SIO 207A: Fundamentals of Digital Signal Processing
Class 10

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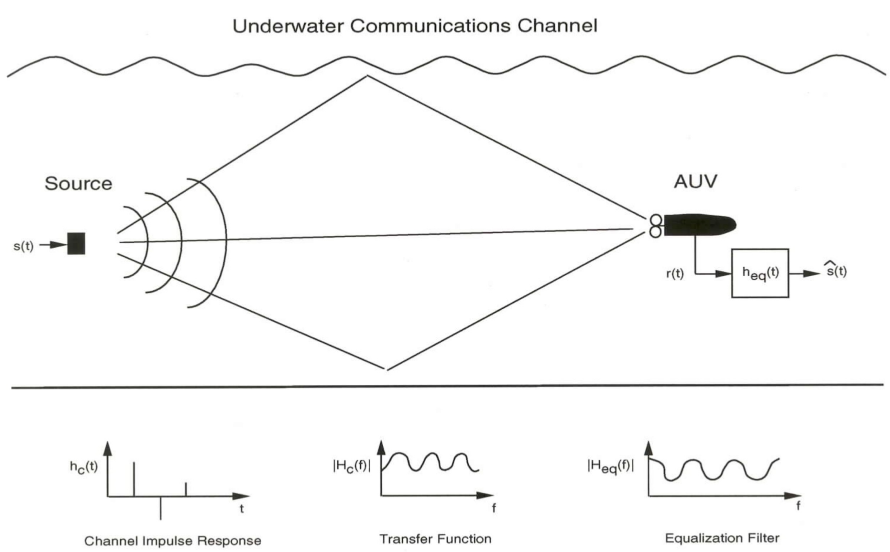
Underwater Communication Channel



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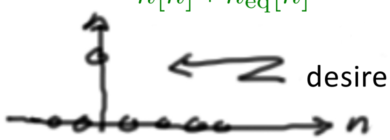
Homework 4 – Multipath Propagation

Underwater Channel

$h[n] * h_{\text{eq}}[n]$



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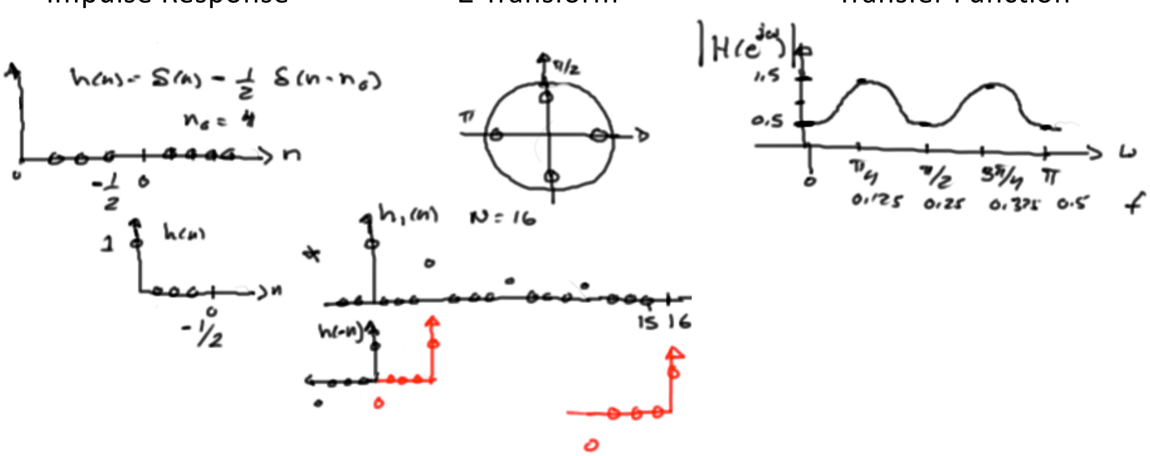
Homework 4 – Multipath Propagation

