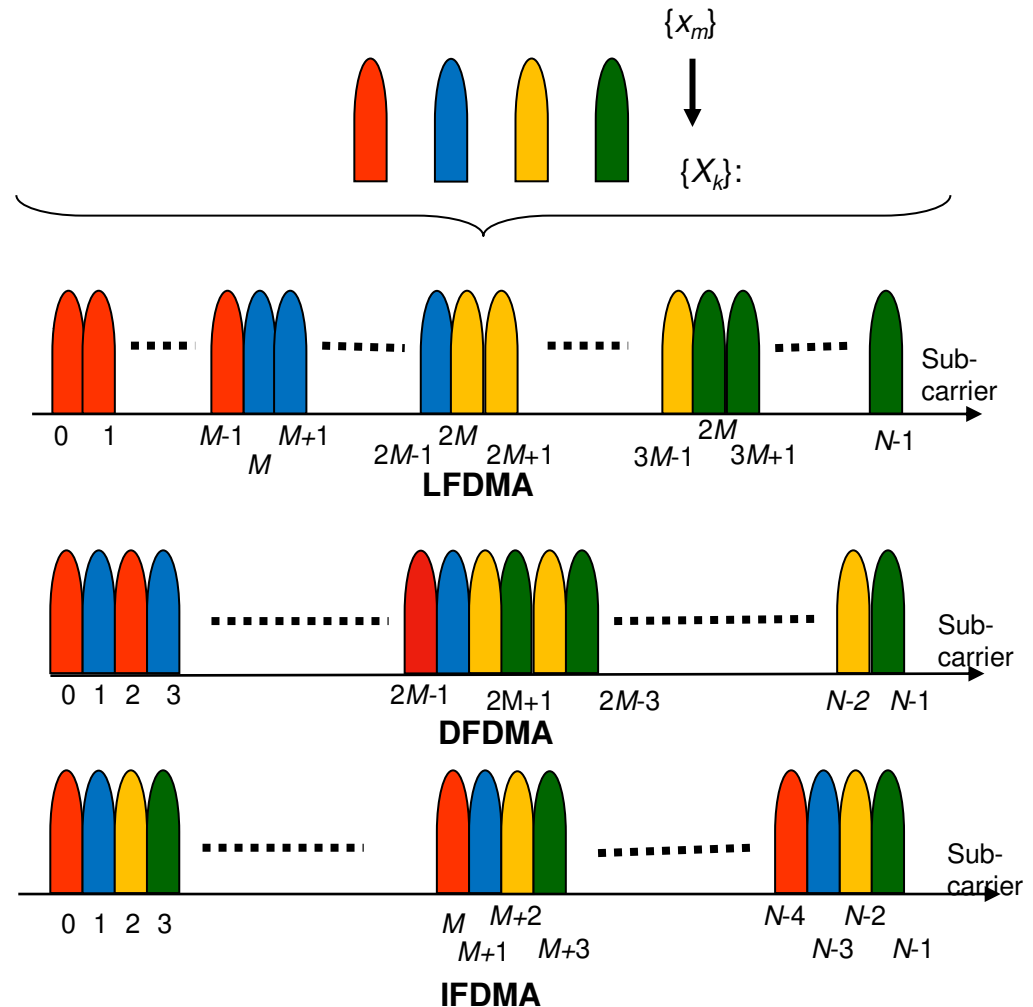


$$P_{\text{PAPR}}(i) = 10 \log \left\{ \frac{\max_t \{ |x_{tx}(t, i)|^2 \}}{E[|x_{tx}(t, i)|^2]} \right\}$$



SC-FDMA Subcarrier Mapping Schemes

- ✓ LFDMA, DFDMA and IFDMA demonstrating that signals of the four (4) different terminals arriving at a base station occupy mutually exclusive sets of subcarriers.
- ✓ M symbols per block, N subcarriers and Q users.

