Software and Systems Engineering

CPE3202

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PAPR Reduction Method for OFDM Systems without Side Information

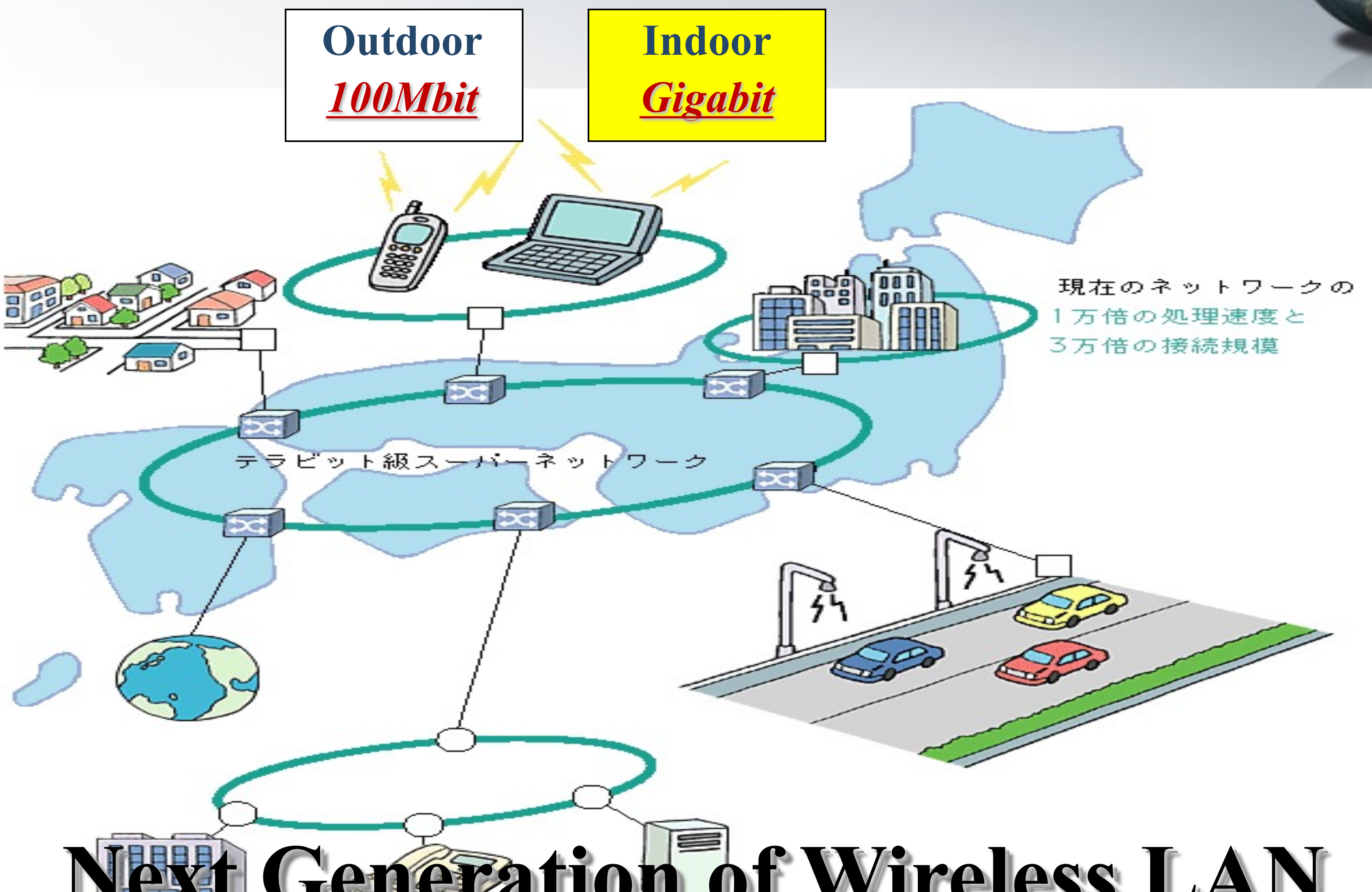
- Research Topic
  - Objective of Research
  - Conventional Methods
  - Proposal of PAPR Reduction Method
  - Performance Evaluation
  - Conclusions

Research Topic

Proposal of PAPR Reduction Method for OFDM Signal without Side Information

OFDM: <u>O</u>rthogonal <u>F</u>requency <u>D</u>ivision <u>M</u>ultiplexing

Target of Research Field



Next Generation of Wireless LAN

Advantages of OFDM

- Enable the higher data rate transmission
- Robustness to multi-path fading
- Efficient usage of frequency bandwidth

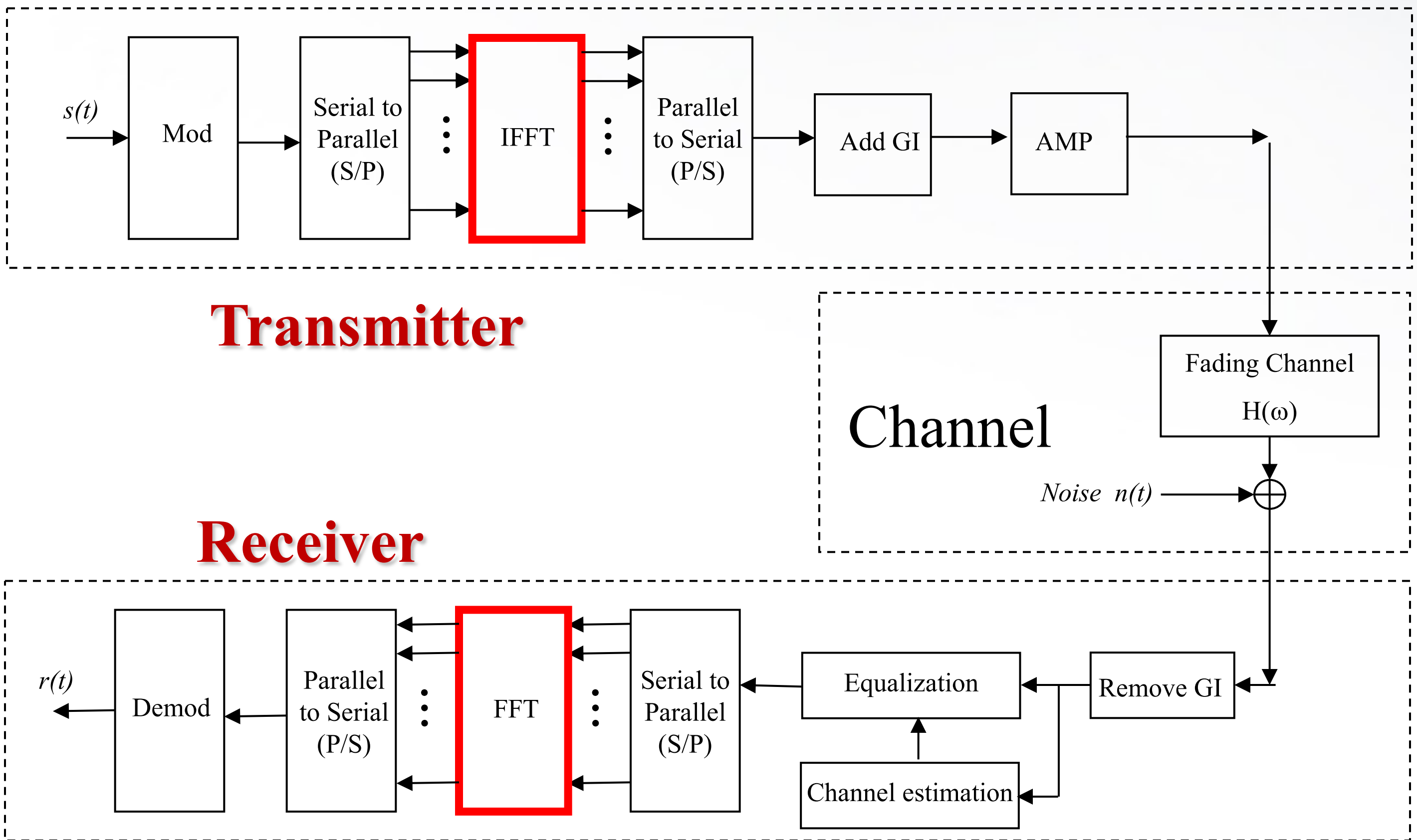
The OFDM has already been adopted as the standard transmission techniques in

- ☐ ADSL (Asynchronous Digital Subscriber Line)
- ☐ Terrestrial Digital TV
- ☐ WiMAX(Worldwide Interoperability for Microwave Access)
- ☐ Wireless LAN(Wireless Local Area Network)

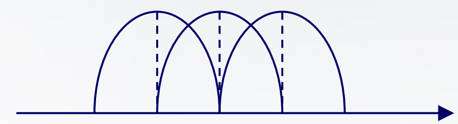
Candidate transmission technique for the next generation of wireless LAN systems

Structure of OFDM System

System Overview

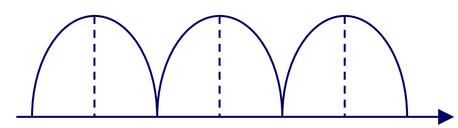


(a) OFDM spectrum



vs.

(b) conventional FDM spectrum



Disadvantage of OFDM

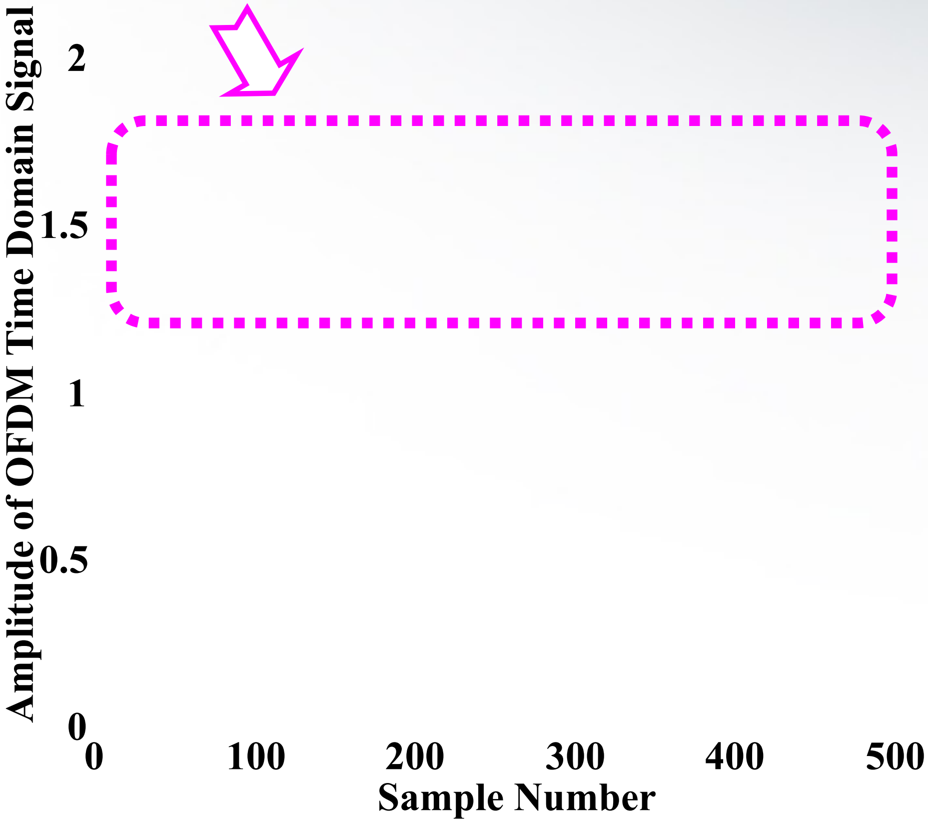
Larger peak to averaged power ratio (PAPR)

