Chapter 4

- DTFT
- Understanding the DFT Equation
- Inverse DFT
- DFT Leakage
- Windows
- DFT Resolution, Zero Padding, and Frequency-Domain Sampling
- DFT Properties
- Frequency Response

DTFT, DFS and DFT

1. DTFT:

$$\begin{cases} X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x(n) e^{-jn\omega} \\ x(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} X(e^{j\omega}) e^{jn\omega} d\omega \end{cases}$$

2. DFS:

$$\begin{cases} \widetilde{X}(k) = \sum_{n=0}^{N-1} \widetilde{x}(n) W_N^{kn} \\ \widetilde{x}(n) = \frac{1}{N} \sum_{k=0}^{N-1} \widetilde{X}(k) W_N^{-kn} \end{cases}$$

3. DFT:

$$\begin{cases} X(k) = \sum_{n=0}^{N-1} x(n) W_N^{kn}, \quad k = 0, \cdots, N-1 \\ x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) W_N^{-kn}, \quad n = 0, \cdots, N-1 \end{cases}$$

$$W_N = e^{-j\frac{2\pi}{N}}$$

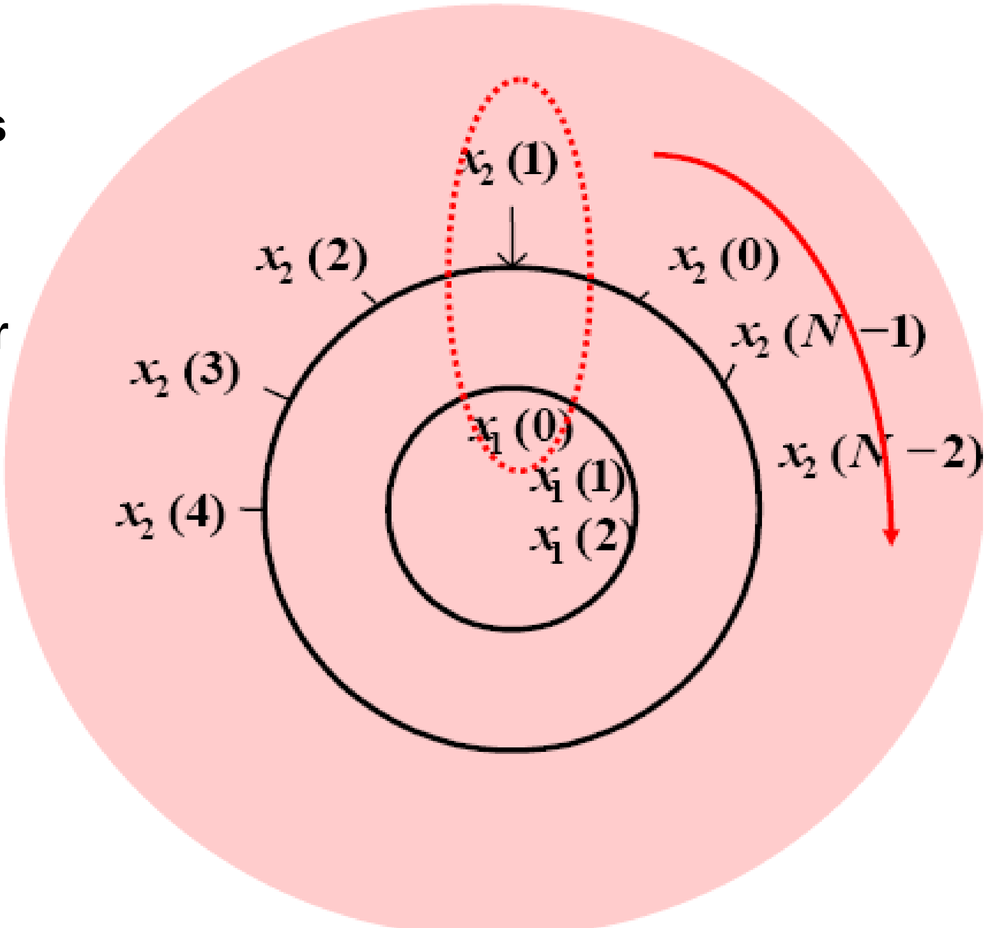
Circular Convolution

Concentric Method:

1) Multiply the corresponding values on the two circles and sum. We get $x_3(0)$;

2) Shift $x_2(n\text{-}m)$ 1 point, i.e., the outer circle rotate 1 point clockwise. Repeat (1) and we get $x_3(1)$;

3) In the same way, we get $x_3(n)$; $0 \le n \le N\text{-}1$.



