PAPR Reduction of Localized Single Carrier FDMA using PTS in LTE Systems

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Telecommunication Engineering Department

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Outline

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- Single Carrier Modulation in Frequency Selective Channels
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- Peak-to-Average Power Ratio Techniques (PAPR)
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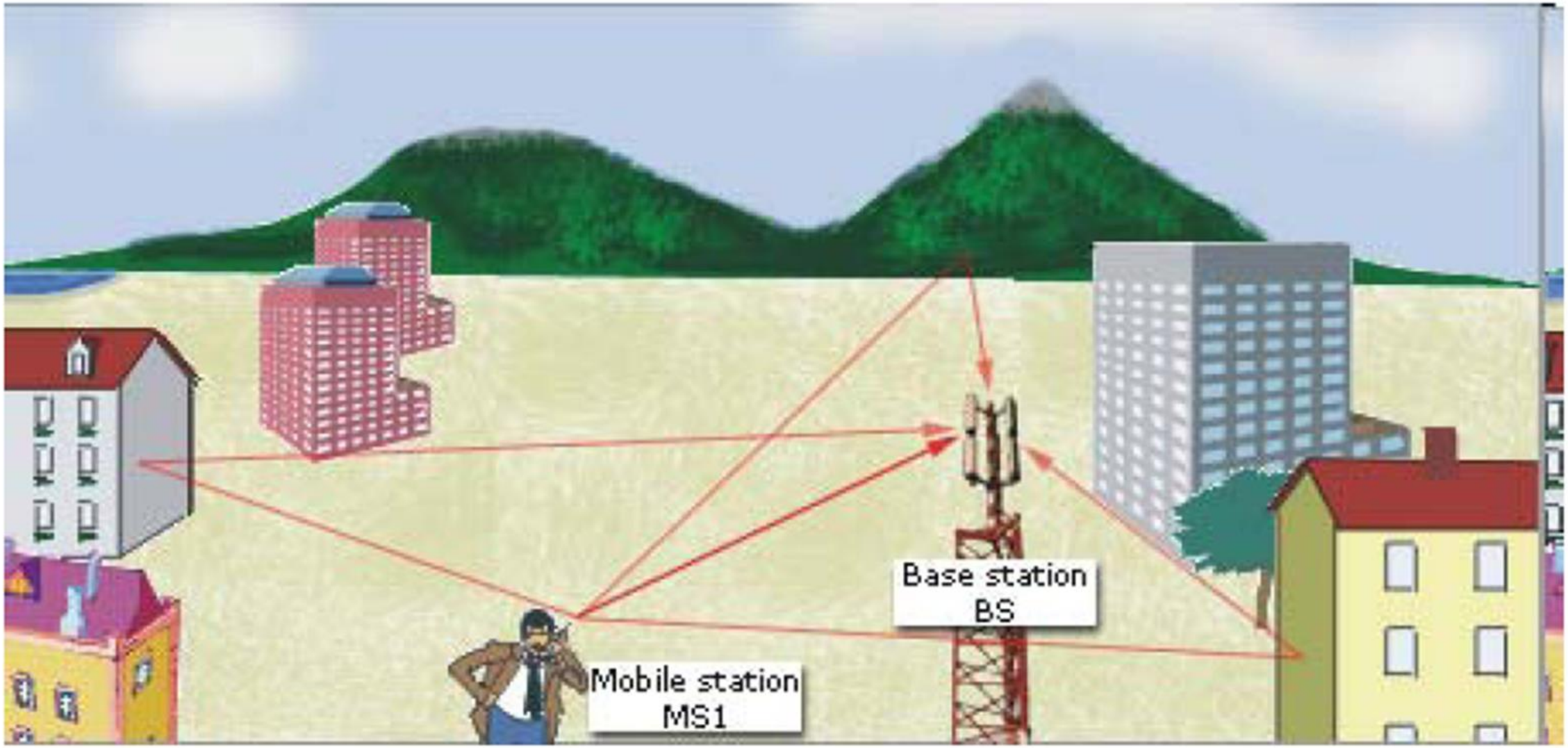
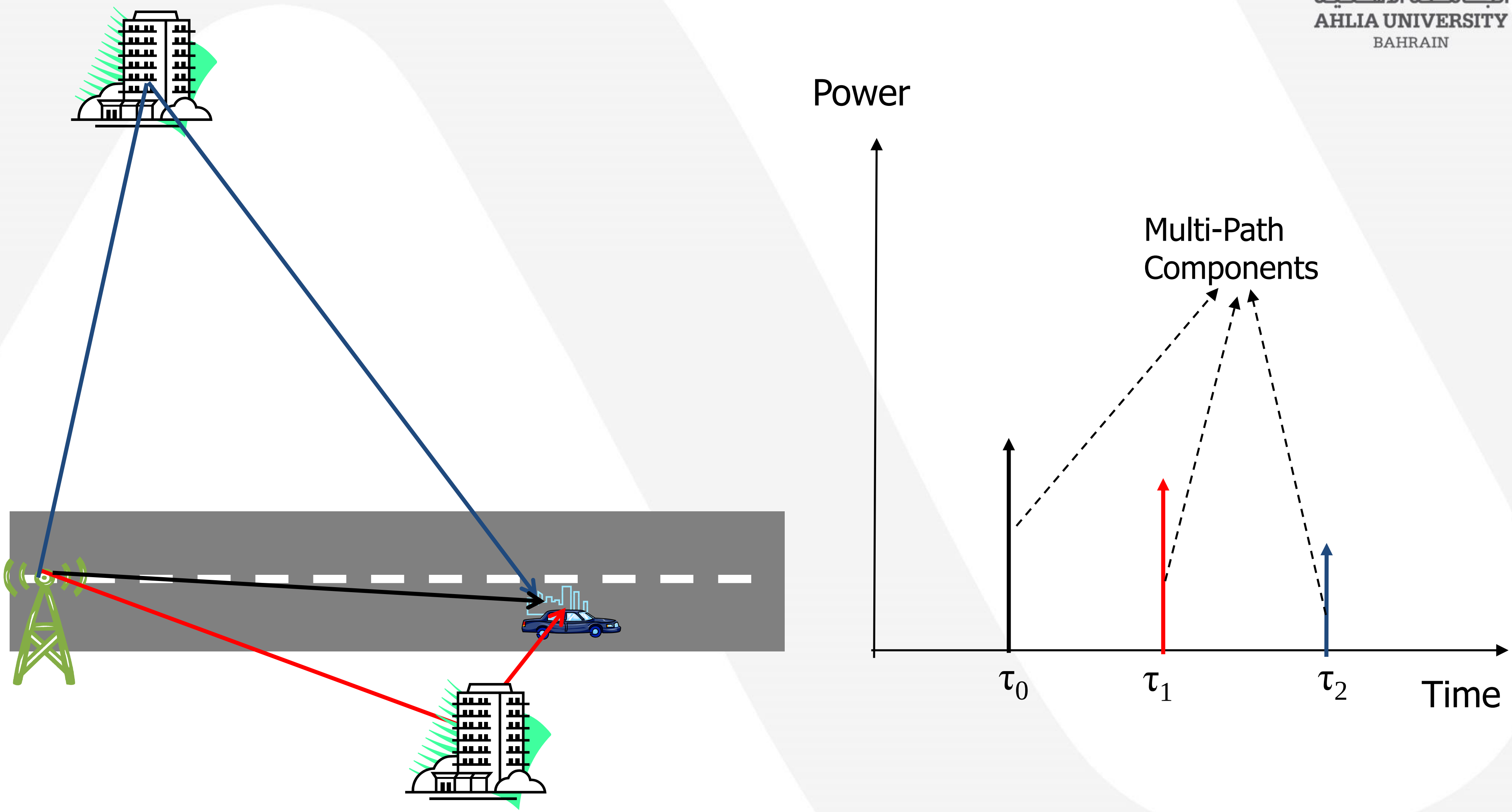
- Conclusions

Wireless Communication Channels



- Communications over wireless channels suffer from multi-path propagation
- Multi-path channels are usually frequency selective
- OFDM supports high data rate communications over frequency selective channels

