EEE 360 Communications Systems I

Lecture Presentation 8

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☞ Discrete Fourier Transform: *Sections 2.8 - 2.9 of the textbook.*

☞ Bandlimited Waveforms

The discrete Fourier Transform (DFT) is defined by

$$X(n) = \sum_{k=0}^{k=N-1} x(k) e^{-j(2\pi/N)nk} \tag{1}$$

where $n = 0, 1, 2 \ldots, N-1$. The inverse discrete Fourier Transform (IDFT) is given by

$$x(k) = \frac{1}{N} \sum_{n=0}^{n=N-1} X(n) e^{-j(2\pi/N)nk} \tag{2}$$

where $k = 0, 1, 2, \ldots, N-1$.

MATLAB uses the same definitions in Eq.(1) and (2) (fft and $ifft$) to compute the discrete Fourier Transform. It should be noted that N is a power of 2.

Using DFT to Compute Continuous FT

Computation of CFT involves three steps:

1. windowing
2. sampling
3. periodic sample generation

These operations are shown in Fig. 1. The relationship between CFT and DFT is given by

$$W_w(f)|_{f=n/T} \approx \Delta t X(n) \tag{3}$$

where $f = n/T$ and $\Delta t = T/N$.

Figure 1: Comparison of DFT and CFT spectra

Using DFT to Compute the Fourier Series

The DFT may also be used to compute the coefficients for the complex Fourier series as follows:

$$c_n \approx \frac{1}{N} X(n) \tag{4}$$

☞ Bandwidth of Signals

There are various definitions of bandwidth of which six are given below:

1. Absolute bandwidth $f_2 - f_1$
2. $3\,dB$ bandwidth: Half-power bandwidth. $f_2 - f_1$ where for frequencies inside the band $f_1 < f < f_2$, the magnitude spectra ($|H(f)|$), fall no lower than $1/\sqrt{2}\max|H(f)|$ and the maximum value occurs inside the band.
3. Equivalent noise bandwidth The power in the band is equal to the

power associated with the actual spectrum over positive frequencies.

$$B_{eq} = \frac{1}{|H(f_0)|^2} \int_0^\infty |H(f)|^2 \, df \tag{5}$$

4. Null-to-null bandwidth $f_2 - f_1$ where f_2 is the first null in the envelope of the magnitude spectrum above f_0 and for bandpass systems, f_1 is the first null in the envelope below f_0. (f_0 is the frequency where the magnitude spectrum is maximum).
5. Bounded spectrum bandwidth $f_2 - f_1$ such that outside the band $f_1 < f < f_2$, the PSD must be down by at least a certain amount below the maximum value of PSD.
6. Power bandwidth $f_2 - f_1$ where $f_1 < f < f_2$ defines the frequency band in which 99% of the total power resides.

There is also the legal definition called the FCC Bandwidth