Larger PAPR will cause the degradation of BER performance and expansion of spectrum re-growth in the non-linear channel

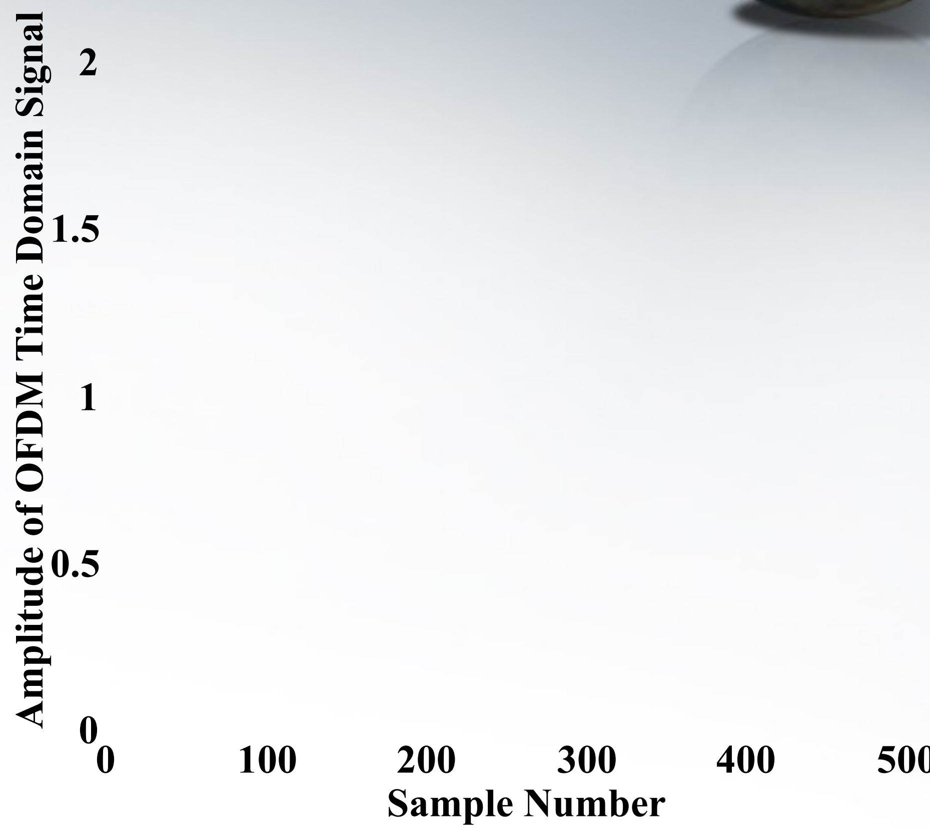
$$PAPR = \frac{P_{\max}}{P_{av}} = \frac{\max\limits_{0 \le n \le N-1} |S_n|^2}{E[|S_n|^2]}, n=0,\cdots,N-1$$

PAPR: Peak to Averaged Power Ratio

Comparison of OFDM Signal with Single Carrier Signal



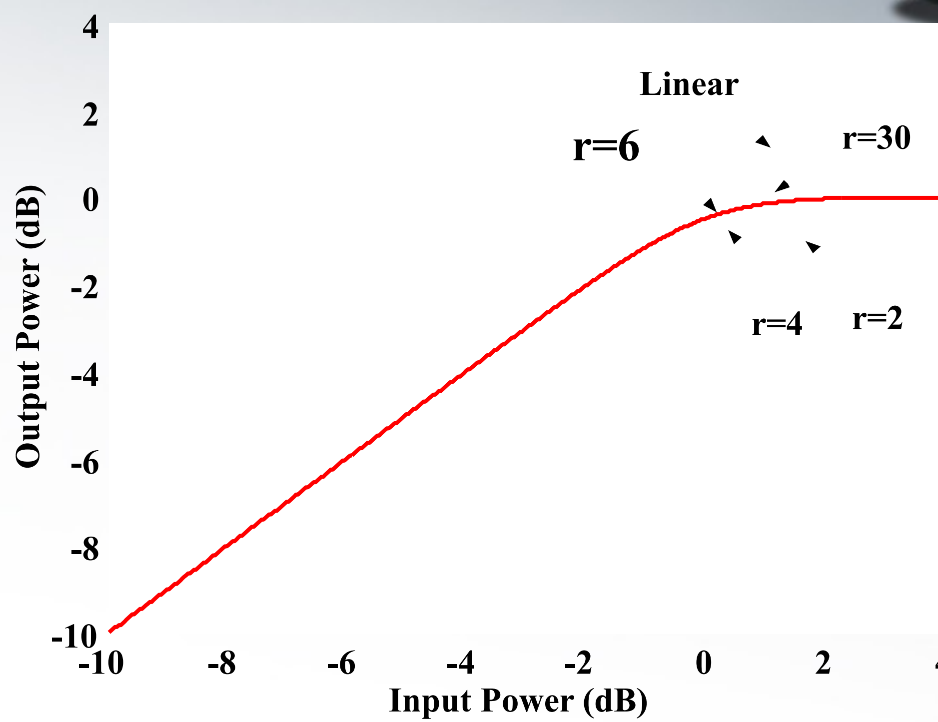
(a) OFDM signals in time domain



(b) Single carrier signal in time domain

Amplitude of OFDM time domain signal is fluctuated much larger than that for single carrier signal

Operation of OFDM Signal at Lower IBO in Non-Linear Channel

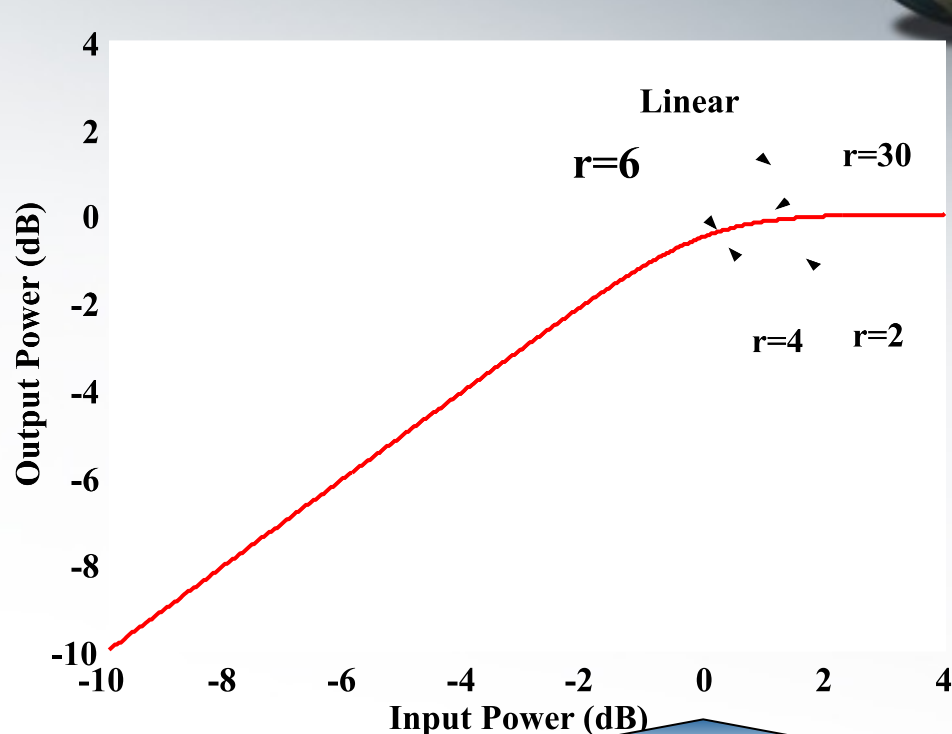


$$s_{(l,k)} = F\left[\left|y_{(l,k)}\right|\right] e^{j\left\{\arg\left(y_{(l,k)}\right)\right\}}$$

where F[ ] represent the AM/AM conversion characteristics of non-linear amplifier

Operation of OFDM Signal at Higher IBO in Non-Linear Channel

Inter-modulation Noise



$$s_{(l,k)} = F\left[\left|y_{(l,k)}\right|\right]e^{j\left\{\arg\left(y_{(l,k)}\right)\right\}}$$

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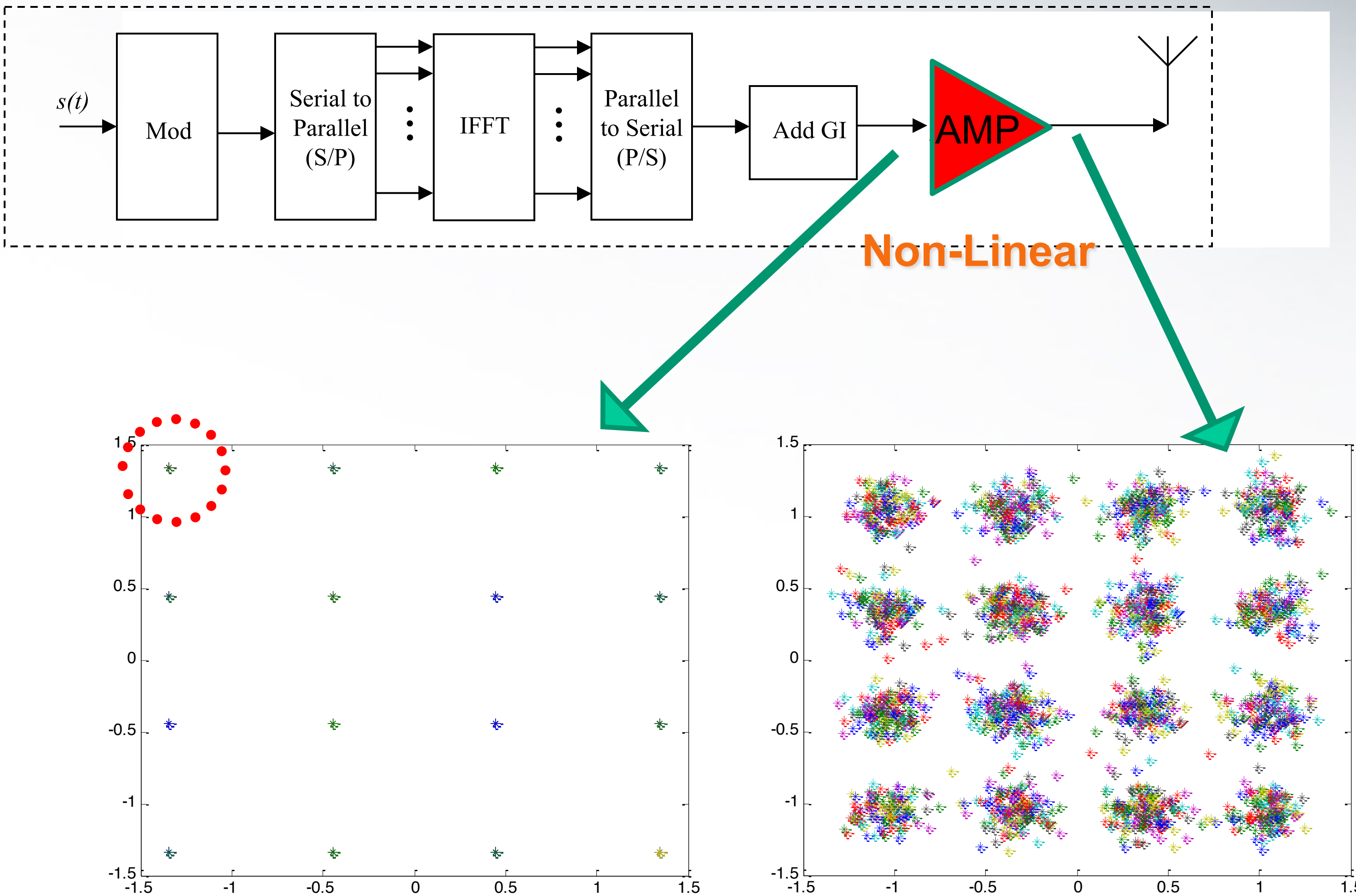
Inter-Modulation Noise Occurred at Non-Linear Amplifier