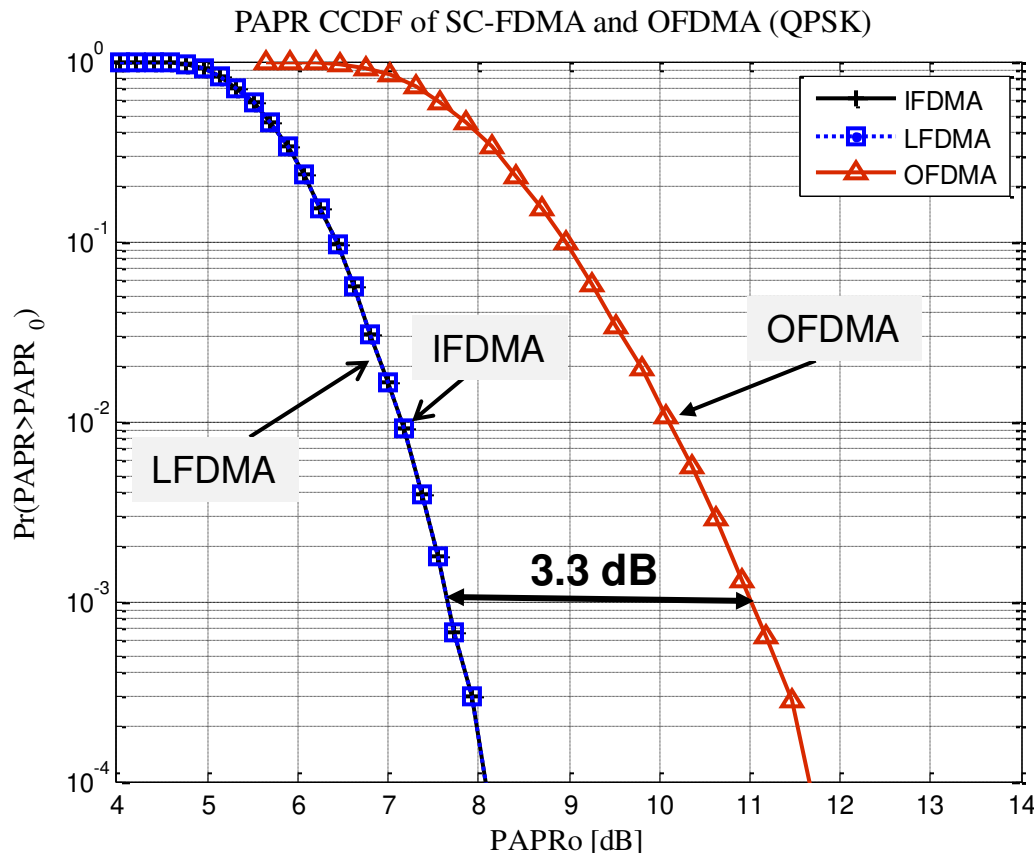


Simulation Parameters/Assumptions

Parameter	Value
Carrier Frequency	2 GHz
System bandwidth	5 MHz
N -size IFFT	512
M -size FFT	128
Modulation scheme	QPSK, 16QAM
Cyclic prefix	32 samples ($6.4 \mu s$)
Antenna scheme	SISO