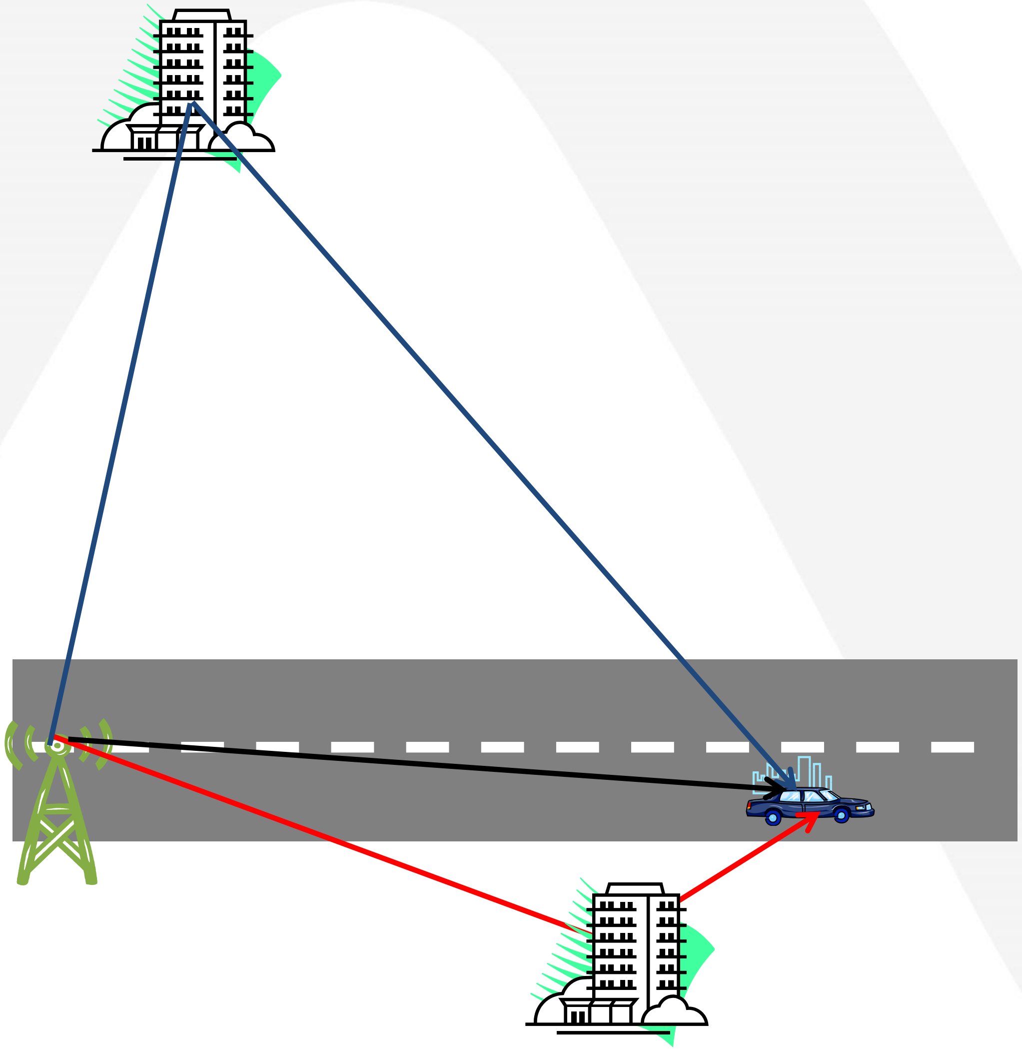
Multi-Path Propagation Modeling

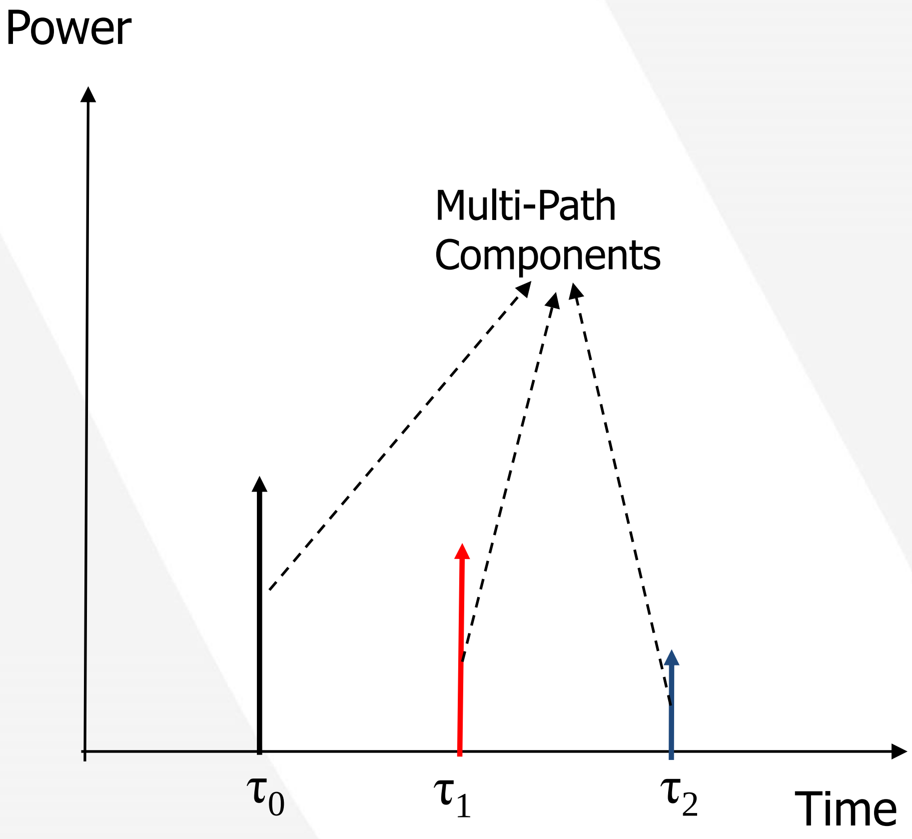


Multi-path results from reflection, diffraction, and scattering off environment surroundings

Note: The figure above demonstrates the roles of reflection and scattering only on multi-path

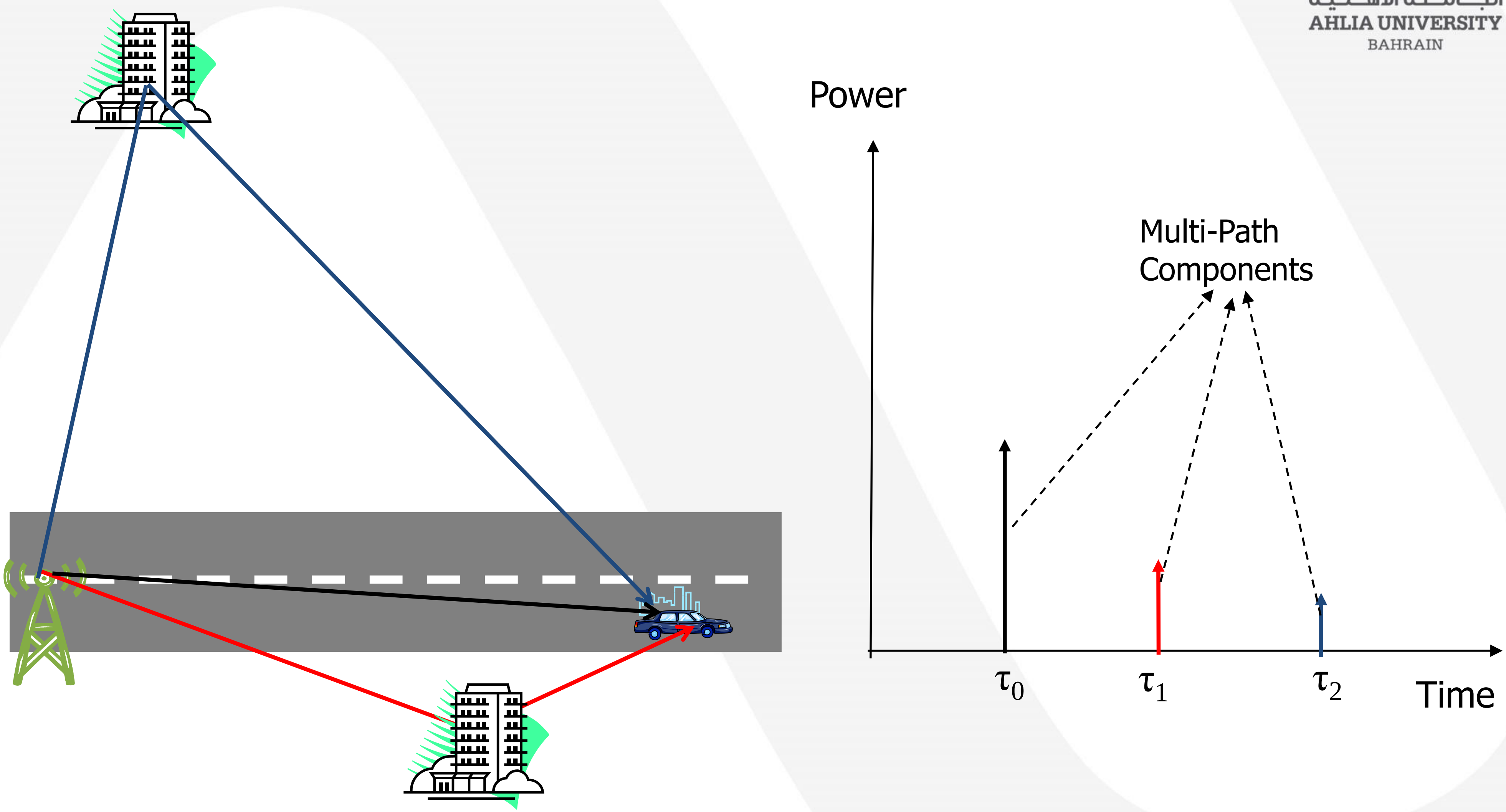
Multi-Path Propagation Modeling





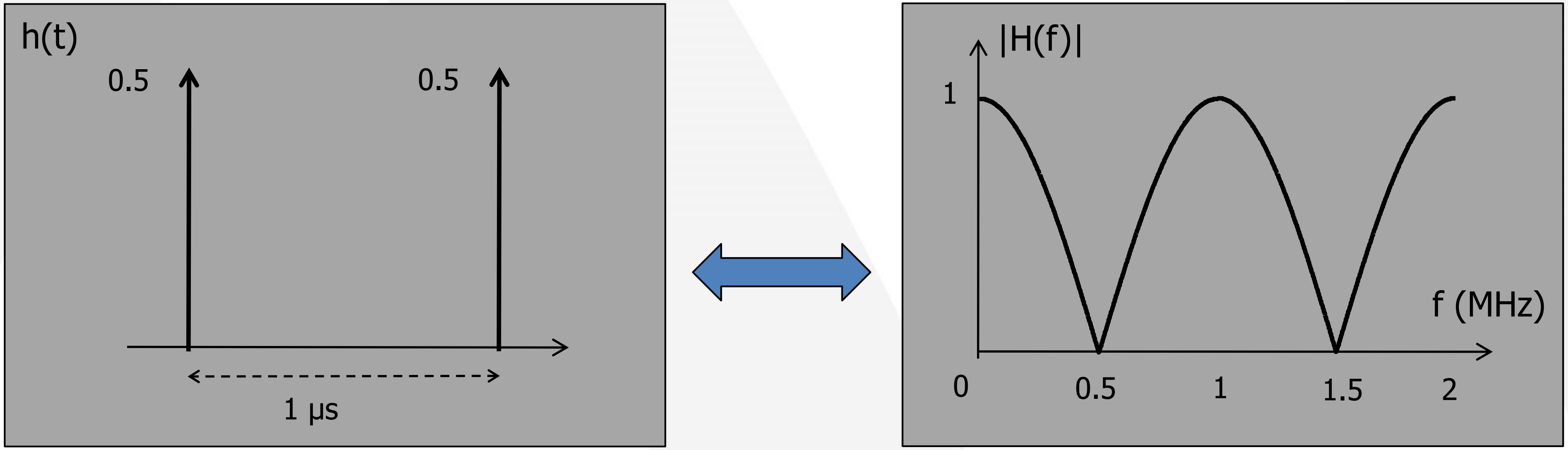
As the mobile receiver (i.e. car) moves in the environment, the strength of each multi-path component varies