Transmitter structure of conventional OFDM



(a) Input of power amplifier

(b) Output of power amplifier

Disadvantage of OFDM Technique

OFDM with *N* sub carriers has PAPR ratio of 10log N [dB]

_N_ sub Carriers

⇩

Larger PAPR

⇩

Required Low Input Back-Off

⇩

Inefficient Usage of Power Amplifier

Improvement of PAPR

Several methods have been proposed to reduce the PAPR of OFDM signal

- **Data coding technique**

  The main disadvantage of this method is to degrade transmission efficiency

- **Clipping technique**

  The main disadvantage of this method is to degrade BER performance

- **Phase alignment technique**

  The main disadvantage of this method is required to transmit side information which leads the degradation of transmission efficiency

Conventional PAPR Reduction Methods Based on Phase Alignment Technique

- **The Selected Mapping (SLM) and Partial Transmission Sequence (PTS) methods which control the phase of data sub-carrier**
- **SLM and PTS are required to inform the phase information to the receiver as the side information (SI) for the correct demodulation**

Although the conventional method could improve the PAPR performance relatively,

the transmission efficiency and system complexity would be degraded because of the necessity of transmission of side information

Objective of Research

Improve PAPR and BER performances without degradation of transmission efficiency

Proposal of *PAPR Reduction Method for OFDM Signal*

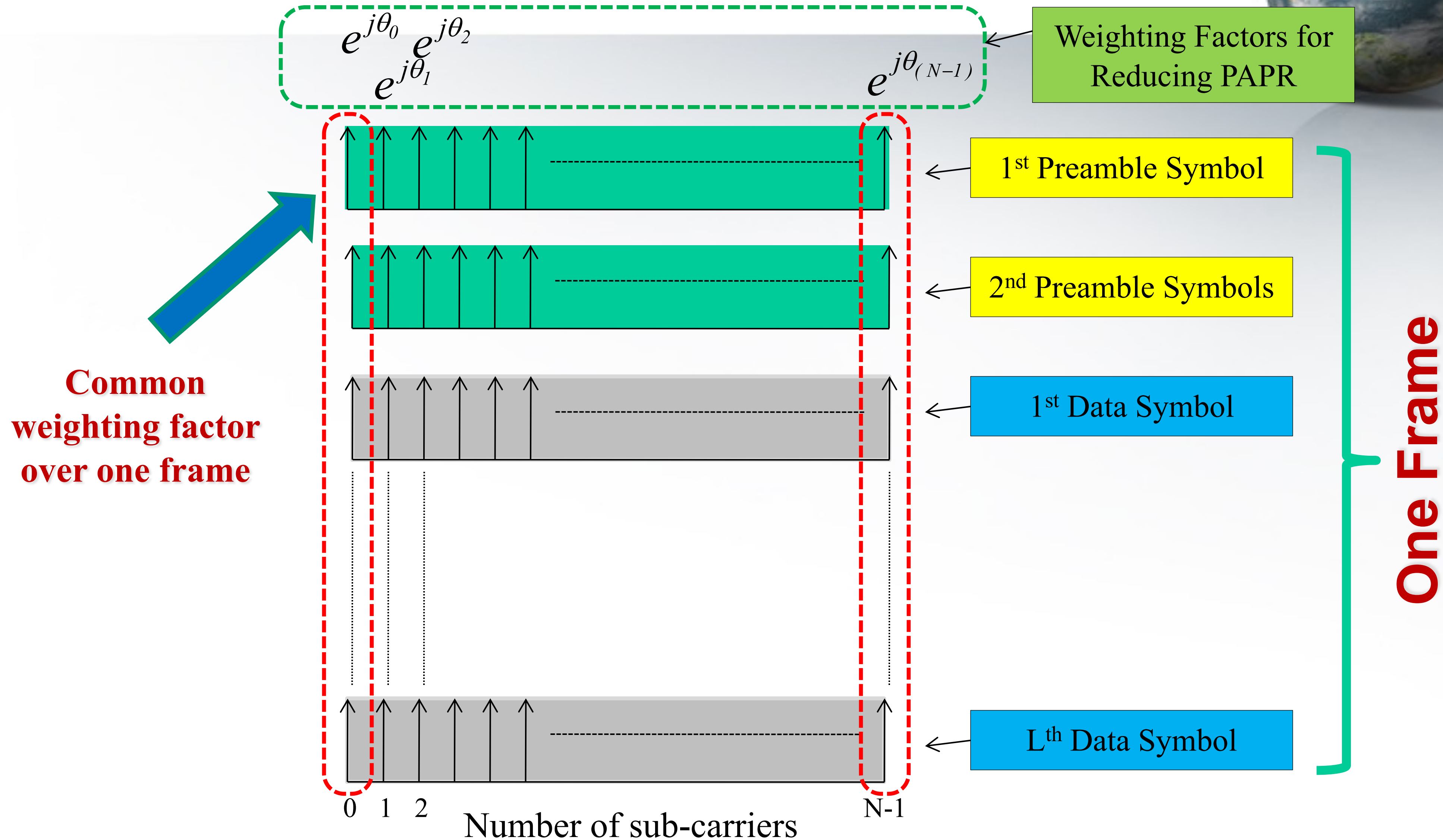
Based on Phase Alignment Technique which Requires No Side Information

Proposal of PAPR Reduction Method for OFDM Signal without Side Information

- **Use the common weighting factor over one frame including the preamble symbols**
- **The time-frequency domain swapping algorithm is employed in the determination of common weighting factor**
- **The common weighting factor can be estimated together with the channel frequency response by using preamble symbols**
- **The common weighting factor can be removed from the received data symbols by using the frequency domain equalization**

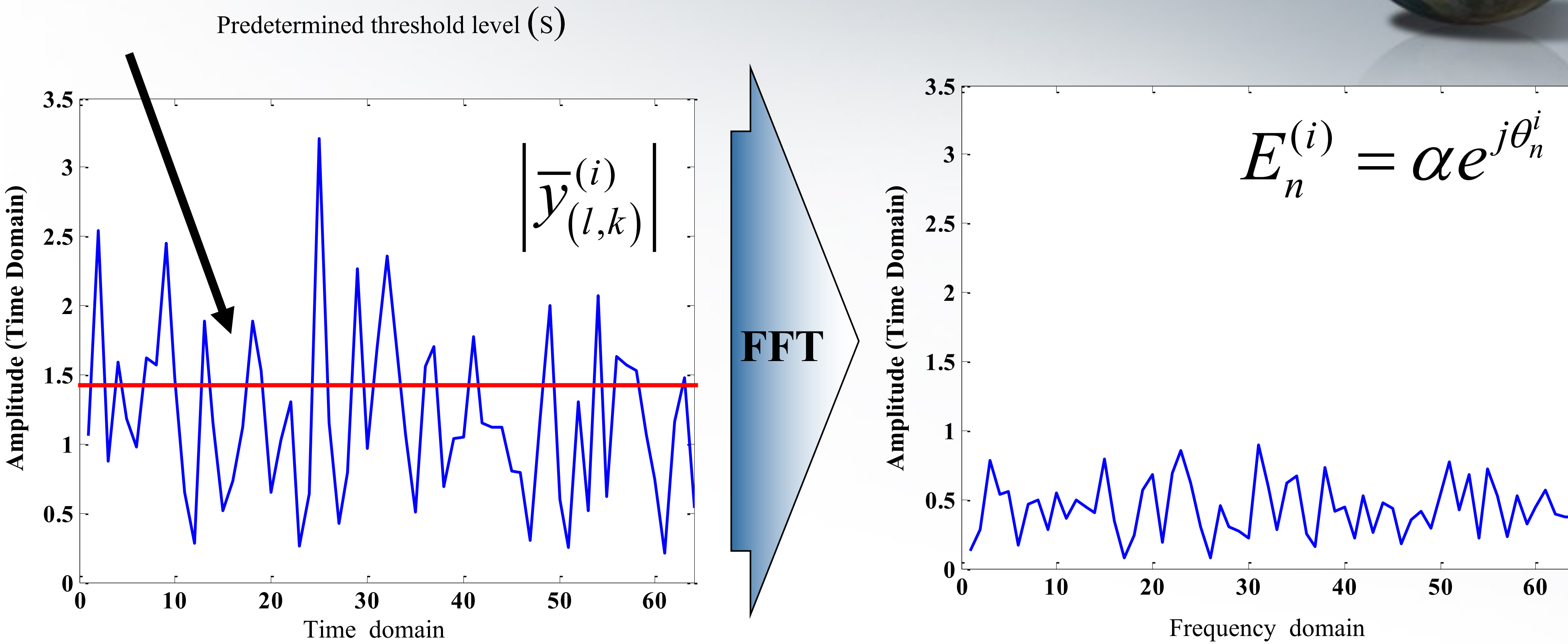
Proposed method could improve the PAPR performance without Side Information