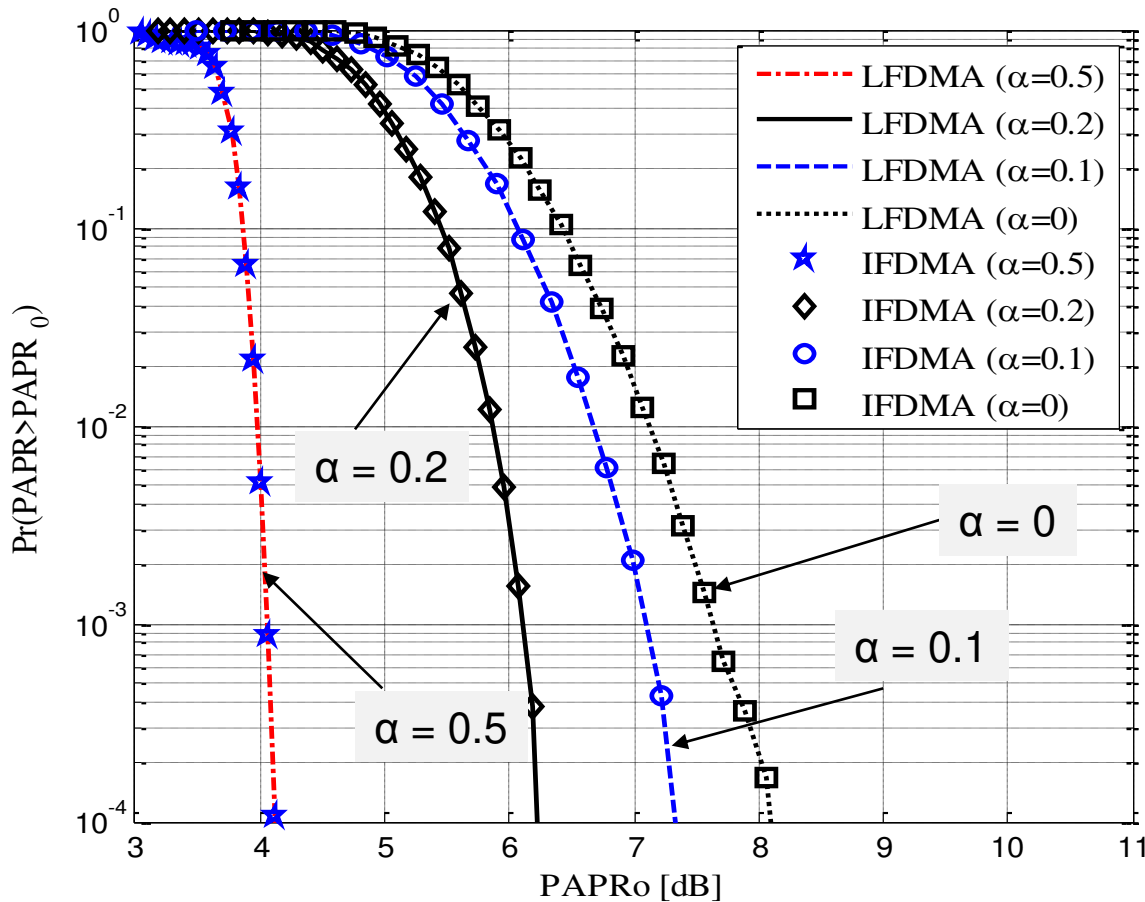


PAPR Comparison of Time Domain Pulse Shaping Filter



- ✓ LFDMA and IFDMA both have significant PAPR improvement compared to OFDMA.
- ✓ OFDMA exhibits a higher PAPR compared to LFDMA and IFDMA.
- ✓ SC-FDMA exhibits a lower PAPR compared to OFDMA because of its single carrier structure.

🔥 The Impact of Pulse Shaping on the PAPR of SC-FDMA signals



QPSK

✓ PAPR *decreases* as roll-off-factor (α) increases.