Multi-Path Propagation Modeling



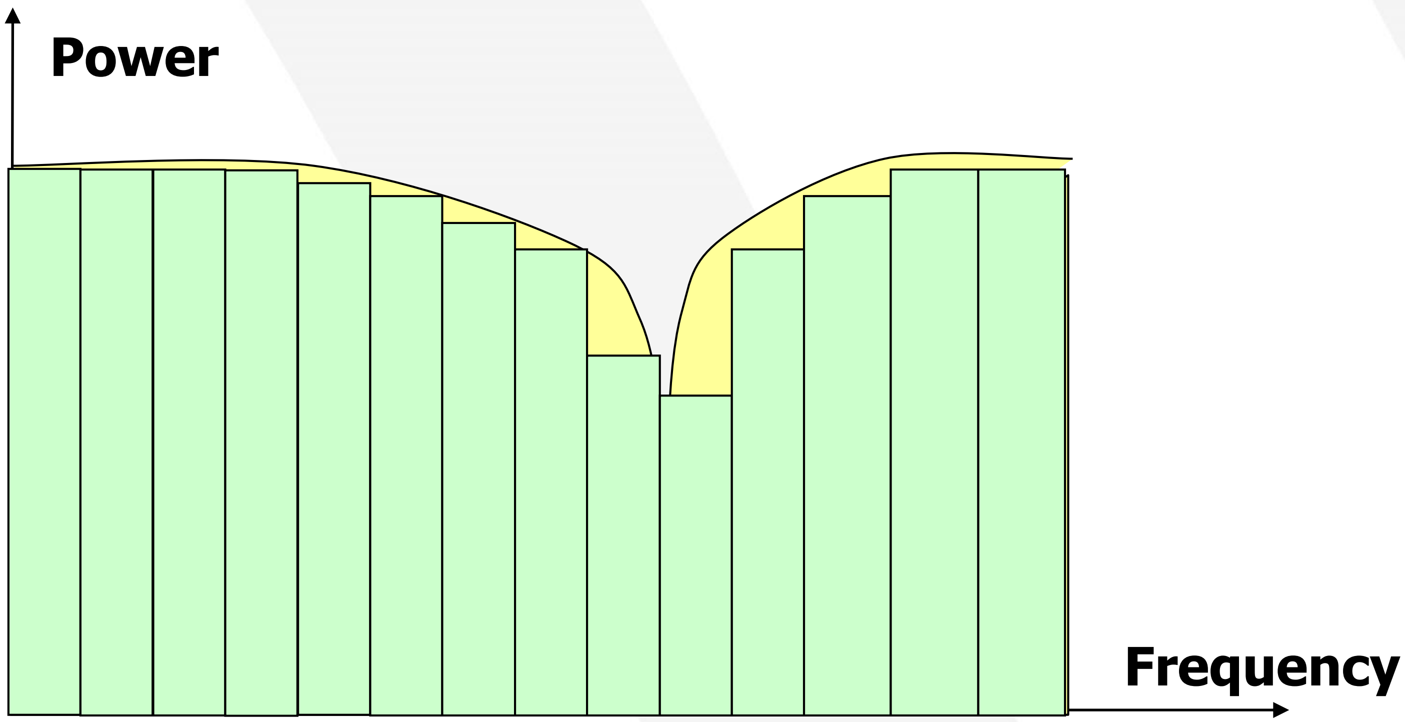
As the mobile receiver (i.e. car) moves in the environment, the strength of each multi-path component varies

Multi-Path = Frequency-Selective!



- A multi-path channel treats signals with different frequencies differently
- A signal composed of multiple frequencies would be distorted by passing through such channel

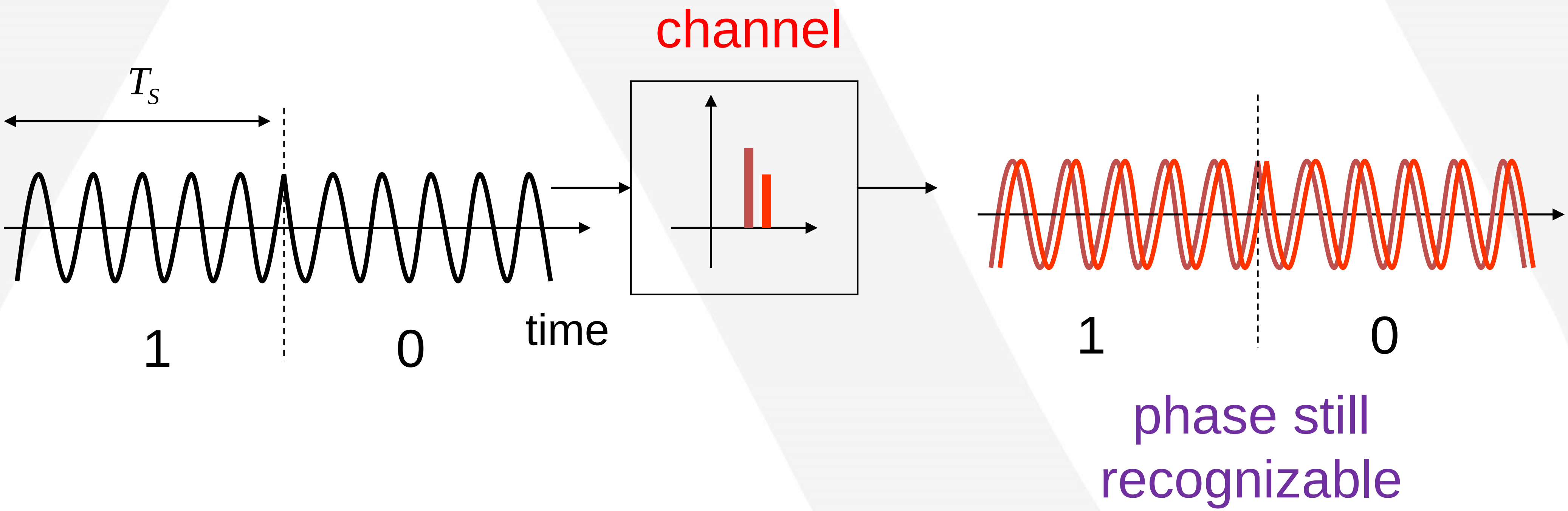
Frequency Division & Coherence Bandwidth



- Subdivide wideband bandwidth into multiple narrowband sub-carriers
- Bandwidth of each channel is selected such that each sub-carrier *approximately* displays Flat Fading characteristics
- The bandwidth over which the wireless channel is assumed to display flat fading characteristics is called the ***coherence bandwidth***

Single Carrier Modulation in Flat Fading Channels

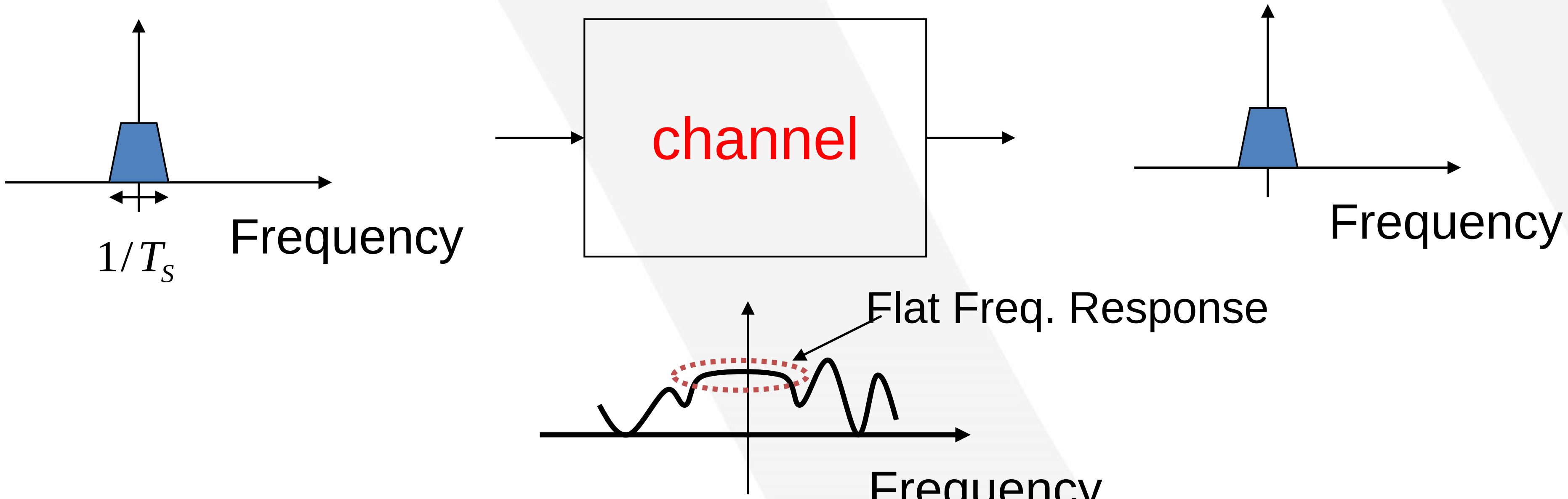
- if *symbol duration* >> *time spread* then there is almost no Inter Symbol Interference (ISI).