Structure of Proposed PAPR Reduction Method



Common weighting factor will be assigned for each sub-carrier over one frame

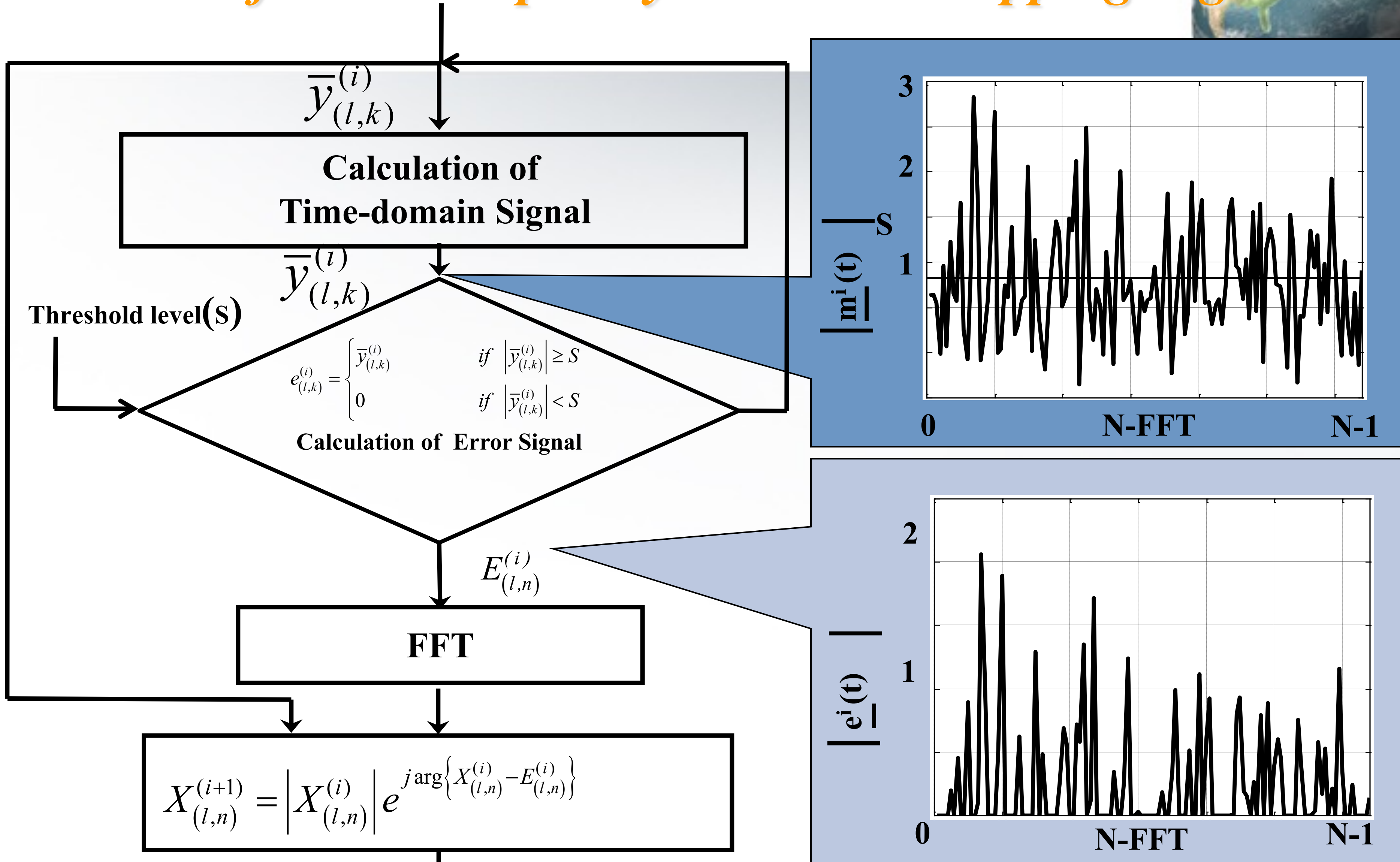
Determination of Weighting Factor by Using Time-Frequency Domains Swapping Algorithm



$$e_{(l,k)}^{(i)} = \begin{cases} \overline{y}_{(l,k)}^{(i)} & \text{if } \left|\overline{y}_{(l,k)}^{(i)}\right| \geq S \\ 0 & \text{if } \left|\overline{y}_{(l,k)}^{(i)}\right| < S \end{cases}$$

Basic concept of Time-Frequency Swapping Algorithm

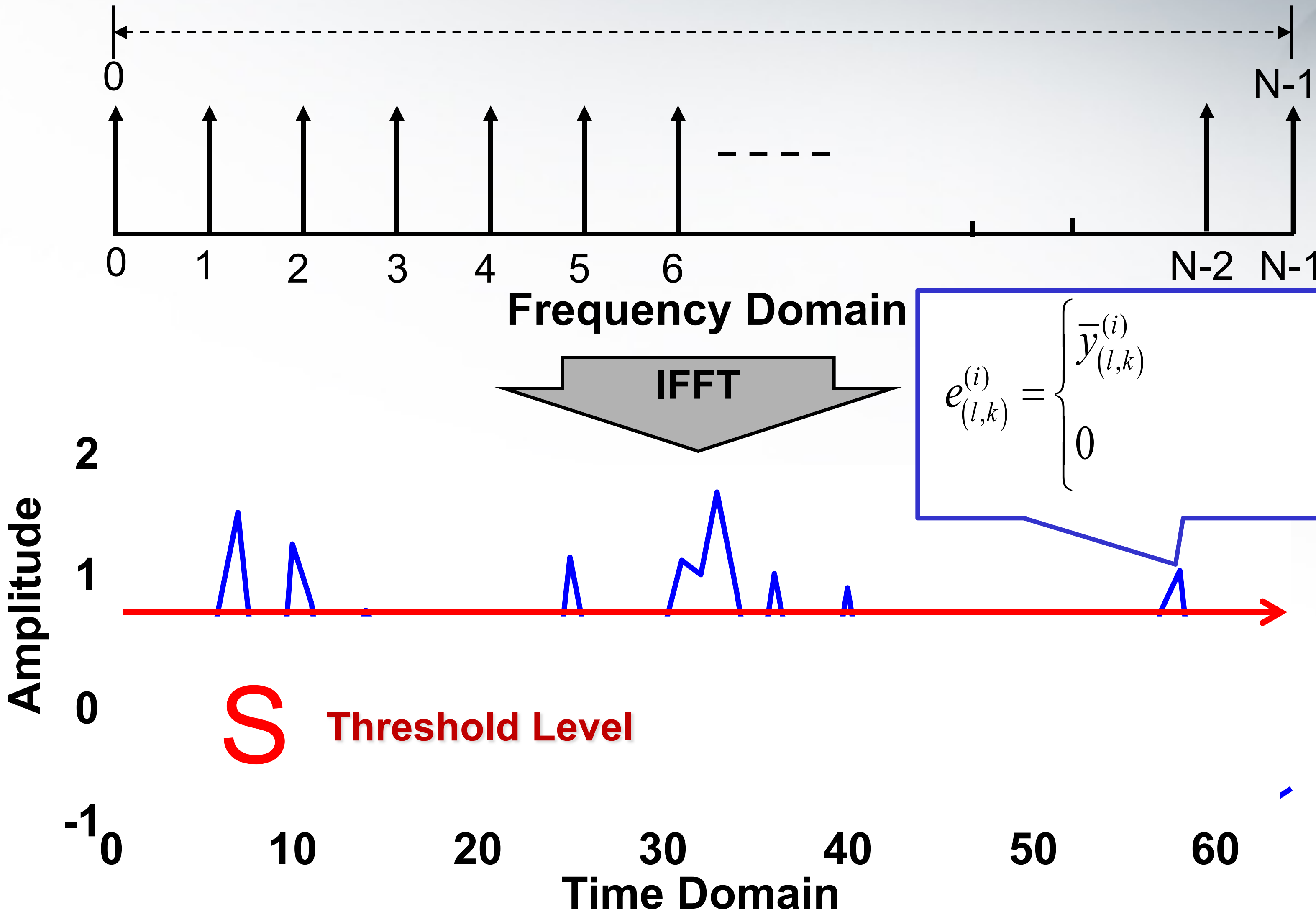
Flowchart of Time-Frequency Domains Swapping Algorithm



$$\theta^{(i+1)}_{(l,n)} = \arg\left\{X^{(i+1)}_{(l,n)}\right\} - \arg\left\{X^{(i)}_{(l,n)}\right\}$$

Determined Phase (weighting factor)

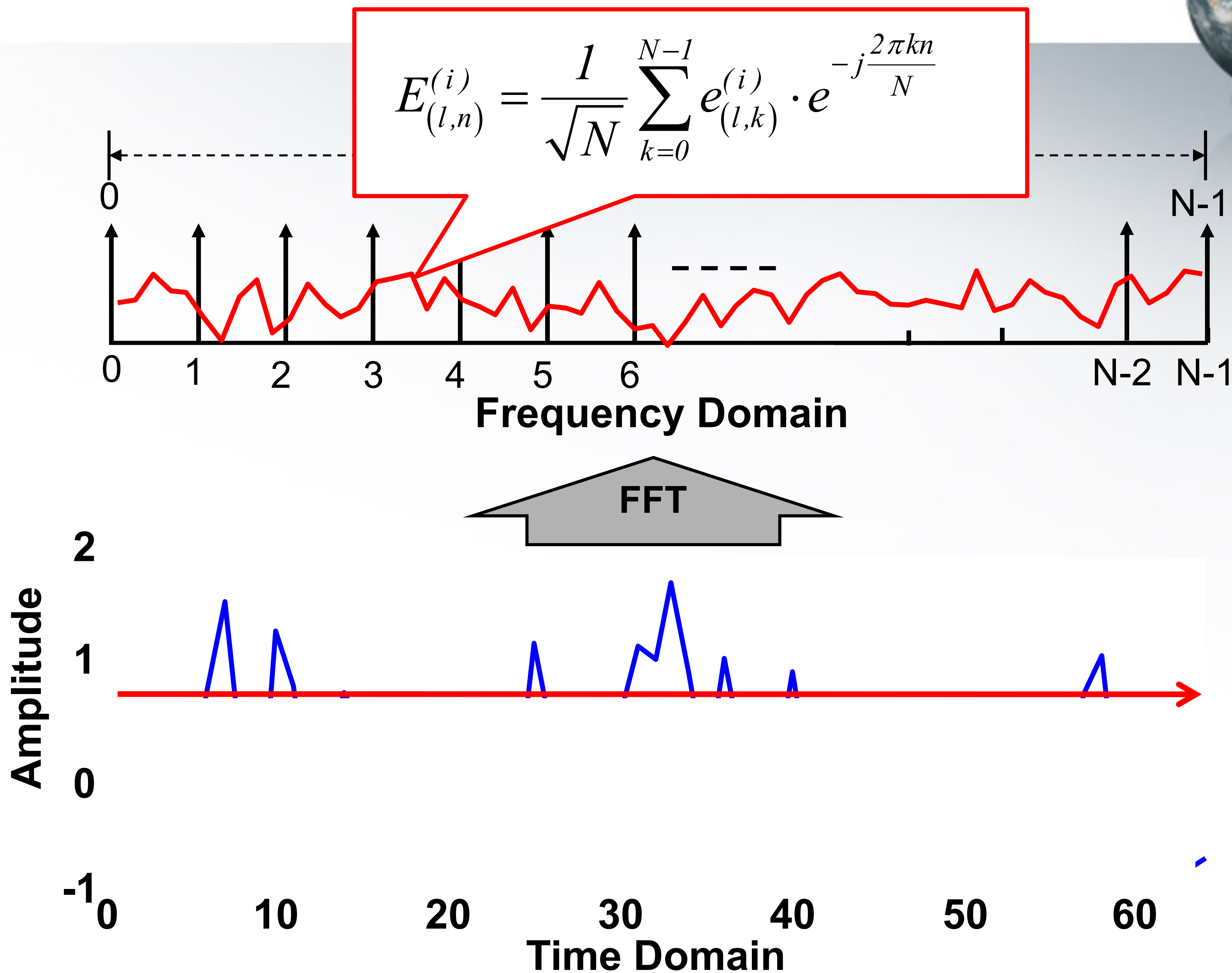
Basic Concept of Proposed Algorithm



$$e^{(i)}_{(l,k)} = \begin{cases} \bar{y}^{(i)}_{(l,k)} & if \ \left|\bar{y}^{(i)}_{(l,k)}\right| \geq S \\ 0 & if \ \left|\bar{y}^{(i)}_{(l,k)}\right| < S \end{cases}$$