Impulse Response

Z-Transform

Transfer Function



Problem 8.64 in *Oppenheim & Schafer, 1999*

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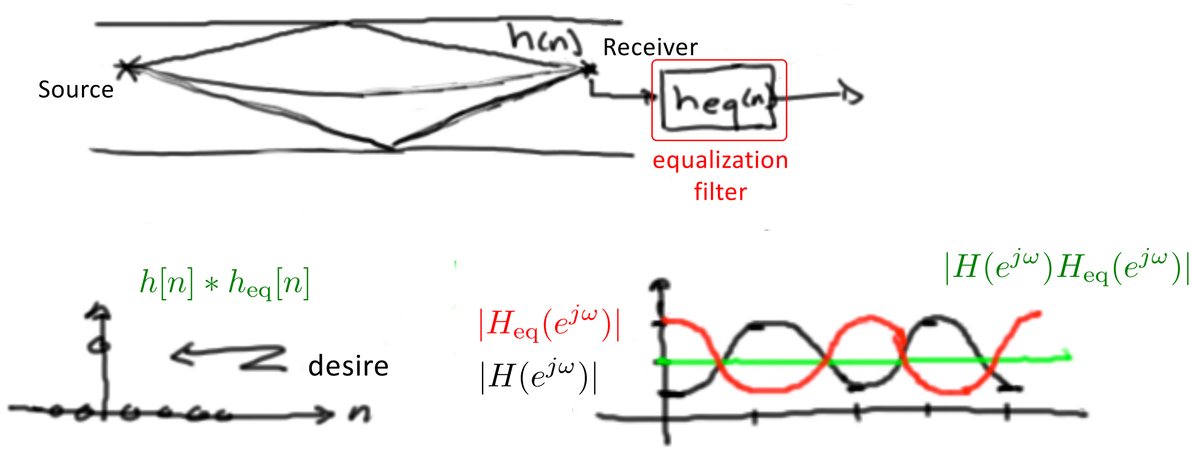
Homework 4 – Multipath Propagation

Underwater Channel



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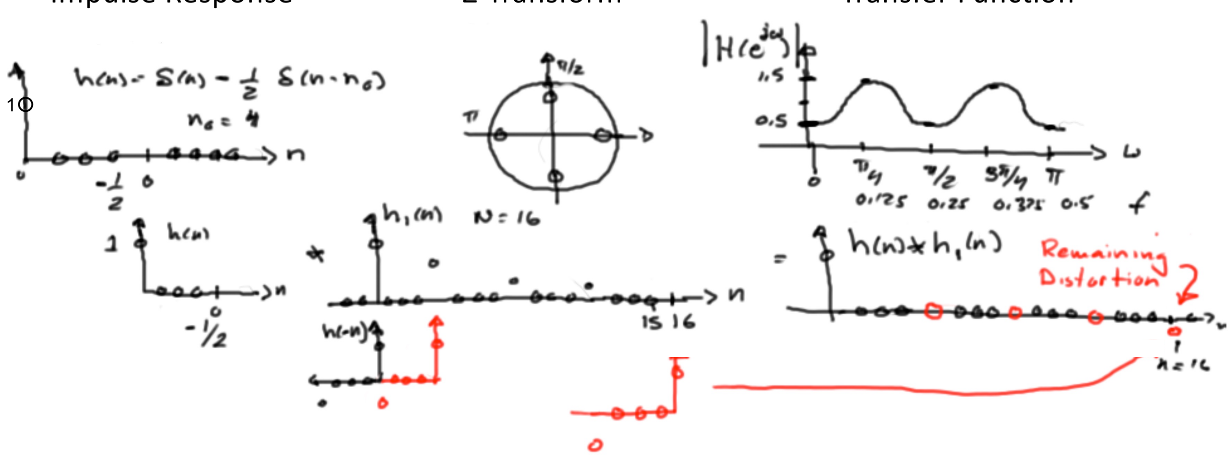