Problem with this system: *Low Data Rate!!!*

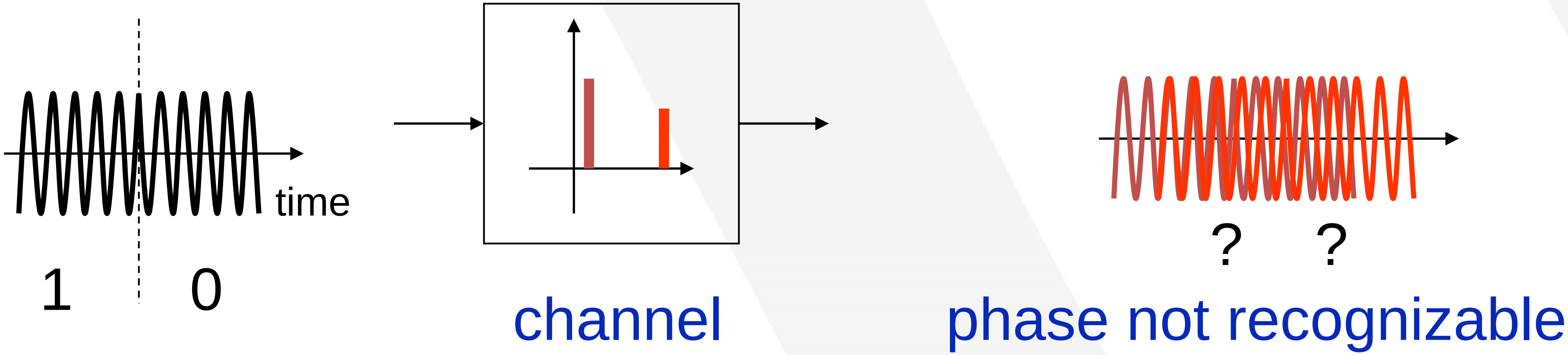
… in the Frequency Domain

- this corresponds to **Flat Fading**

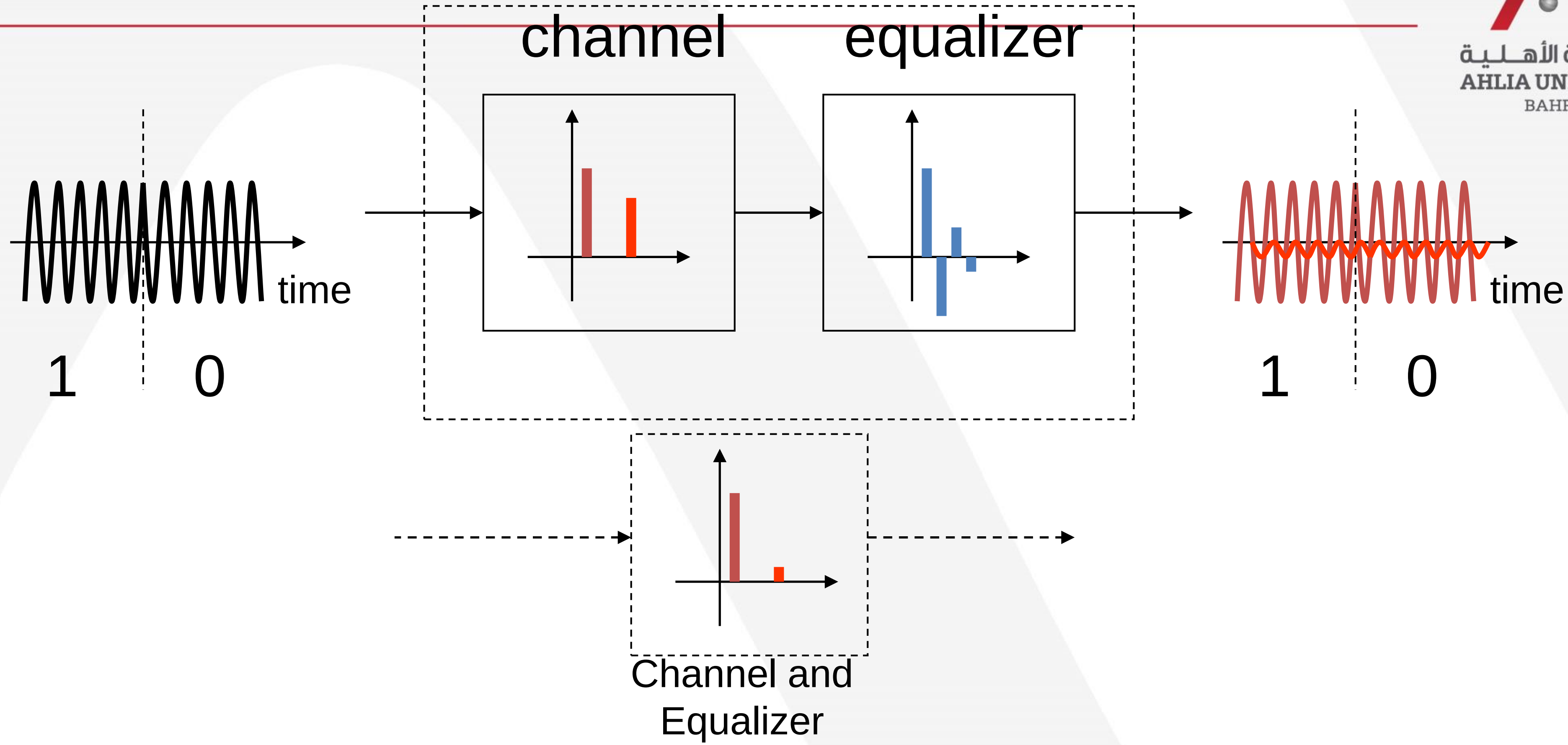


Single Carrier Modulation in Frequency Selective Channels

- if *symbol duration ~ time spread* then there is considerable Inter Symbol Interference (ISI).



One Solution: *we need equalization*



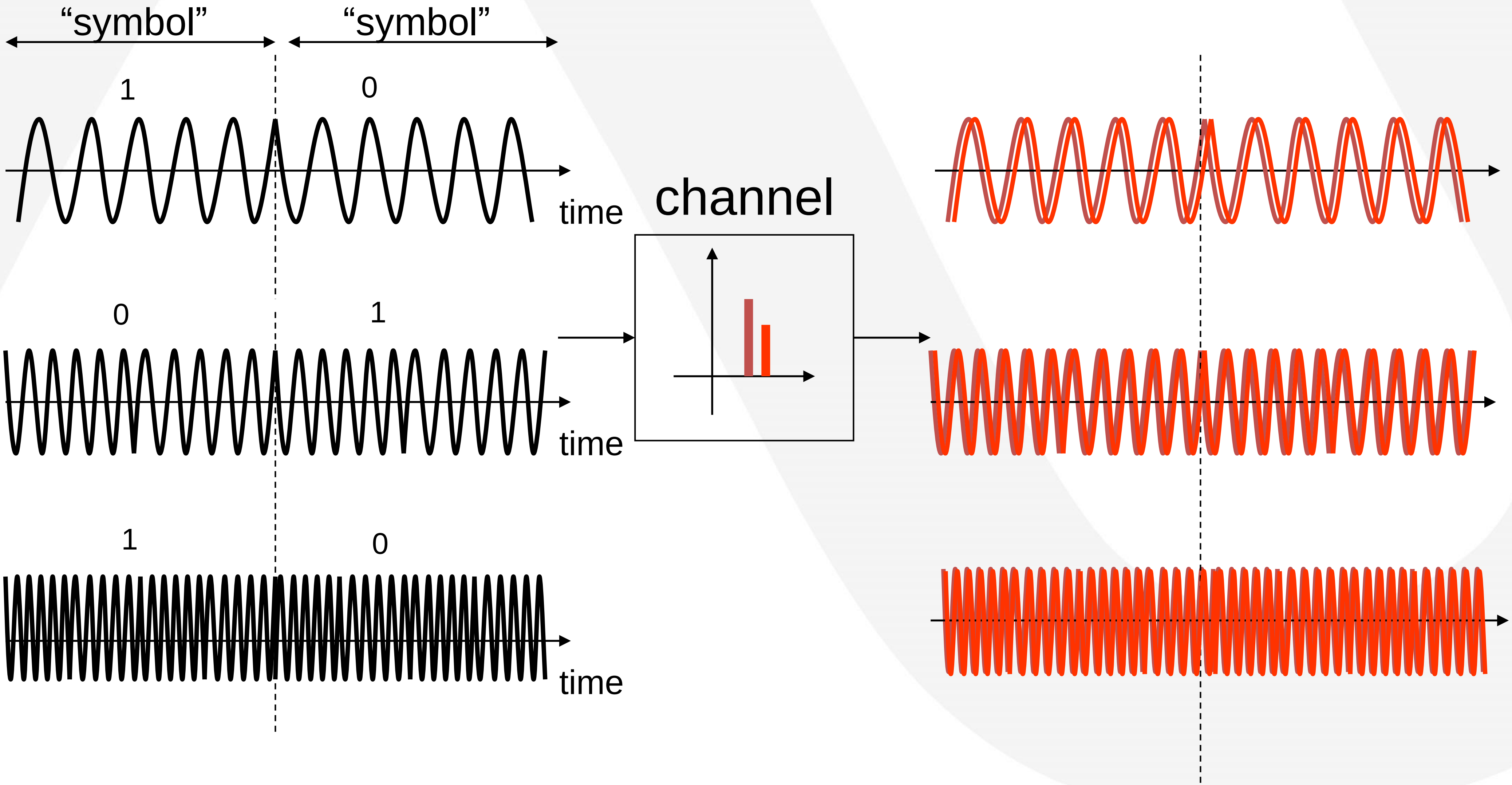
Problems with equalization:

- it might require training data (thus loss of bandwidth)
- if blind, it can be expensive in terms computational effort
- always a problem when the channel is time varying