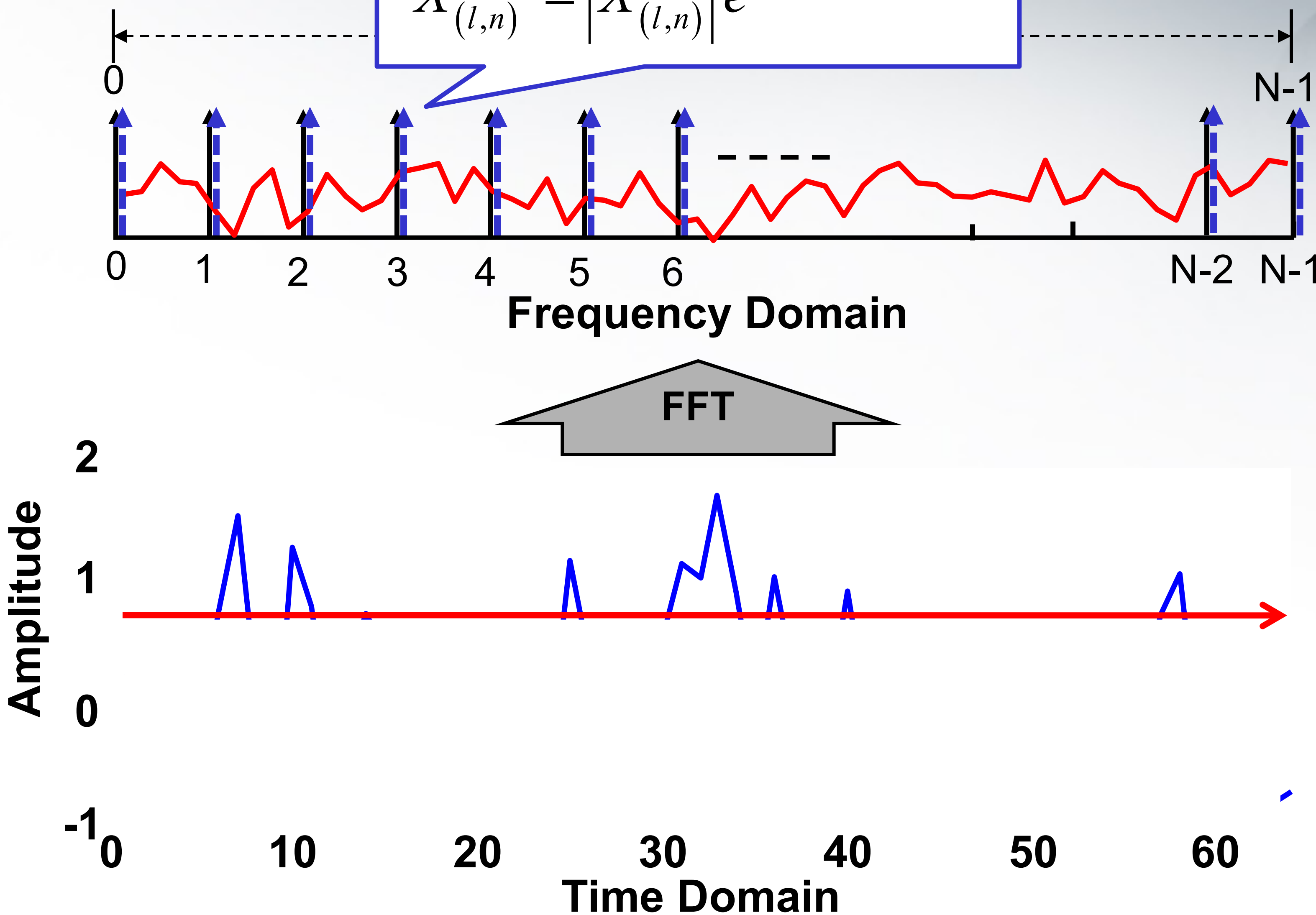
Basic Concept of Proposed Algorithm

$$E_{(l,n)}^{(i)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} e_{(l,k)}^{(i)} \cdot e^{-j\frac{2\pi kn}{N}}$$

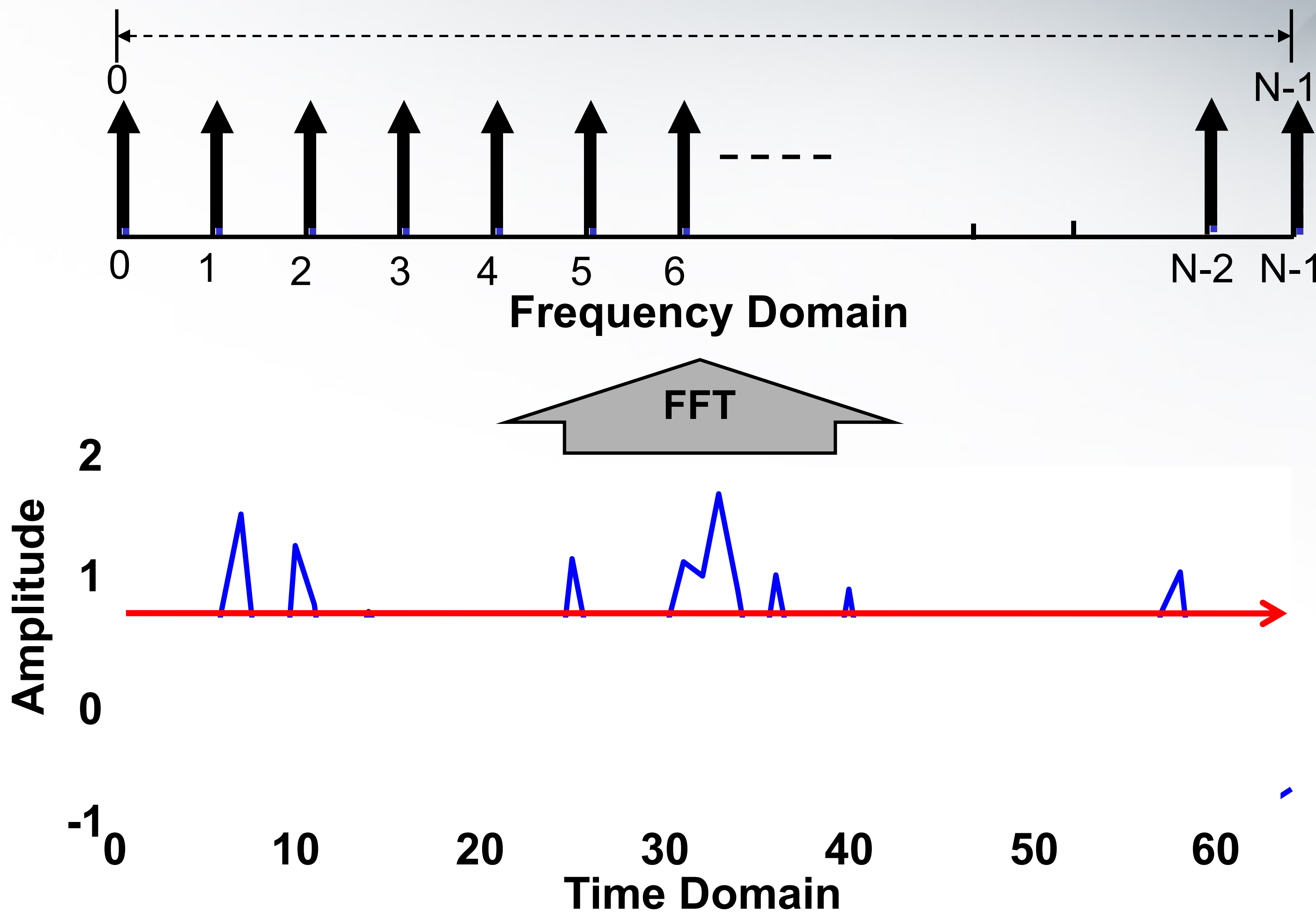


Basic Concept of Proposed Algorithm

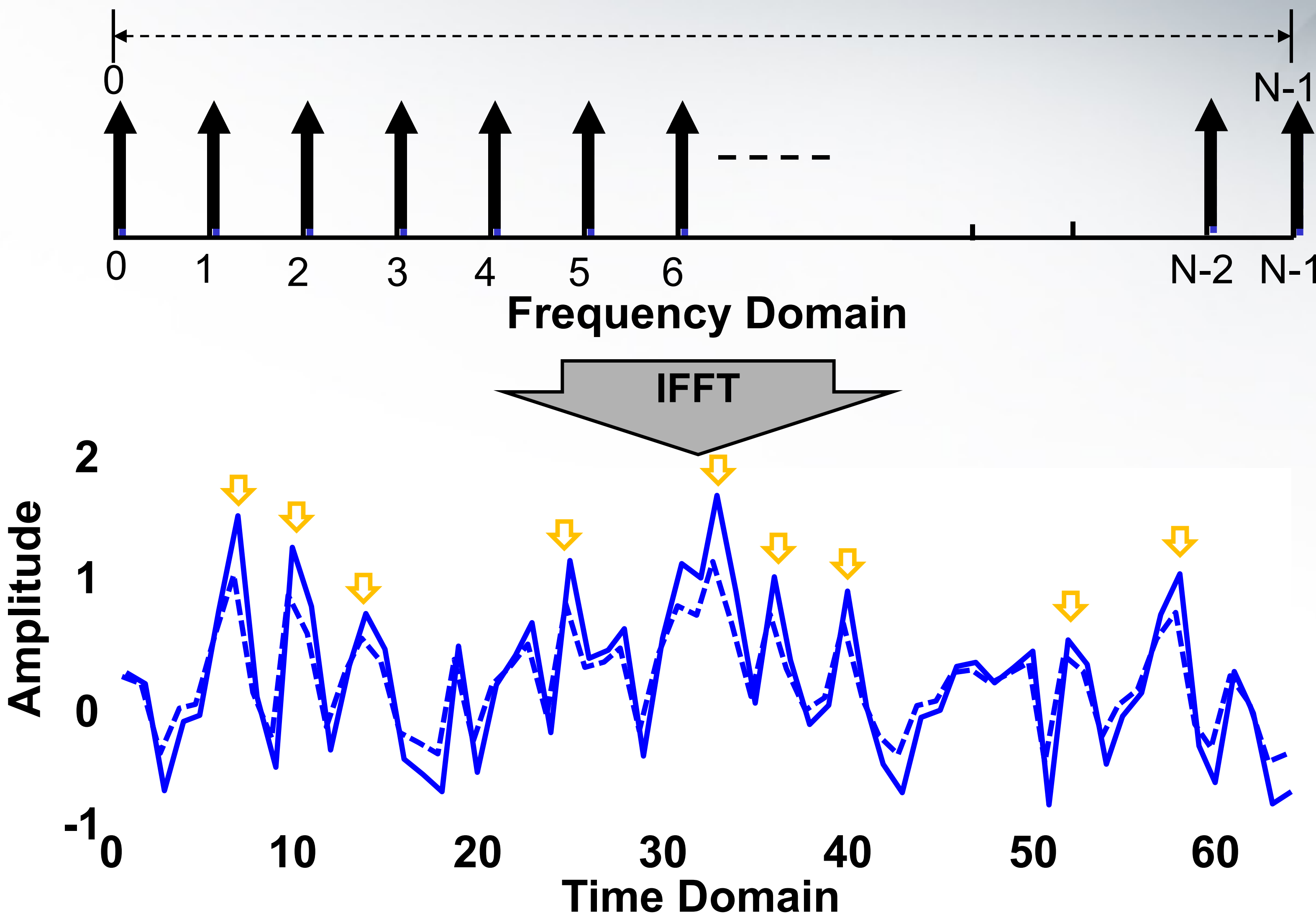
$$X_{(l,n)}^{(i+1)} = \left| X_{(l,n)}^{(i)} \right| e^{j \arg\left\{ X_{(l,n)}^{(i)} - E_{(l,n)}^{(i)} \right\}}$$



