

# Download File PDF Statistical Digital Signal Processing Hayes Solution Manual

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Chapter 2  
SOLUTIONS TO CHAPTER 2  
Background  
2.1 The DFT of a sequence  $x(n)$  of length  $N$  may be expressed in matrix form as follows  
$$X = WX$$
where  $x = [x(0), x(1), \dots, x(N-1)]^T$  is a vector containing the signal values and  $X$  is a vector containing the DFT coefficients  $X(k)$ .  
(a) Find the matrix  $W$ .  
(b) What properties does the matrix  $W$  have?  
(c) What is the inverse of  $W$ ?  
Solution  
(a) The DFT of a sequence  $x(n)$  of length  $N$  is  
$$X(k) = \sum_{n=0}^{N-1} x(n)e^{-j2\pi kn/N} = \sum_{n=0}^{N-1} x(n)W_N^{kn}$$
where  $W_N = e^{-j2\pi/N}$ . If we define  
$$w_N^k = [1, W_N^k, W_N^{2k}, \dots, W_N^{(N-1)k}]^T$$
then  $X(k)$  is the inner product  
$$X(k) = w_N^k \cdot x$$
Arranging the DFT coefficients in a vector we have  
$$X = \begin{bmatrix} X(0) \\ X(1) \\ \vdots \\ X(N-1) \end{bmatrix} = \begin{bmatrix} w_N^0 \cdot x \\ w_N^1 \cdot x \\ \vdots \\ w_N^{N-1} \cdot x \end{bmatrix} = Wx$$
where  
$$W = \begin{bmatrix} w_N^0 \\ w_N^1 \\ \vdots \\ w_N^{N-1} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & \dots & 1 \\ 1 & W_N & W_N^2 & \dots & W_N^{N-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & W_N^{N-1} & W_N^{2(N-1)} & \dots & W_N^{(N-1)^2} \end{bmatrix}$$
(b) The matrix  $W$  is symmetric and unitary. In addition, due to the orthogonality of the complex exponentials,  
$$w_N^k \cdot w_N^p = \sum_{n=0}^{N-1} e^{-j2\pi n(k-p)/N} = \begin{cases} N & k=p \\ 0 & k \neq p \end{cases}$$
It follows that  $W$  is orthogonal.  
(c) Due to the orthogonality of  $W$ , the inverse is  
$$W^{-1} = \frac{1}{N} W^*$$

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