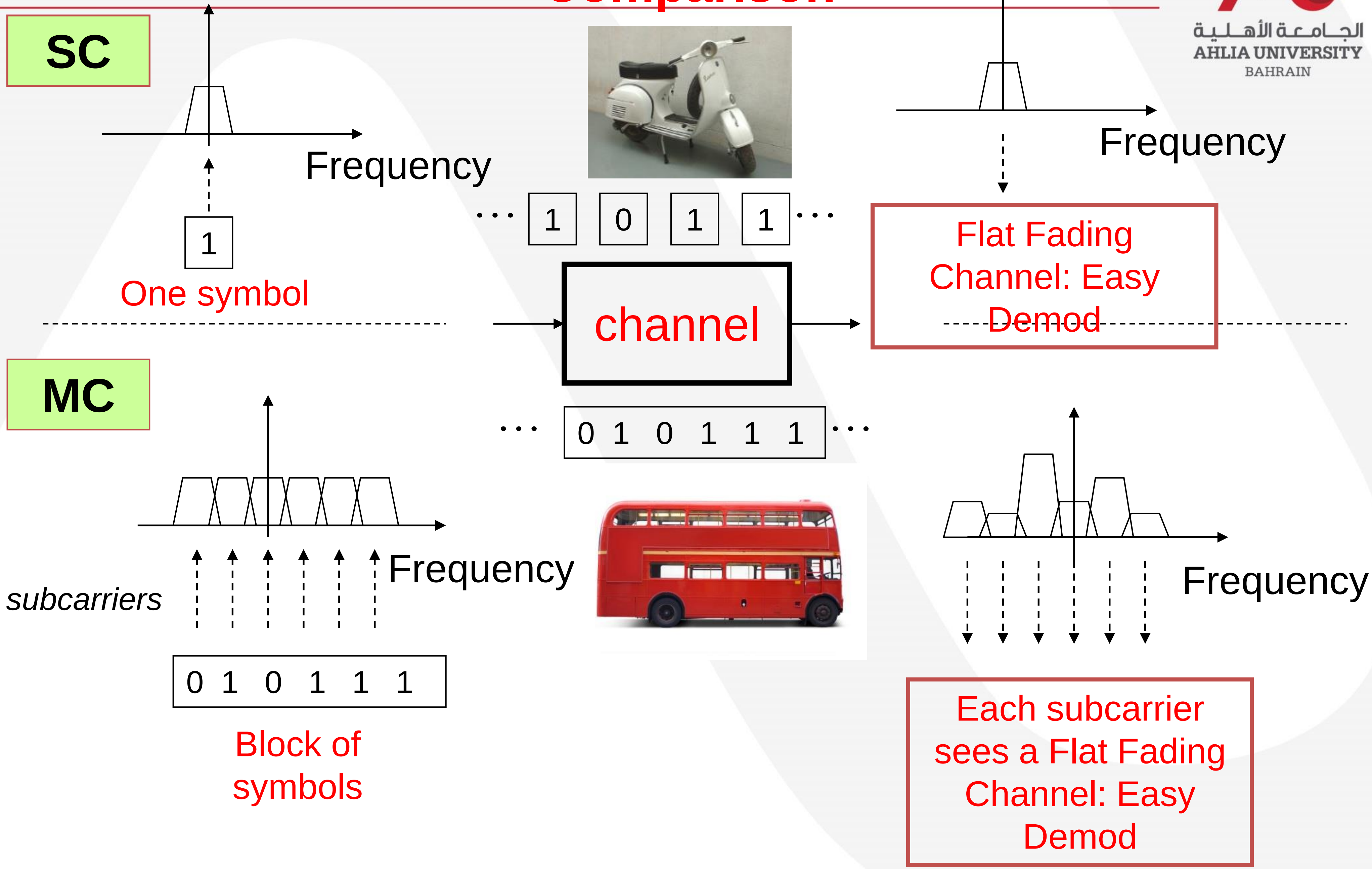
The Multi Carrier Approach

- let *symbol duration* >> *time spread* so there is almost no Inter Symbol Interference (ISI);

- send a **block of data** using a number of carriers (Multi Carrier)



Single Carrier and Multi Carrier Modulation Comparison



Multicarrier Signal

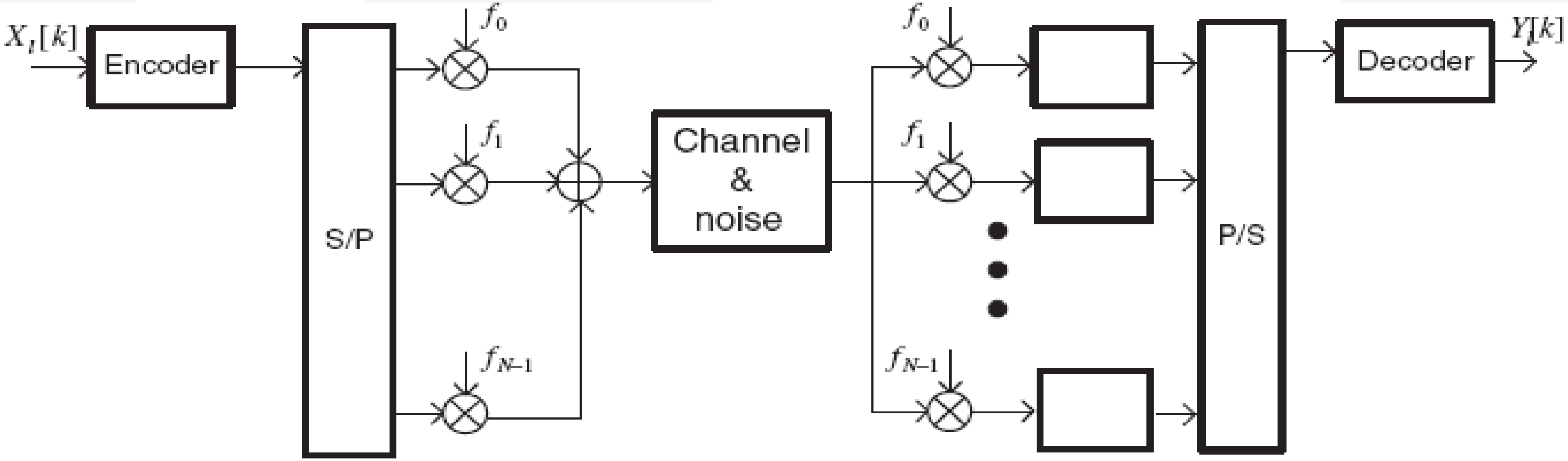
The complex baseband representation of a multicarrier signal consisting of N subcarriers is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \cdot e^{j2\pi n \Delta f t}, 0 \le t \le T$$

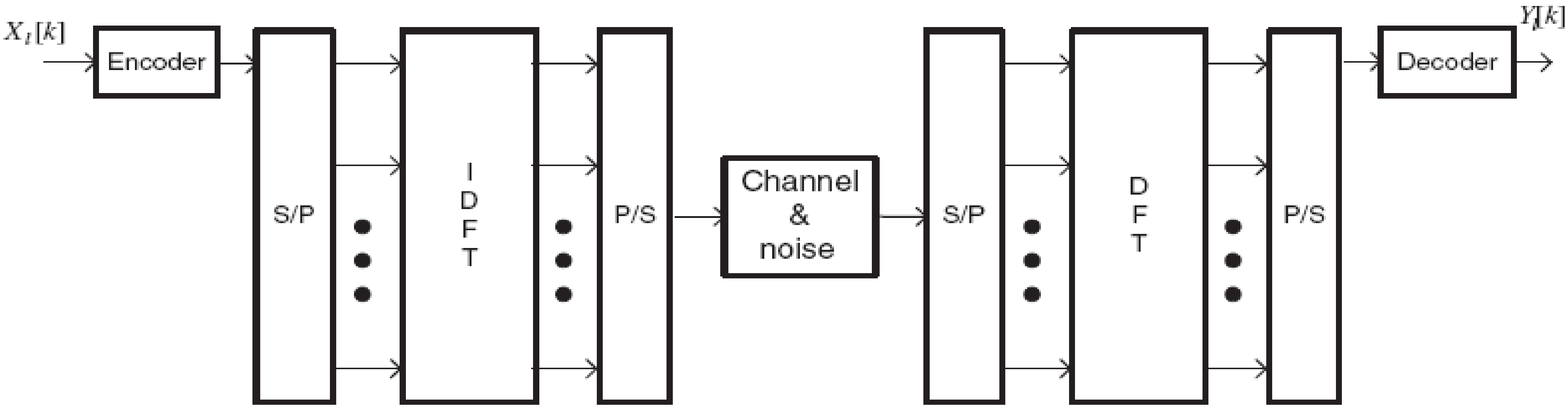
where Δf is the subcarrier spacing.

In OFDM systems, the subcarriers are chosen to be orthogonal. (i.e., $\Delta f = 1/T$)