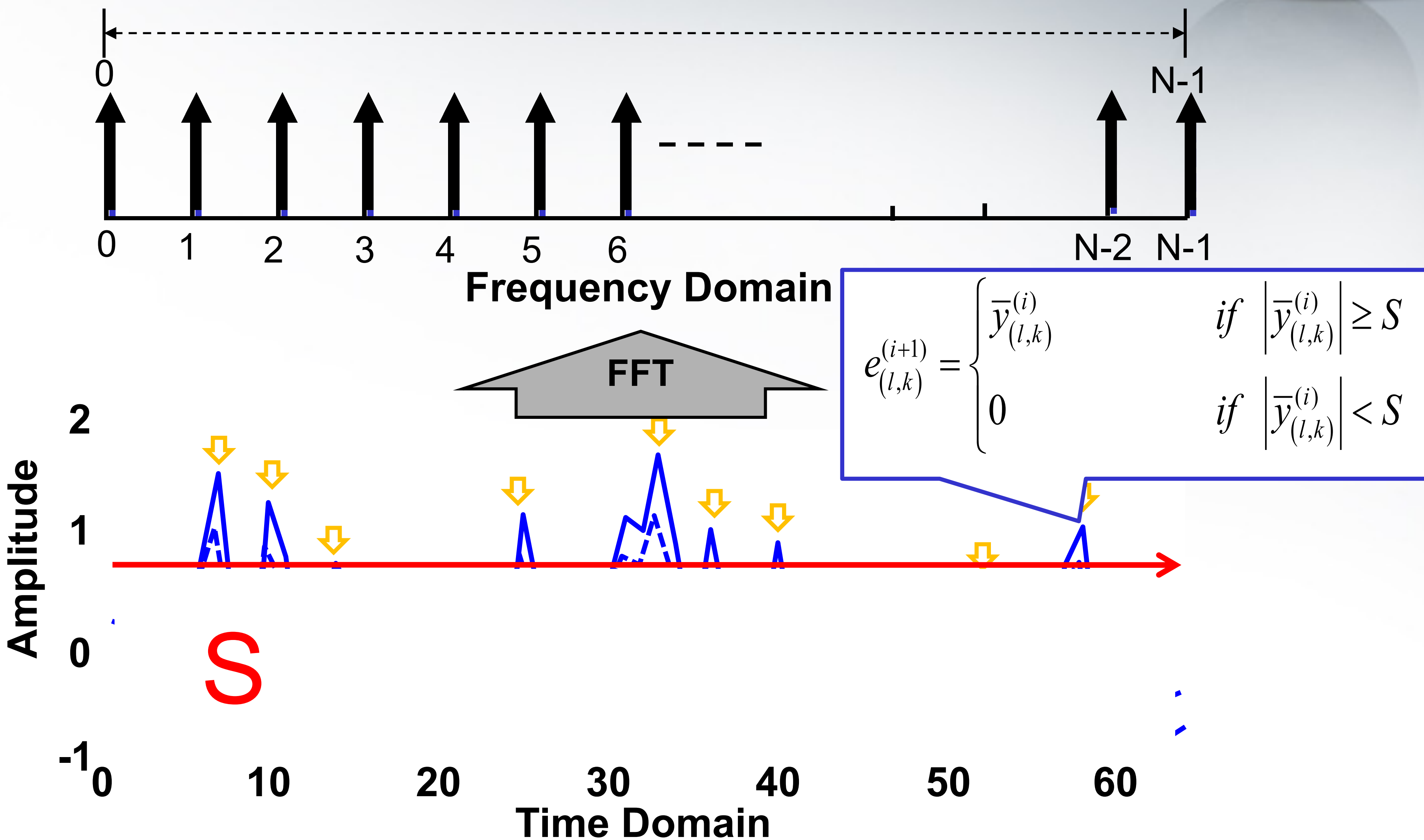
Basic Concept of Proposed Algorithm



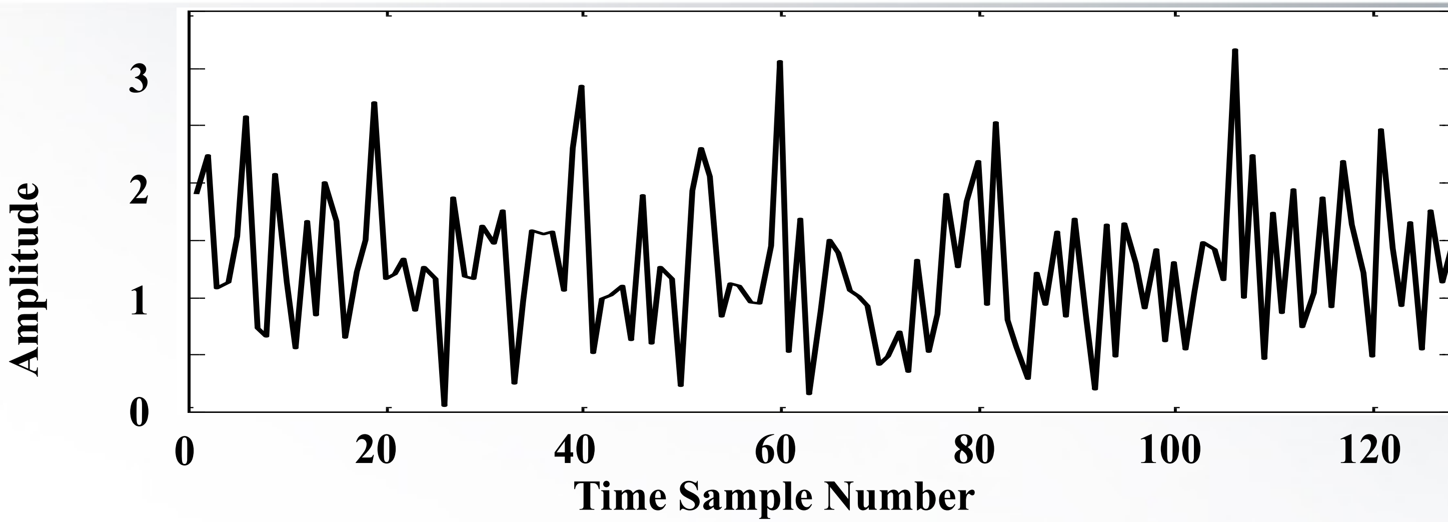
Basic Concept of Proposed Algorithm



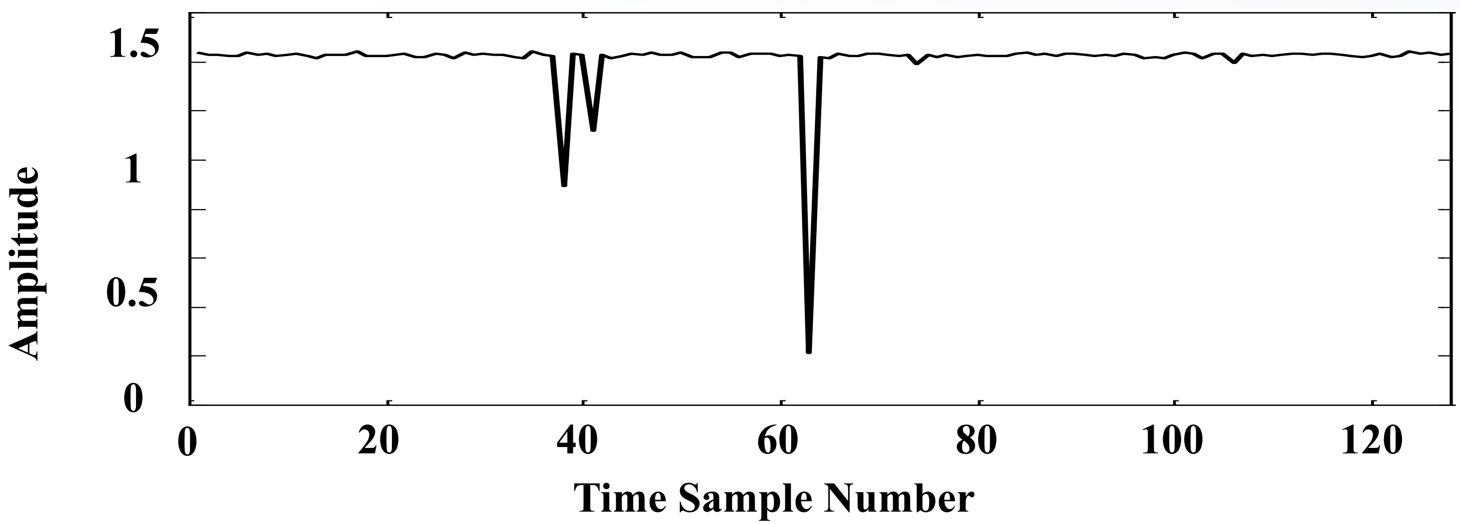
Basic Concept of Proposed Algorithm



Amplitude of OFDM signal in the time domain



(a) Before T-F Swapping Algorithm



(b) After T-F Swapping Algorithm

Determination of Weighting Factor

$$E_{(l,n)}^{(i)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} e_{(l,k)}^{(i)} \cdot e^{-j\frac{2\pi kn}{N}}$$

Error signal in frequency domain

$$X_{(l,n)}^{(i+1)} = \left| X_{(l,n)}^{(i)} \right| e^{j\arg\left\{ X_{(l,n)}^{(i)} - E_{(l,n)}^{(i)} \right\}}$$

OFDM signal in frequency domain

$$\theta_{(l,n)}^{(i+1)} = \arg\left\{ X_{(l,n)}^{(i+1)} \right\} - \arg\left\{ X_{(l,n)}^{(i)} \right\}$$

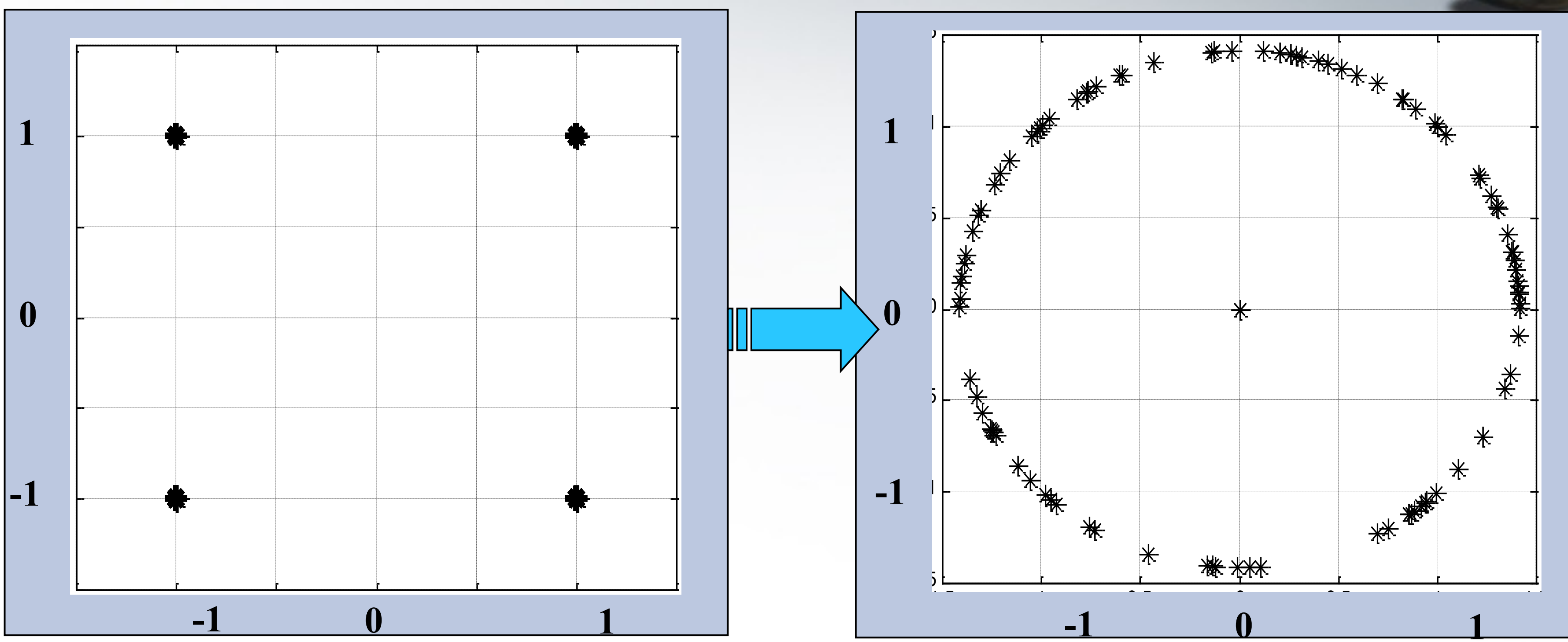
Determined weighting factor

Average for the weighting factors obtained for all symbols

$$\theta_n^{(i+1)} = \frac{\arg\left\{ \sum_{l=1}^{L} e^{j\theta_{(l,n)}^{(i+1)}} \right\}}{L}$$