Frequency Response

LTI System:

a. **Frequency Response:** $H(e^{jw})$

b. **Transfer Function:** $H(z)$

c. **Difference Equation**

Chapter 5

Fast Fourier Transform - FFT

FFT Reverse & Rearrangement and In-place Computation

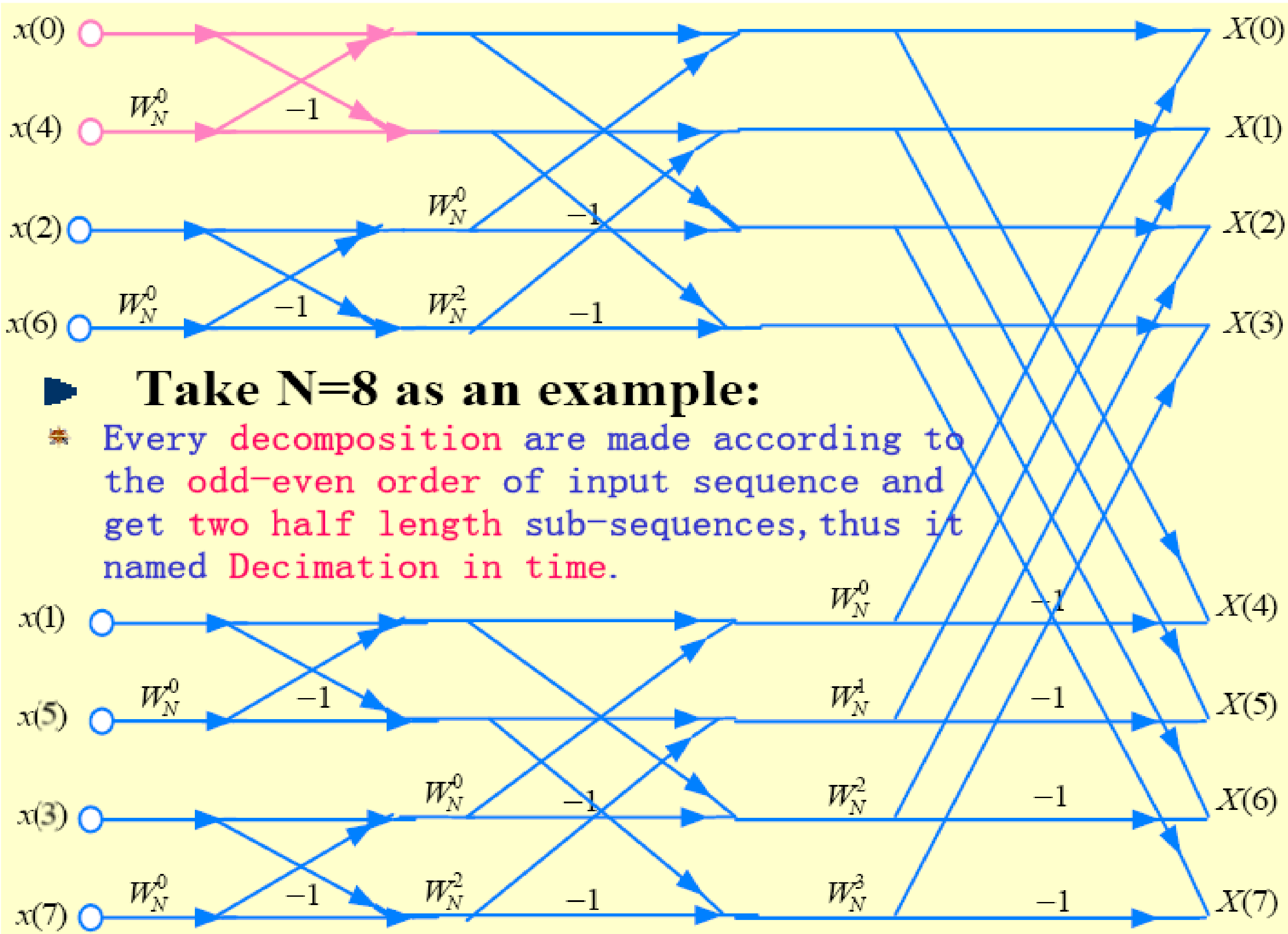
Inverse Fast Fourier Transform - IFFT

High-efficient FFT for Real Sequences

Discrete Convolution Using FFT

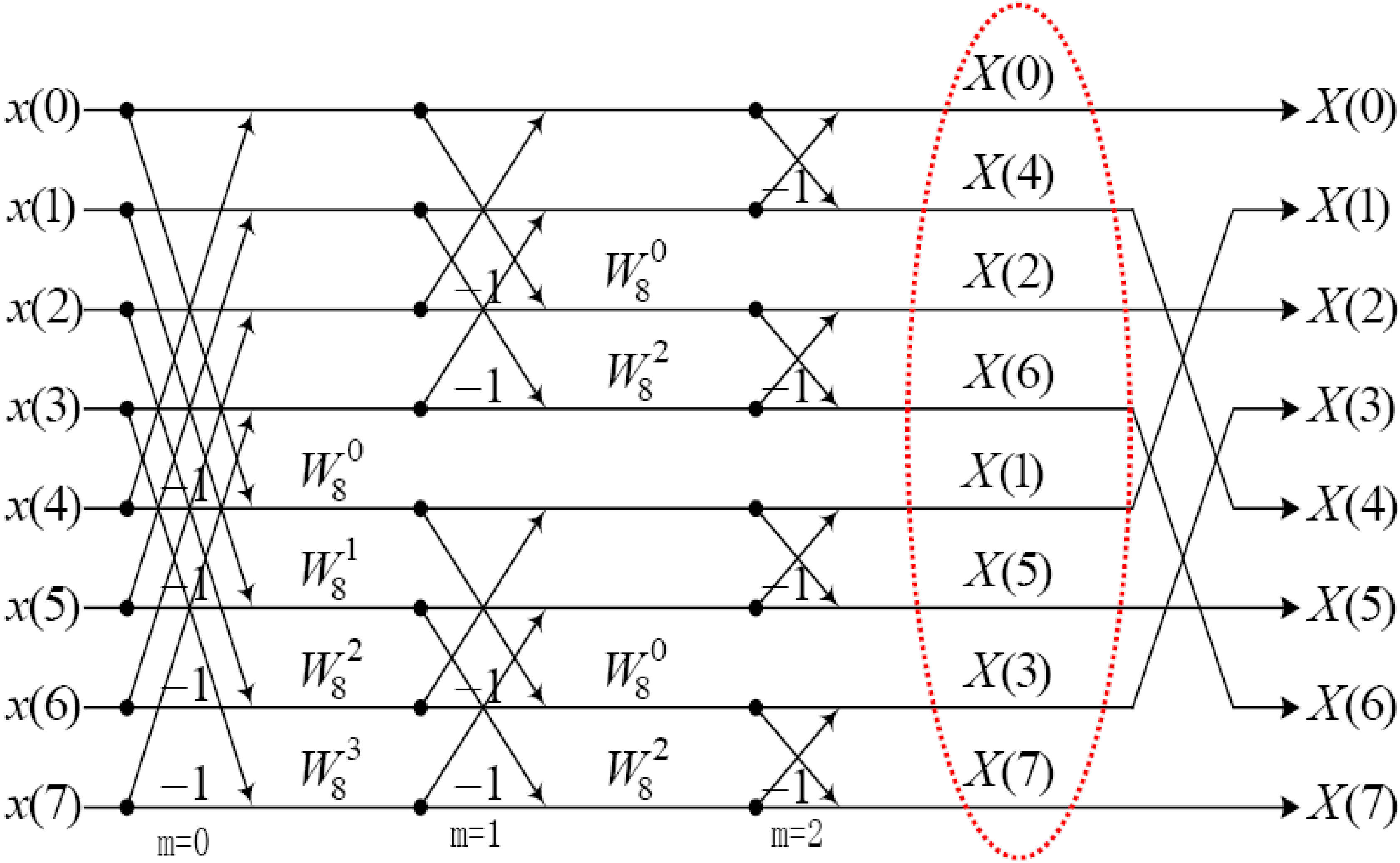
Piecewise Convolution for Long Sequences

Decimation in Time FFT (DIT-FFT)



- **Take N=8 as an example:**
  - Every decomposition are made according to the odd-even order of input sequence and get two half length sub-sequences, thus it named Decimation in time.

Decimation in Frequency FFT (DIF-FFT)



Discrete Conv. using DFT

1.Using DFT to do Discrete Convolution

The most important condition:

<u>The Length of Circular Convolution must bigger than or equal to that of Linear Convolution:</u>

<u>N’>=N+M-1</u>

2.Piecewise Convolution for Long Sequence:

a. Overlap-Add method

b. Overlap-Save method