OFDM Transmission Schemes

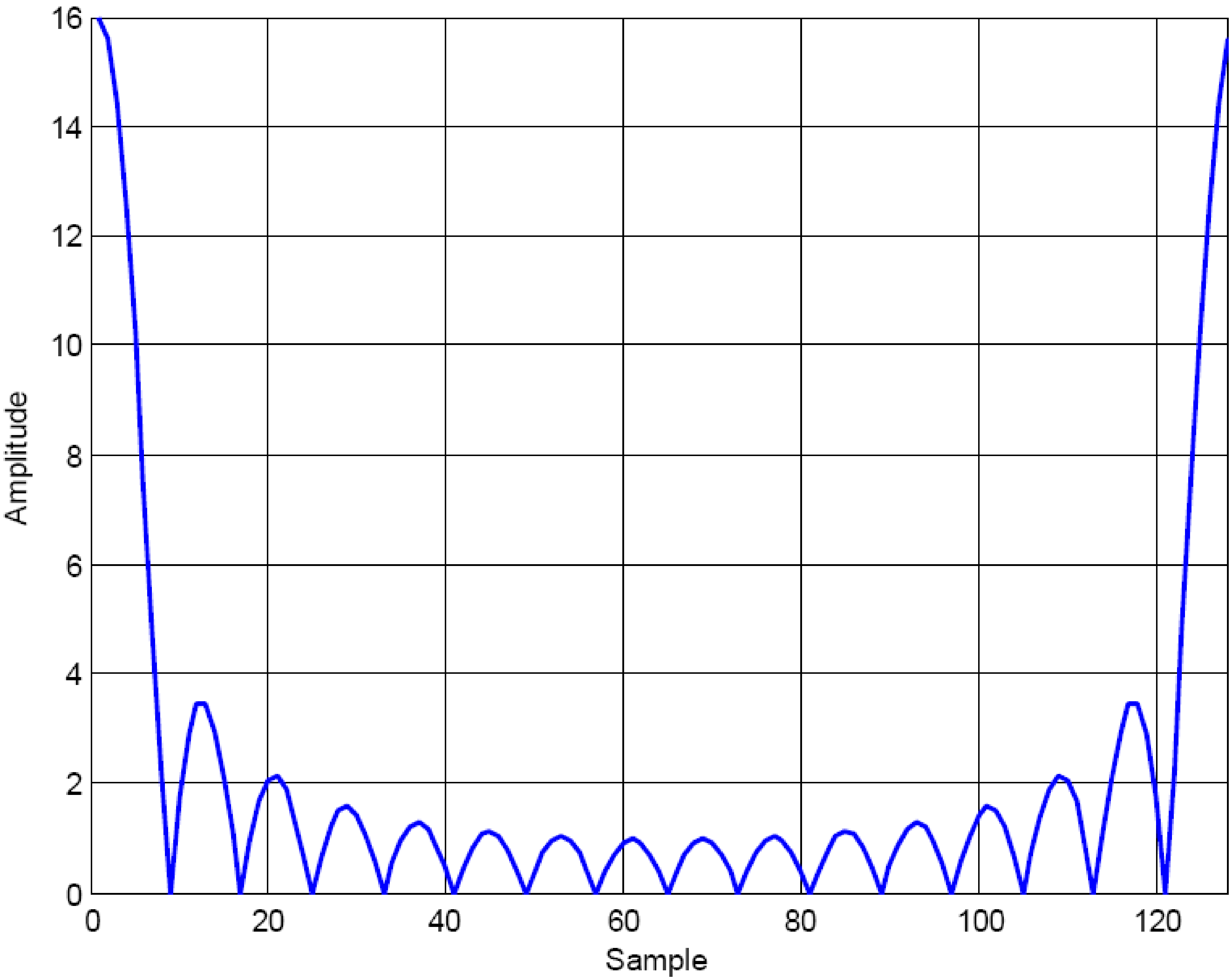


(a) Outline of OFDM transmission scheme



(b) OFDM transmission scheme implemented using IDFT/DFT

OFDM signal waveform in time domain



Peak-to-Average Power Ratio (PAPR)

- Due to the large number of sub-carriers in typical OFDM systems, the amplitude of the transmitted signal has a large dynamic range, leading to in-band distortion and out-of-band radiation when the signal is passed through the nonlinear region of power amplifier.

- Although the above-mentioned problem can be avoided by operating the amplifier in its linear region, this inevitably results in a reduced power efficiency.

- The PAPR of the transmit signal is defined as

$$PAPR = \frac{\max\limits_{0 \le t \le T} |x(t)|^2}{1/T \cdot \int_0^T |x(t)|^2 \, dt}$$

PAPR Reduction Performance Measures

- The Complementary Cumulative Distribution Function (CCDF) of the PAPR is one of the most frequently used performance measures for PAPR reduction techniques. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold.
- The CCDF of the PAPR of a data block with Nyquist rate sampling is derived as

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - \exp(-z))^N . \end{aligned}$$