Common weighting factor over one frame

Scatter Diagram of Preamble and Data Symbols

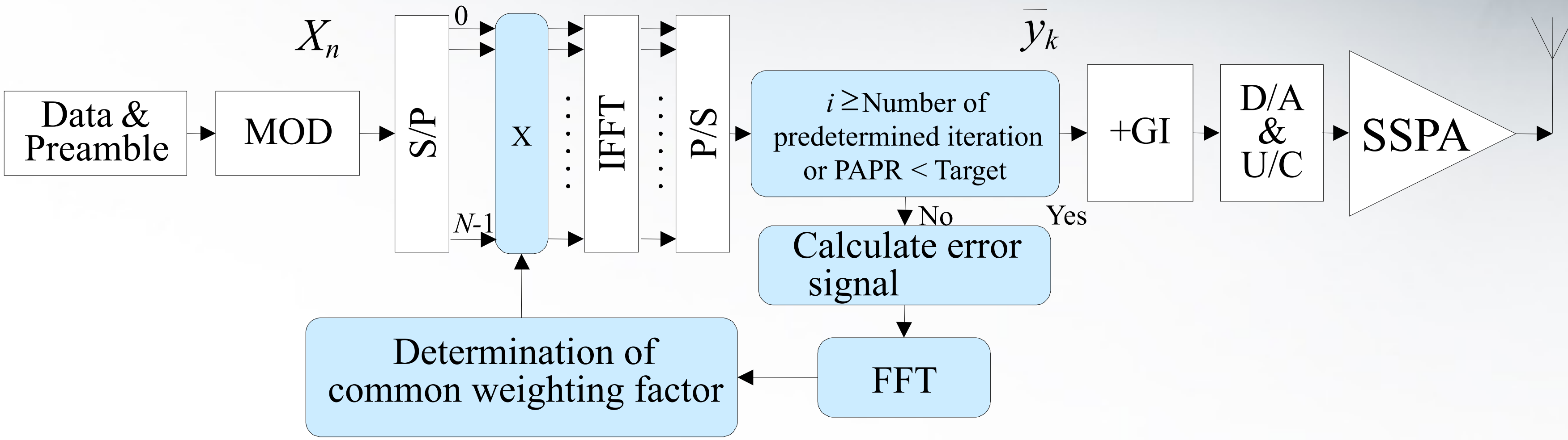


(a) (b)

(a) Original OFDM Signal

(b) Phase Rotation due to weighting factor

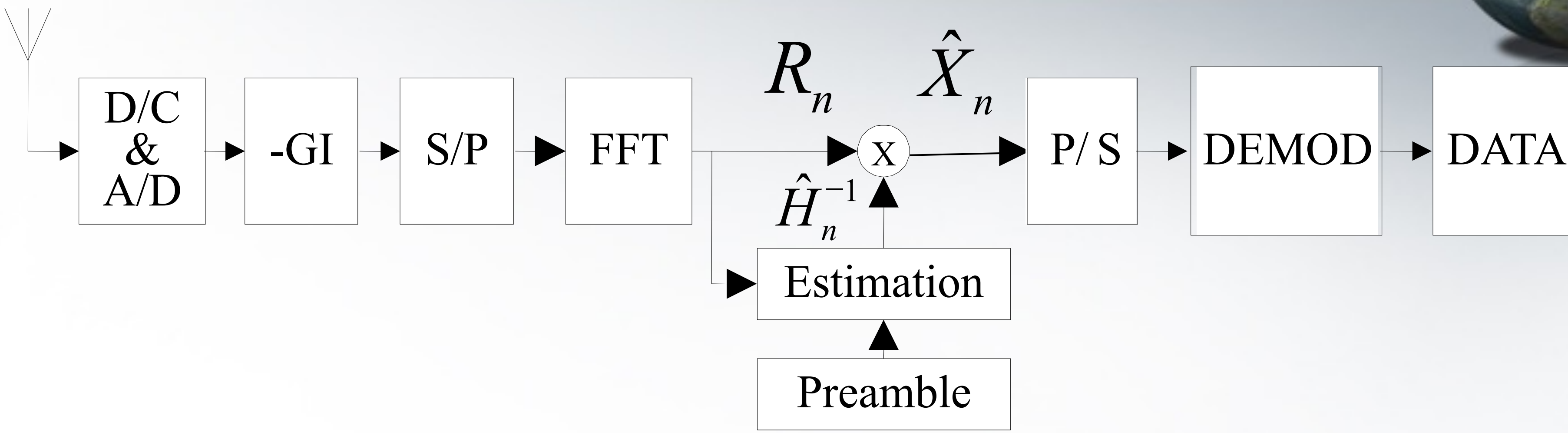
Structure of Transmitter for Proposal Method



$$\bar{y}_k^{(i+1)} = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} \left\{ X_n^{(i)} \cdot e^{j\theta_n^{(i+1)}} \right\} \cdot e^{j\frac{2\pi kn}{N}}$$

$$= \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n^{(i+1)} \cdot e^{j\frac{2\pi kn}{N}}$$

Structure of Receiver for Proposed Method



$R_n = X_n \cdot e^{j\theta_n} \cdot H_n + N_n$ **Received Data**

$$\hat{H}_n = (X_n \cdot e^{j\theta_n} \cdot H_n + N_n) / X_n$$

$$= e^{j\theta_n} \cdot H_n + N_n / X_n$$

$$\approx e^{j\theta_n} \cdot H_n$$

Estimated Channel Response

θ_n **: Weighting Factor at n-th Sub-Carrier**

Frequency Domain Equlization

$$\hat{X}_n = R_n / \hat{H}_n$$

$$= (X_n \cdot e^{j\theta_n} \cdot H_n + N_n) / (e^{j\theta_n} \cdot \hat{H}_n)$$

$$= X_n + N_n / (e^{j\theta_n} \cdot \hat{H}_n)$$

$$\approx X_n$$

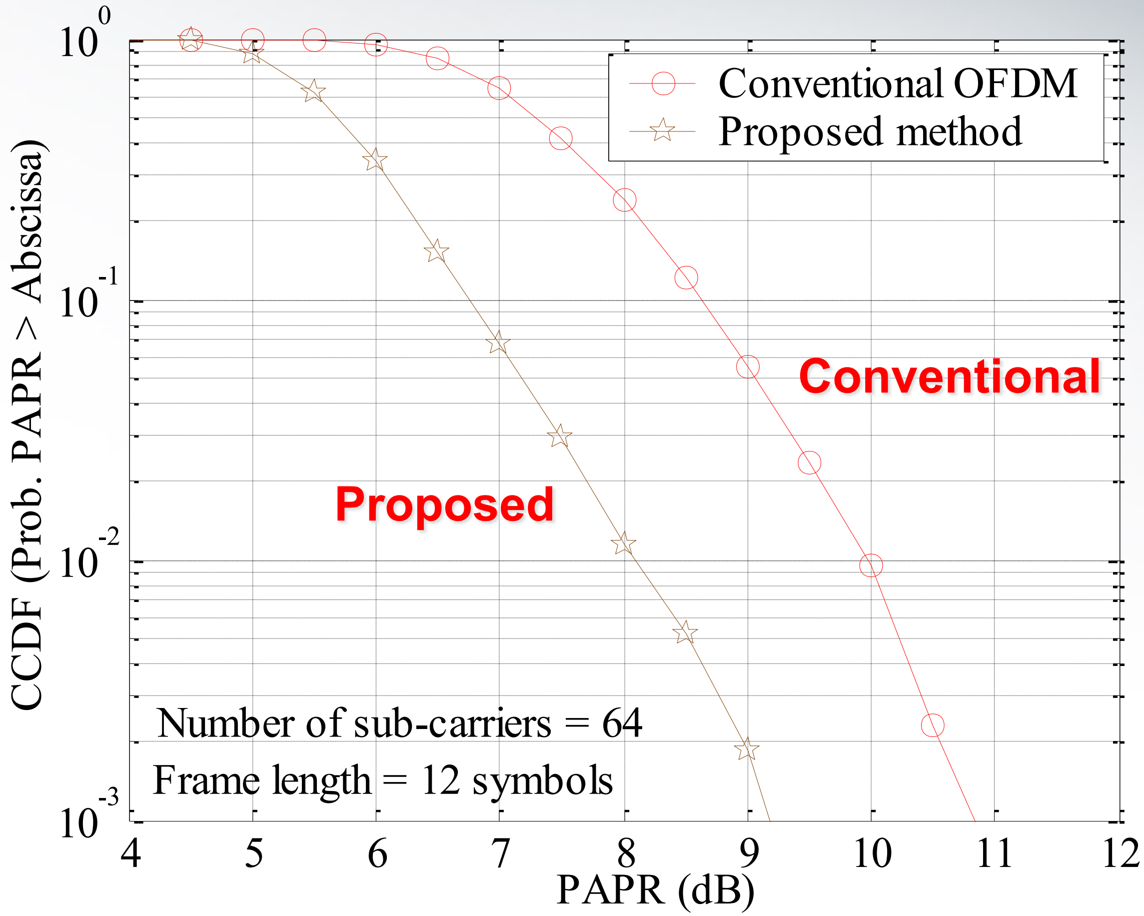
Demodulated Data

List of Parameters in Performance Evaluation

Modulation	**64QAM**
Demodulation	**Coherent**
Allocated bandwidth	**5MHz**
Number of *FFT* points	**256**
Number of sub-carriers	**64**
Symbol duration	**12.8 μs**
Guard interval	**1.28 μs**
Non-linear amplifier	**SSPA**
Non-linear parameter of SSPA	$r=2$
Number of data symbols in one frame	**12**
Number of preamble symbols in one frame	**2**
Multi-path fading model	
Power delay profile	**Exponential**
Number of delay paths	**16**
Decay constant	**-1 dB**