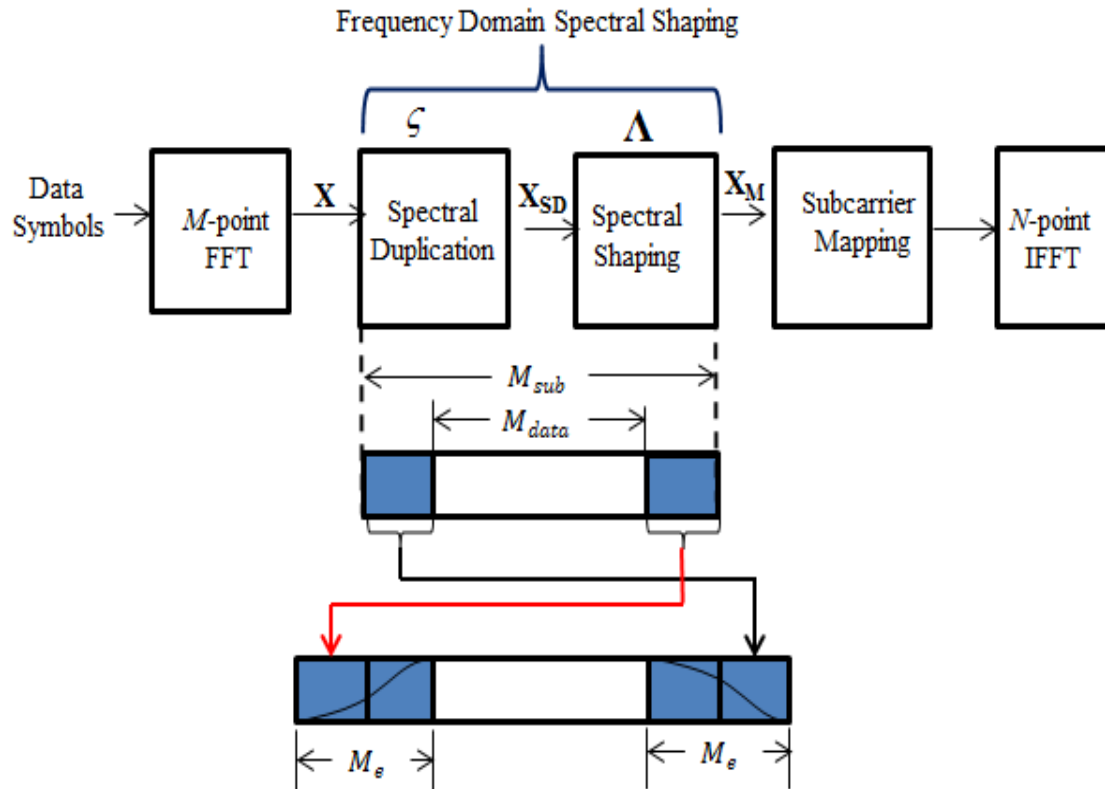
Frequency Domain Spectral Shaping (1)

- ✓ What is the difference between the time domain pulse shaping used in traditional single carrier systems and the frequency domain spectral shaping used in SC-FDMA?
 - A traditional time domain pulse shaping filter is used to **band limit** the transmit signal.
 - However, the frequency domain spectral shaping process is applied to **reduce PAPR**.

- ✓ The PAPR of SC-FDMA signals with RC frequency domain spectral shaping is now further investigated.



🔥 PAPR Reduction via Spectral Shaping



✓ The SC-FDMA uplink requires pulse shaping to limit the inter-symbol interference (ISI) between neighboring time symbols

✓ Frequency domain spectral shaping can be used in SC-FDMA to achieve PAPR reduction