Selective Mapping (SLM) Technique

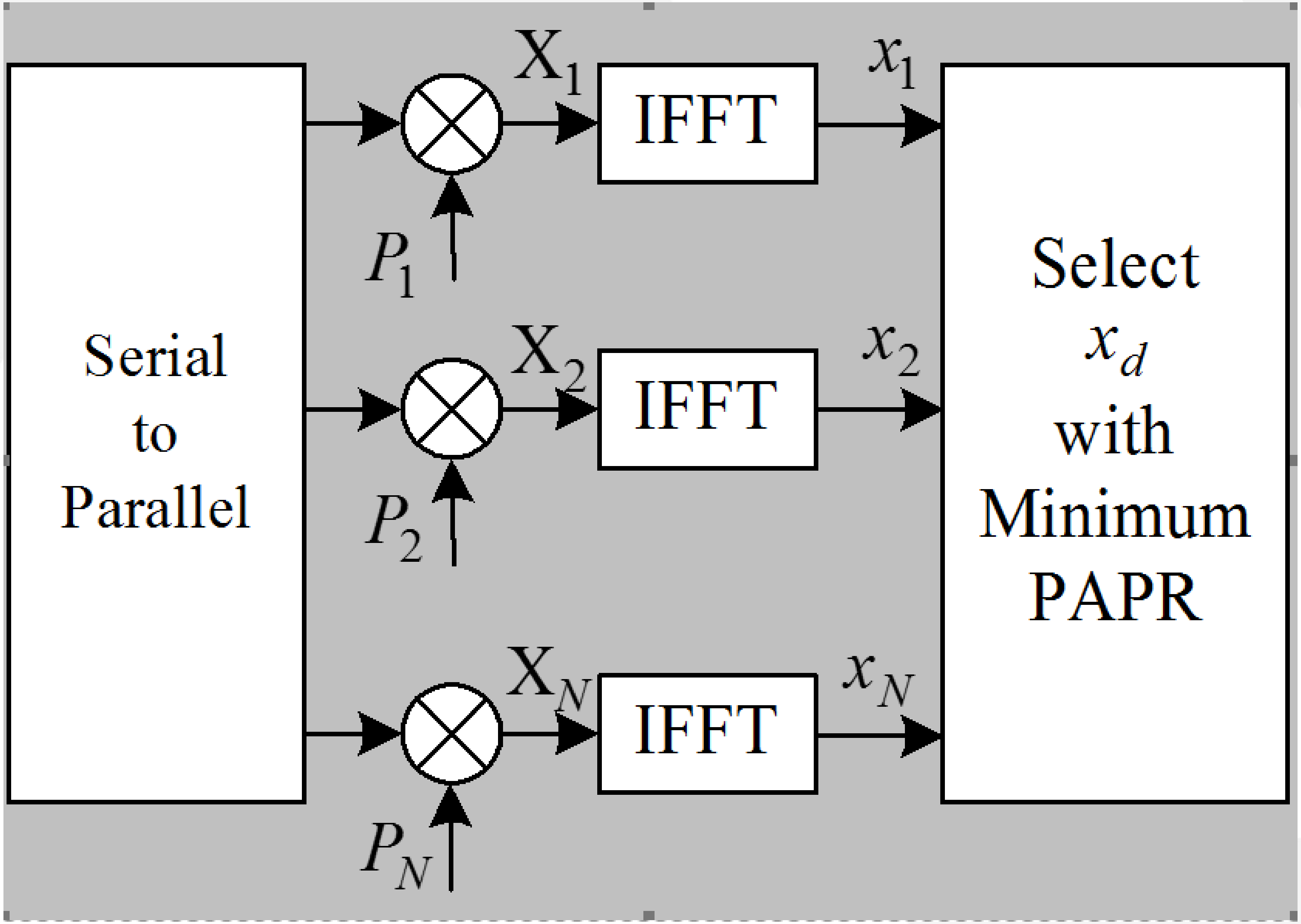


Figure 1. Block diagram of SLM technique

Partial-Transmit Sequence (PTS) Technique

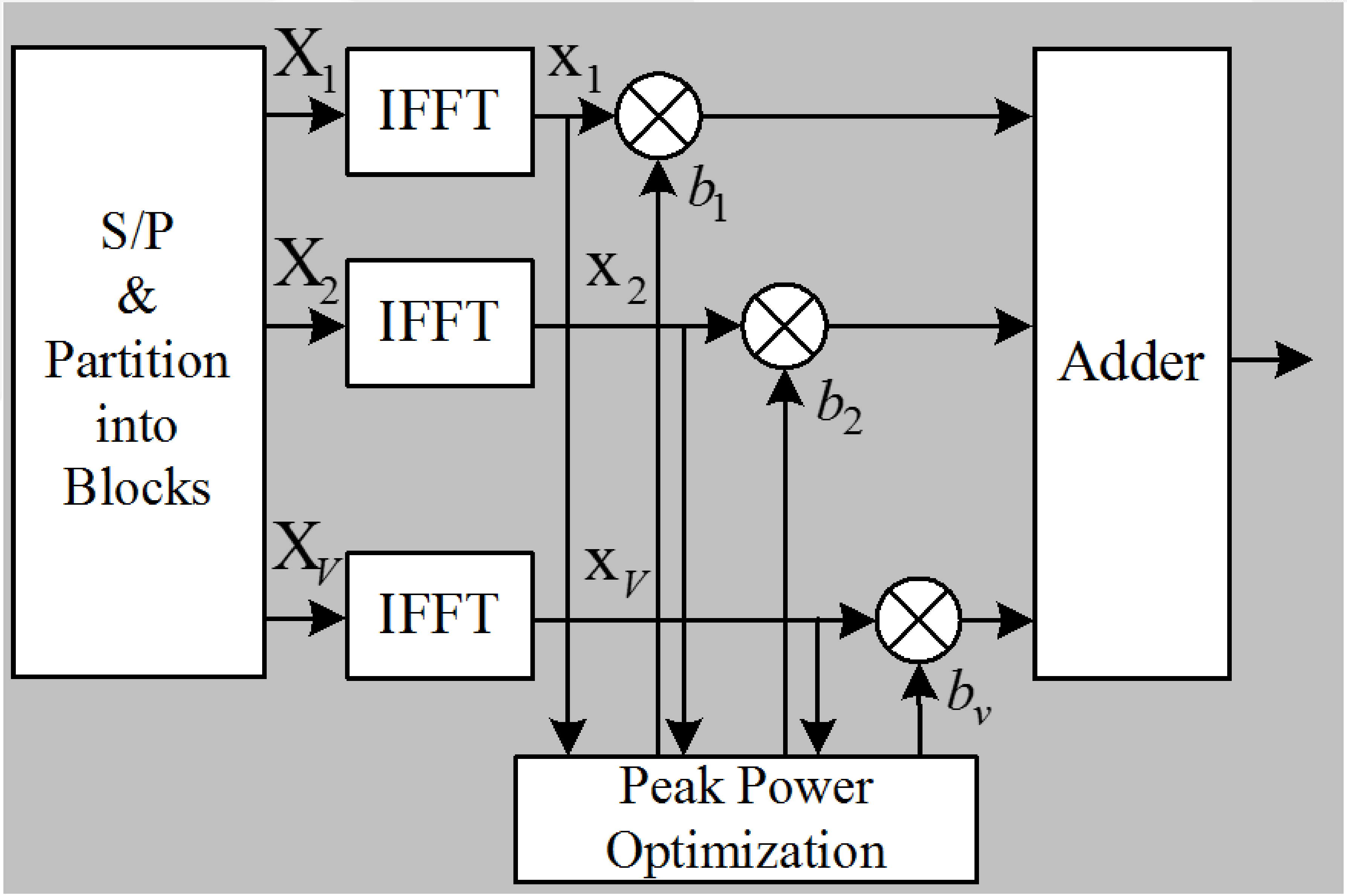


Figure 2. Block diagram of PTS technique

PTS-based LFDMA Uplink System

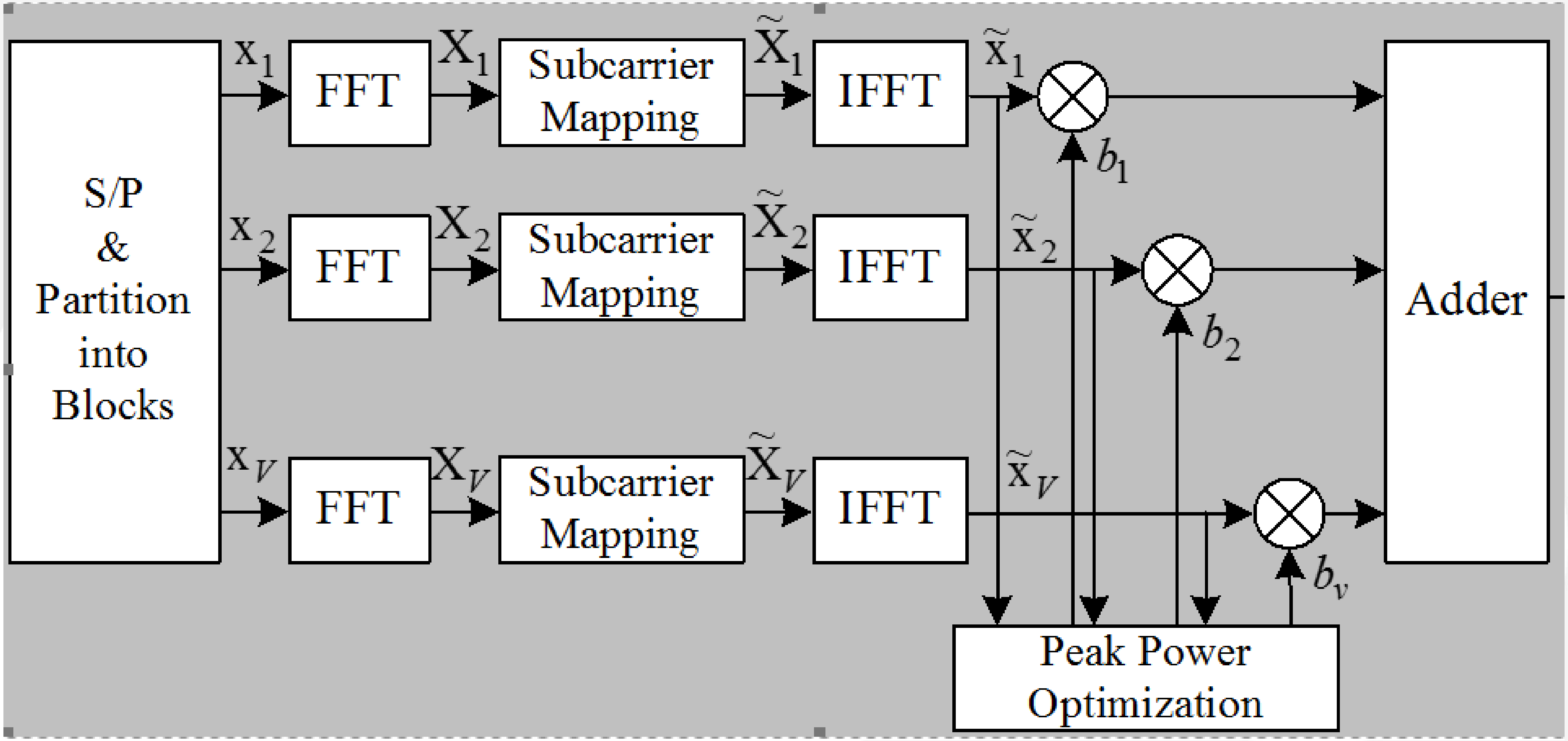
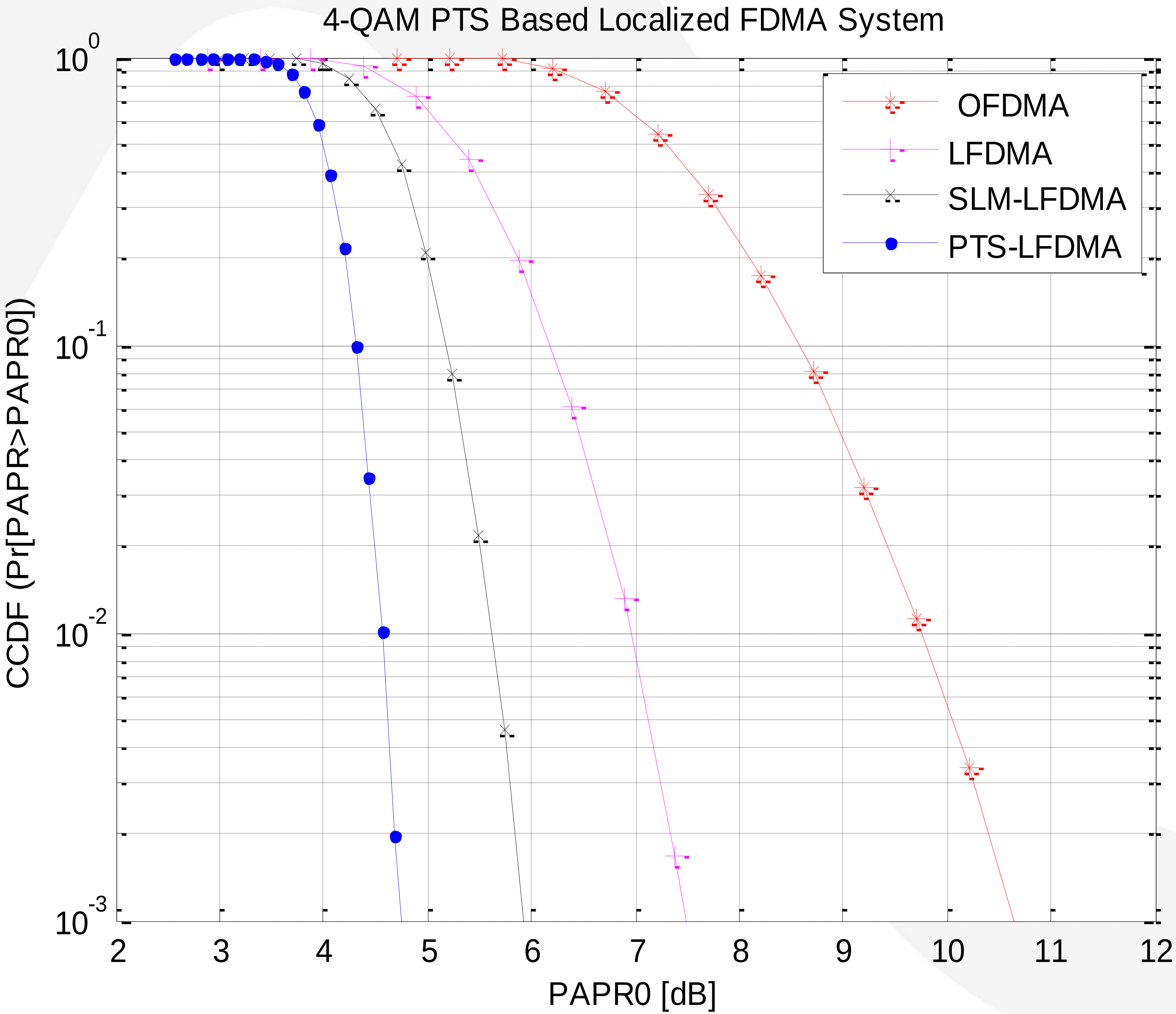


