Principles of Digital Signal Processing

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DSP

Discrete Fourier Transform

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Frequency domain sampling
DFT

DFT and IDFT expressed as

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{kn} \qquad k = 0, 1, \ldots, N-1$$

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) W_N^{-kn} \qquad n = 0, 1, \ldots, N-1$$

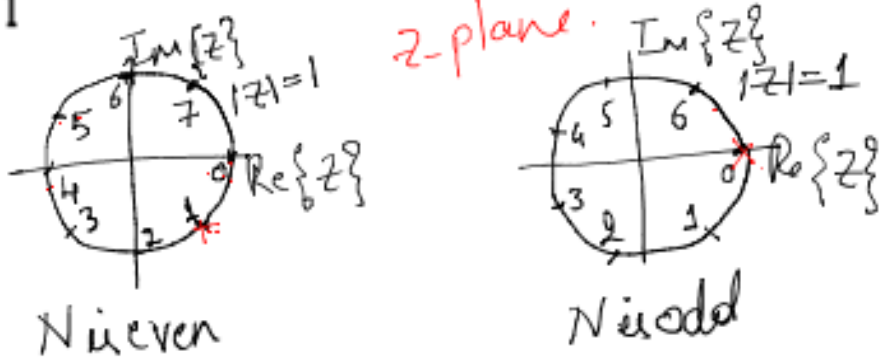
Where, $W_N = e^{-j2\pi/N}$

The *Nth* root of unity

W_N is periodic with a period N

i.e., $W_N^{a+N} = W_N^a$

where 'a' is any integer



W_N^n $N=8$ $n = 0 \cdots N-1$

Frequency domain sampling

DFT

$x(n) = (1, 0, 0, 1)$ 4-pt DFT

$$x(k) = \sum_{n=0}^{N-1} x(n) W_N^{kn} \qquad k = 0 \cdots N-1$$

$N = 4$

$$X(k) = 1 \times W_4^{k(0)} + 0 * 0 + 1 \times W_4^{k(3)}$$

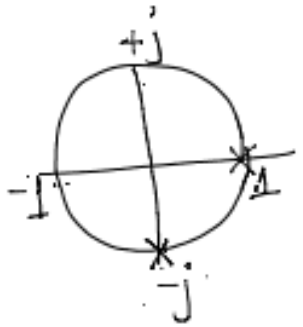
$$X(k) = 1 + W_4^{3k} \qquad k = 0 \cdots 3.$$

$k=0$ $\quad X(k) = 1 + W_4^{3(0)} = 2$

$k=1$ $\quad X(k) = 1 + W_4^{3(1)} = 1 + (+j) = 1+j$

$k=2$ $\quad X(k) = 1 + W_4^{3(2)} = 1 - 1 = 0$

$k=3$ $\quad X(k) = 1 + W_4^{3(3)} = 1 - j$



$W_4^0 = 1$

$W_4^1 = -j$

$W_4^2 = -1$

$W_4^3 = +j$

$$W_N^n = \left(e^{-j\frac{2\pi}{N}}\right)^n$$

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$$X(K) = \{2, 1+j, 0, 1-j\}$$

Frequency domain sampling

DFT

IDFT $X(k) = \{2, 1+j, 0, 1-j\}$ $x(n) = [1, 0, 0, 1]$

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) W_N^{-kn} \qquad n = 0 \ldots N-1$$

$$W_N^{-kn} = [W_N^{kn}]^*$$

$$x(n) = \frac{1}{4} \sum_{k=0}^{3} X(k) W_N^{-kn} \qquad n = 0 \ldots 3$$

$$x(n) = \frac{1}{4} [2 + (1+j) W_4^{-n} + 0 + (1-j) W_4^{-3n}]$$

$W_4^0 = 1$

$W_4^{-1} = (W_4^1)^* = (-j)^* = j$

$W_4^{-2} = -1$

$W_4^{-3} = (W_4^3)^* = -j$

$n = 0, 1, 2, 3$

$n = 0$ $x(n) = 1$

$n = 1$, $x(n) = \frac{1}{4} [2 + (1+j)j + (1-j)(-j)] = 0$

$n = 2$, $x(n) = 0$

$n = 3$ $x(n) = 1$

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THANK YOU

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