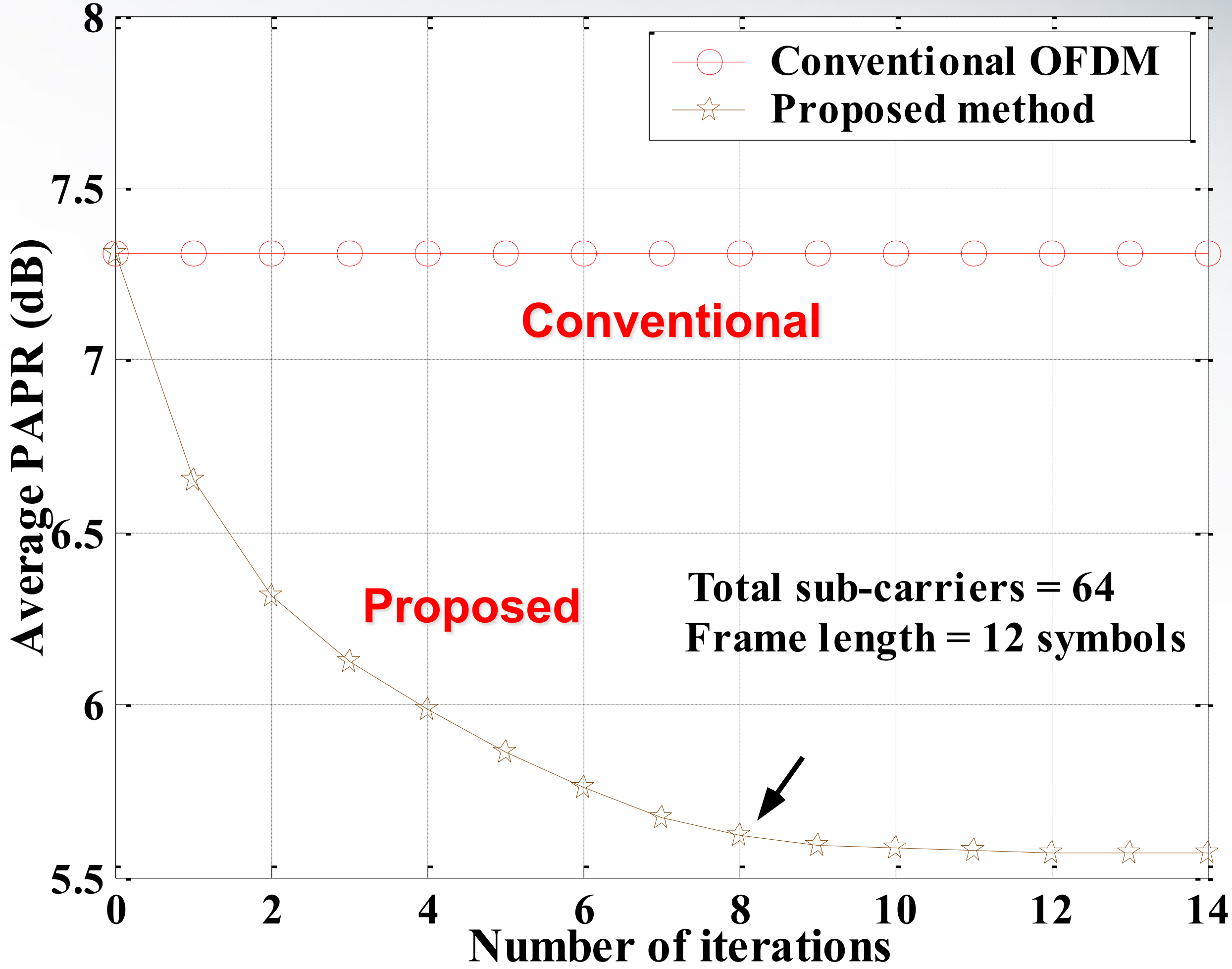
PAPR Performance

Modulation Method =64QAM



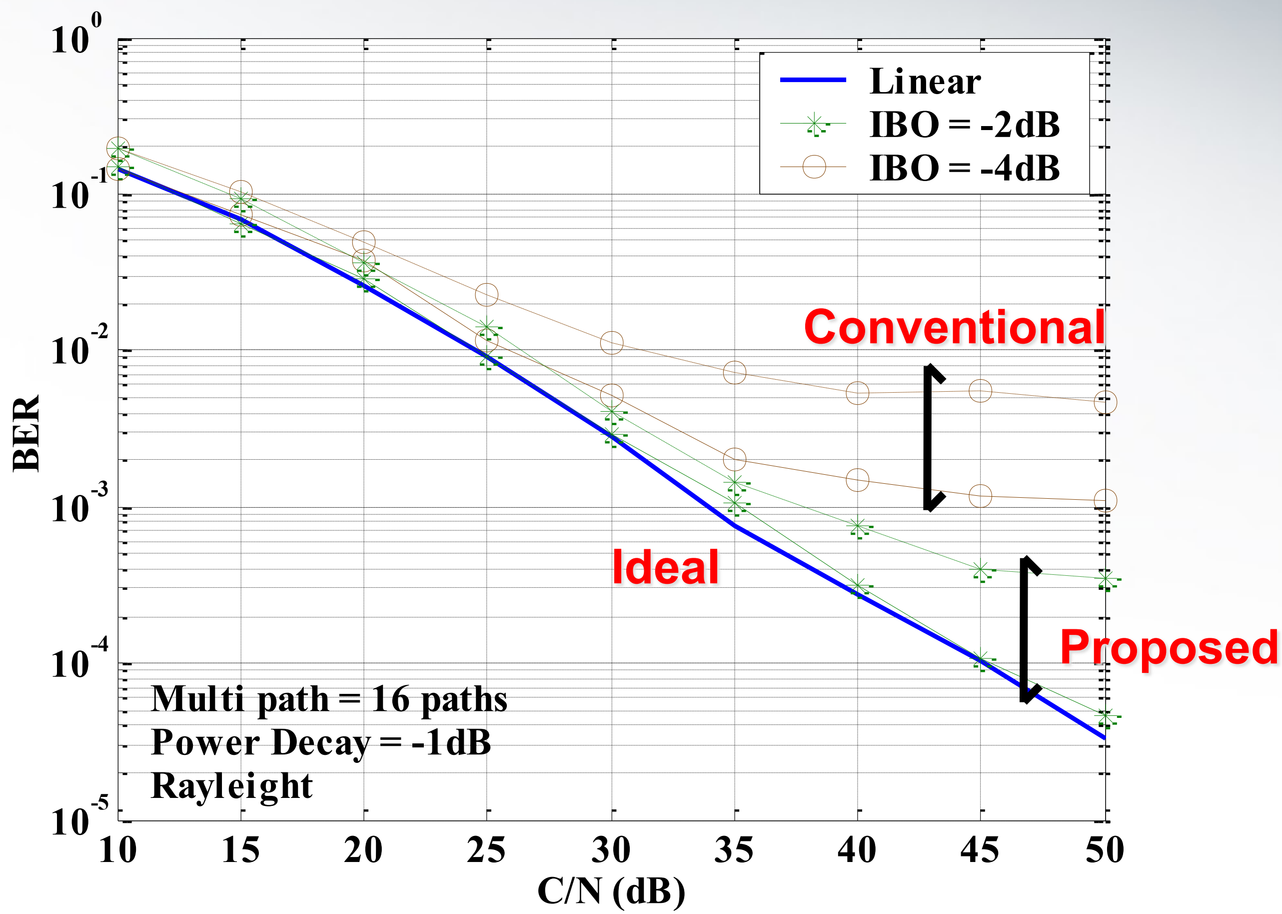
PAPR Performance vs. Number of Iterations

Modulation Method =64QAM

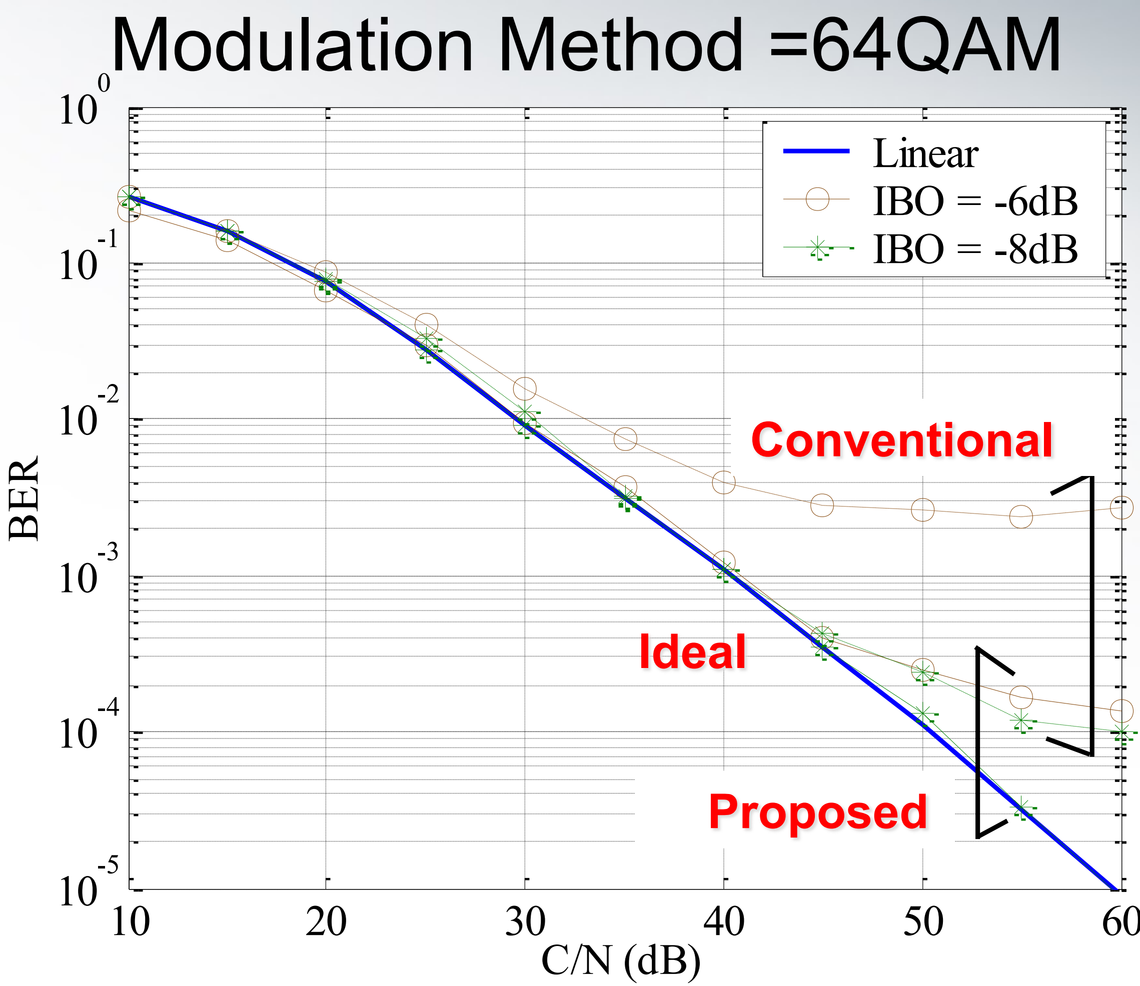


BER Performance

Modulation Method =16QAM



BER Performance



Conclusions

- **Proposed the PAPR reduction method for OFDM signal without side information**
  - **Use the common weighting factor over one frame including the preamble symbols**
  - **The time-frequency domain swapping algorithm is employed in the determination of common weighting factor**
  - **The common weighting factor can be removed from the received data symbols by using the frequency domain equalization**
  - **The common weighting factor can be estimated together with the channel frequency response by using preamble symbols**

Conclusions

The proposed technique can achieve the better PAPR performance and better BER performance than the conventional OFDM in the channel of non-linear amplifier and multi-path fading