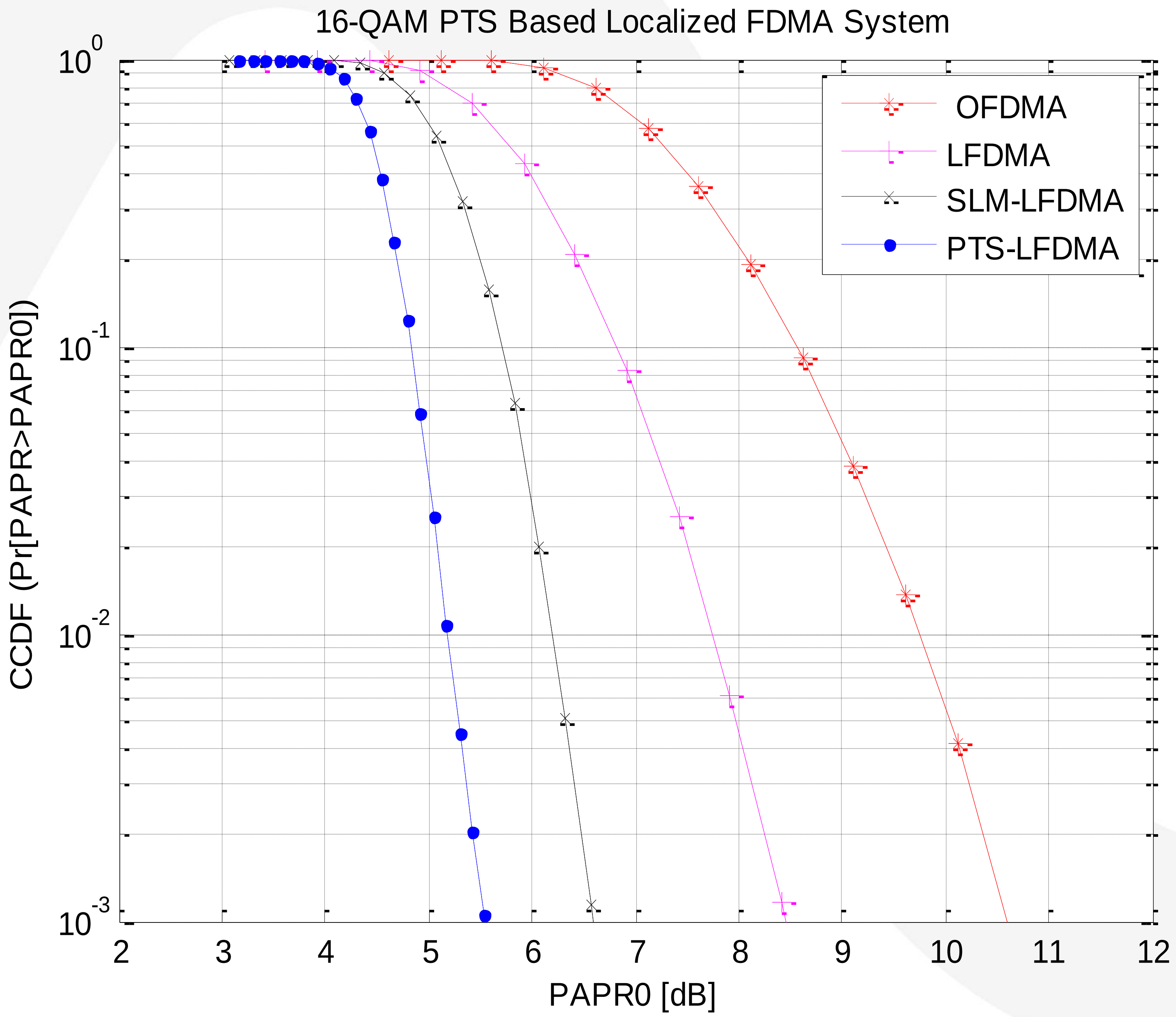
Figure 3. PTS-based LFDMA Uplink System

Simulation Results

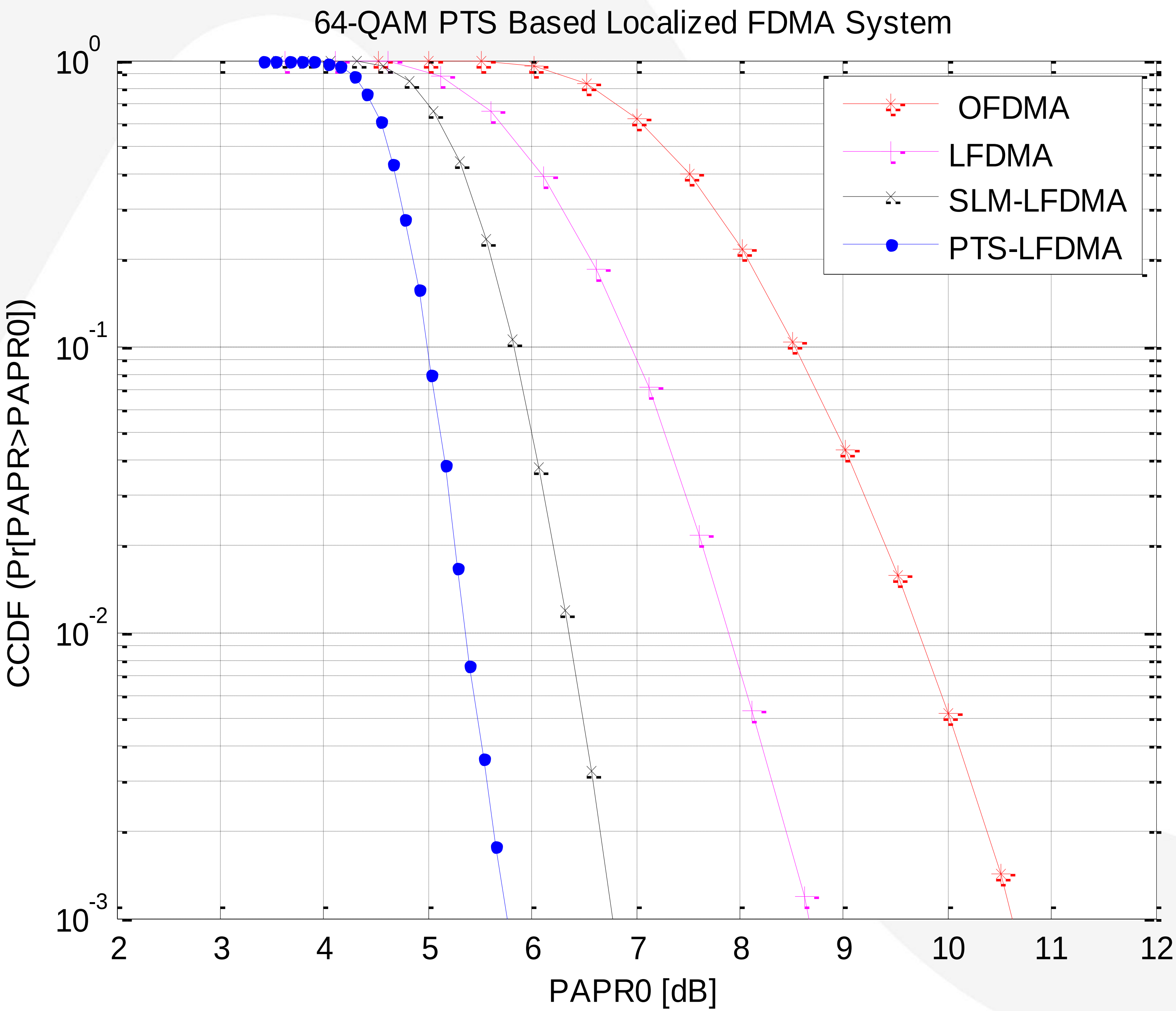
- The new system is evaluated and the data is modulated with 4QAM, 16QAM and 64QAM, respectively.
- The PAPR is calculated by using the (CCDF) technique.
- The CCDF for the PAPR of the LFDMA uplink signal has been used to represent the probability of being larger a specific value of threshold PAPR0 (CCDF = Prob(PAPR> PAPR0)).
- The simulation results of the suggested system are compared with the OFDMA, the SLM based LFDMA system, and the localized SC-FDMA (LFDMA) uplink systems, respectively.
- The following Figures display the CCDF comparisons for PAPR of the OFDMA, the LFDMA, the SLM based LFDMA, the PTS based LFDMA uplink systems with $V=4$, for $M=64$ and $N=256$ with 4-QAM, 16-QAM, and 64-QAM.



4-QAM PTS Based Localized FDMA System
CCDF (Pr[PAPR>PAPR0])
PAPR0 [dB]
OFDMA
LFDMA
SLM-LFDMA
PTS-LFDMA
10^0
10^-1
10^-2
10^-3
2
3
4
5
6
7
8
9
10
11
12



16-QAM PTS Based Localized FDMA System
OFDMA
LFDMA
SLM-LFDMA
PTS-LFDMA
CCDF (Pr[PAPR>PAPR0])
PAPR0 [dB]
10^0
10^-1
10^-2
10^-3
2
3
4
5
6
7
8
9
10
11
12


64-QAM PTS Based Localized FDMA System
OFDMA
LFDMA
SLM-LFDMA
PTS-LFDMA
CCDF (Pr[PAPR>PAPR0])
PAPR0 [dB]
10^0
10^-1
10^-2
10^-3
2
3
4
5
6
7
8
9
10
11
12

Uplink Transmission Scheme	PAPR [dB]		
	4QAM	16QAM	64QAM
OFDMA	10.7	10.7	10.7
LFDMA	7.5	8.5	8.7
SLM-LFDMA	5.9	6.6	6.8
PTS-LFDMA	4.7	5.6	5.8

Conclusions

- In this paper, the PTS based LFDMA uplink system is presented for PAPR reduction.
- Simulation results have shown that, the suggested system has less PAPR than the OFDMA, the LFDMA and the SLM based LFDMA uplink systems, respectively.
- The PAPR for the new system may be reduced more if the size of V is increased.
- However, if we increase of V size, it will increase the suggested system complexity. Therefore, the values of V must be selected carefully.
- Because of the low PAPR values, the new PTS based LFDMA uplink system is very suitable for the LTE mobile standard LTE-Advanced than the LFDMA uplink system which is already used in the LTE.

Thank You

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PAPR Reduction of Localized Single Carrier FDMA using Partial Transmit Sequence in LTE Systems

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Abstract: In this paper, the partial transmit sequence (PTS) technique is used to decrease the peak-to-average power ratio (PAPR) of the localized single-carrier frequency division multiple access (LFDMA) in the uplink of LTE systems. For a clipping rate of 0.1% with 64 user subcarriers and 256 system subcarriers with four different phase sequences; the gain of PAPR for the suggested PTS based LFDMA system is 6.56 dB and 3.06 dB, respectively when compared with the orthogonal frequency division multiple access (OFDMA) and the LFDMA uplink systems with QPSK modulation.

Keywords: Partial transmit sequence (PTS), Peak-to-Average Power Ratio (PAPR), Localized Frequency Division Multiple Access