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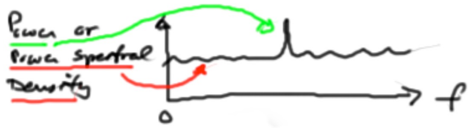
Recovering Sinusoid Amplitude and Power from FFT



Power of Sinusoid: $A^2/2$

$$x[n] = A \sin \omega n$$
$$= A\Big\{\frac{e^{j\omega n} - e^{-j\omega n}}{2j}\Big\}$$

let $\omega = \dfrac{2\pi}{N} k'$

N length of FFT

$$X(k) = \sum_{n=0}^{N-1} w[n] x[n] e^{-j\frac{2\pi}{N}nk}$$
$$= A \sum_{n=0}^{N-1} w[n] \Big\{\frac{e^{j\frac{2\pi}{N}nk'} - e^{-j\frac{2\pi}{N}nk'}}{2j}\Big\} e^{-j\frac{2\pi}{N}nk}$$
$$= \frac{A}{2j} \sum_{n=0}^{N-1} w[n]$$ for $k = k'$ (sinusoid is bin centered)

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Calibration

Amplitude and Power of Bin-Centered Sinusoid:

$$X(k) = \frac{A}{2j} \sum_{n=0}^{N-1} w[n] \qquad k = k'$$

sinusoid amplitude $$A = \frac{2}{\sum_{n=0}^{N-1} w[n]} |X(k')|$$

True regardless of phase of sinusoid

sinusoid power $$\frac{A^2}{2} = \frac{2}{\left(\sum_{n=0}^{N-1} w[n]\right)^2} |X(k')|^2$$

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Scalloping Loss

Amplitude and Power of Sinusoid at Bin Border:

Scalloping loss (dB) - See F. Harris Table I p. 56

Rectangle Window 3.92 dB

Kaiser - Bessel 1.2 dB

$\alpha = 2.5$

$\beta = 7.85$

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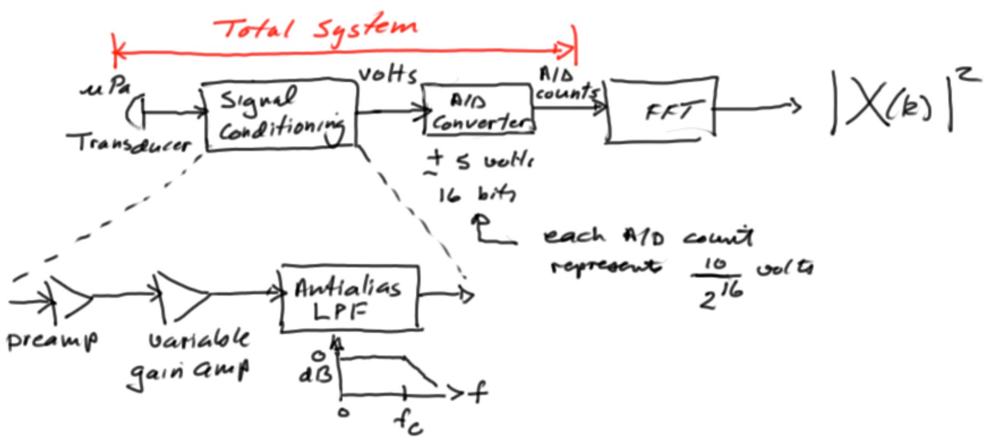
Calibration

Sinusoid Power units of $(\text{A/D counts})^2$ $\longrightarrow$ $$\frac{A^2}{2} = \frac{2}{\left(\sum_{n=0}^{N-1} w[n]\right)^2} |X(k')|^2$$



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Calibration

<u>Example</u> : Transducer = -200 dB

Preamp + Variable Gain Amp = 100 dB

A/D = $20 \log_{10} \frac{65536}{10}$ = 76 dB

Total System Gain

-200 dB + 100 dB + 76 dB

= -24 dB

To calibrate the sinusoid power from $(\text{A/D counts})^2$ to $(\mu Pa)^2$ must remove gains of system - in this example need to <u>add</u> 24 dB

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