PAPR and Bandwidth Efficiency

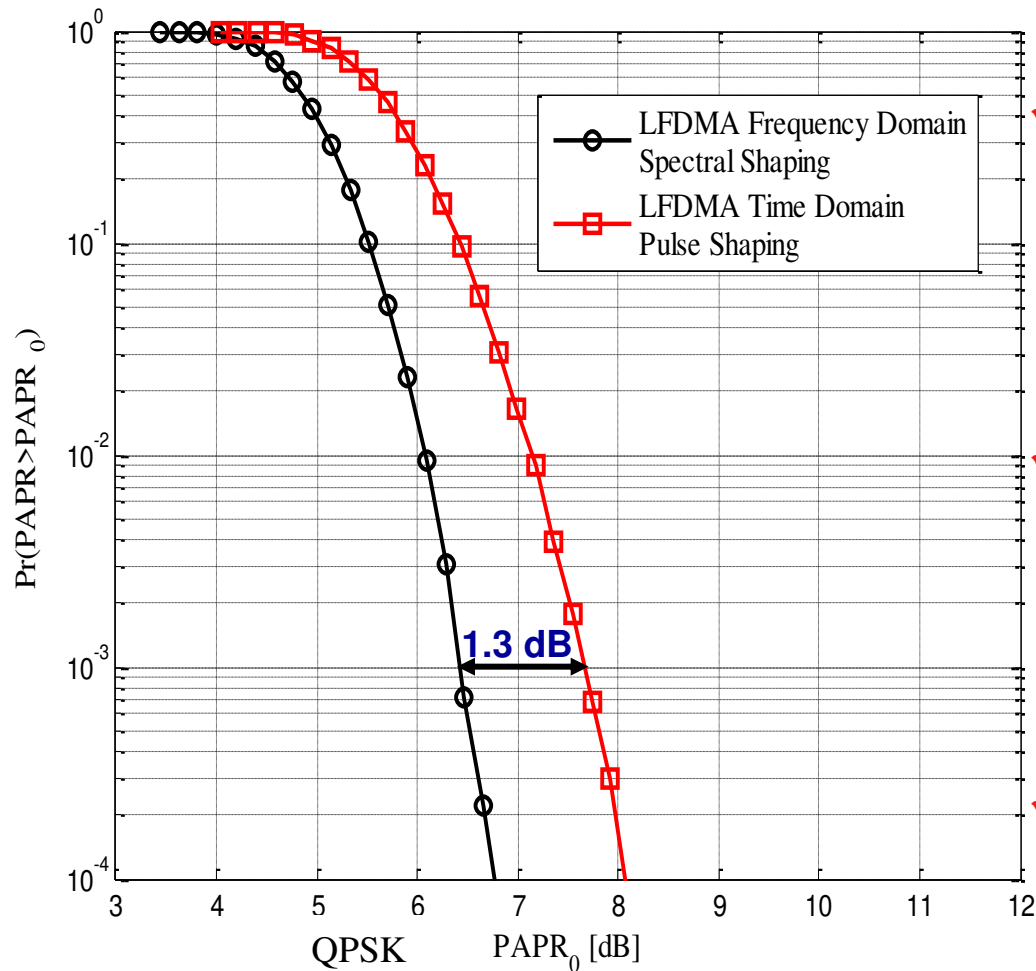
Comparison of PAPR and bandwidth efficiency using RC frequency domain spectral shaping at $\alpha = 0.2$ with QPSK modulation.

Bandwidth Efficiency	78.1%	85.9%	100%
PAPR of LFDMA at CCDF = 10^{-3}	6.4dB	6.6dB	7.7dB

- ✓ The number of transmit data symbols, $M_{data} = 100, 110$ and 128 .
- ✓ The PAPR of SC-FDMA signals can be reduced at the cost of degraded bandwidth efficiency



PAPR Reduction



✓ PAPR of SC-FDMA for LFDMA employed RC frequency domain spectrum shaping and time domain pulse shaping with QPSK signaling at $\alpha = 0.22$.

✓ Results show that a PAPR reduction of 1.3 dB can be achieved for QPSK when RC frequency domain spectral shaping is used with roll-off factor of 0.22.

✓ Compared to the unfiltered version, the bandwidth efficiency is reduced to 78.1%.

Conclusions

- ✓ SC-FDMA is suitable for uplink transmissions as it has a lower PAPR than OFDMA (since it improves the power efficiency of the mobile transmitter).
- ✓ In this paper we have shown that by applying a frequency domain spectral shaping filter, the **PAPR** of a localized FDMA (LFDMA) signal can be further **reduced** (**1.3 dB**) at the expense of **degraded bandwidth efficiency** (78.1%).
- ✓ The resulting **PAPR reduction** can be used to enhance handset power efficiency, or alternatively to improve uplink throughput and/or operating range.



Thank You

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