

EE228

Applications of Course Concepts

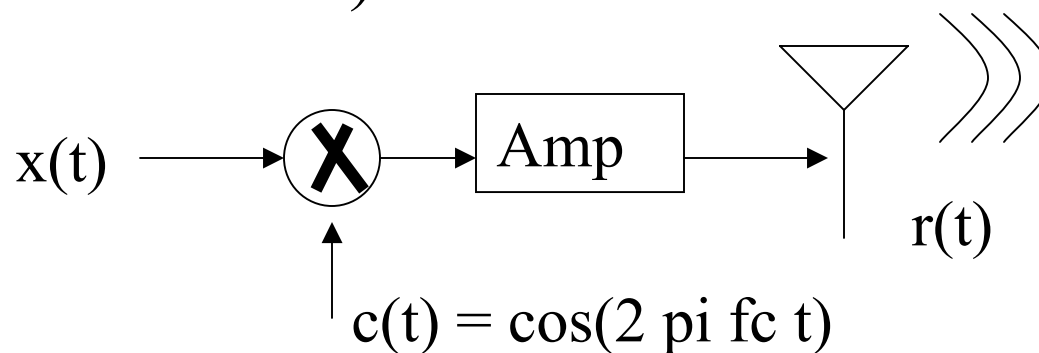
DePiero

Purpose

- Describe applications of concepts in EE228.
Applications may help students recall and synthesize concepts.
- Also discuss:
 - Some advanced concepts
 - Highlight important concepts that arise in subsequent courses. ‘TTR’ ‘Things to Remember’

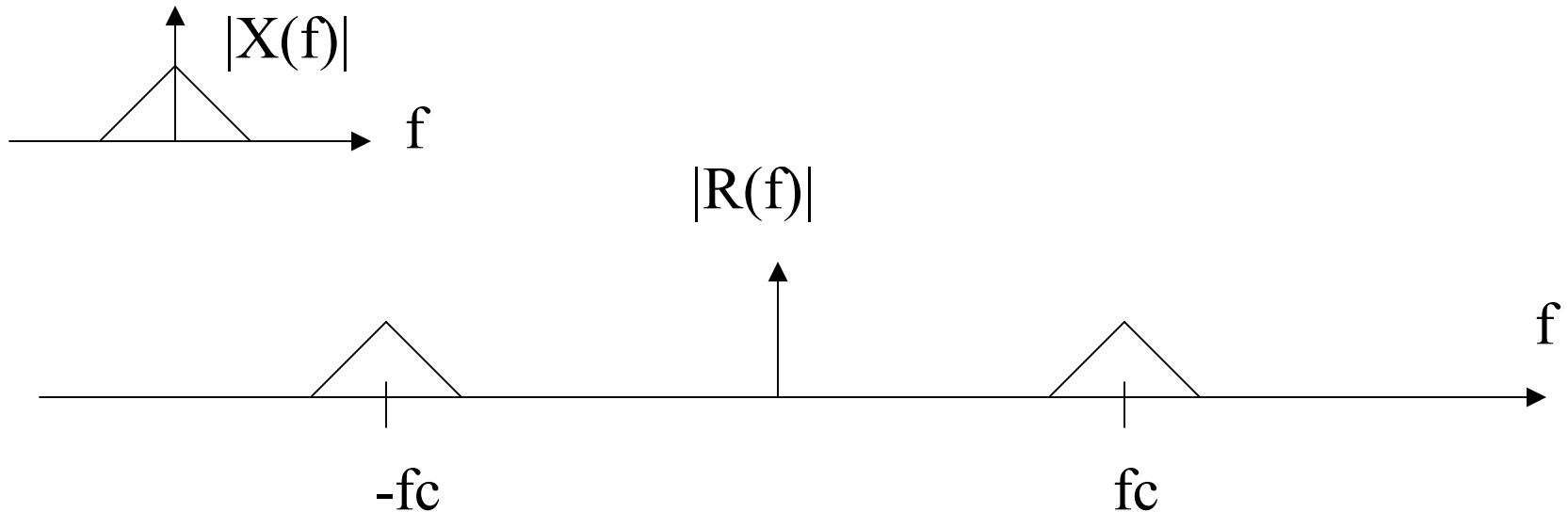
Communications is an Important Area of Signal & Systems

- With RF need to broadcast in MHz range to provide:
 - Efficient radiation from antenna
 - Good propagation of waves
 - Reasonable antenna size
- However, message signal $x(t)$ is at baseband.
- AM Approach: Multiply by ‘carrier’ $c(t)$ at f_c (simplified version)



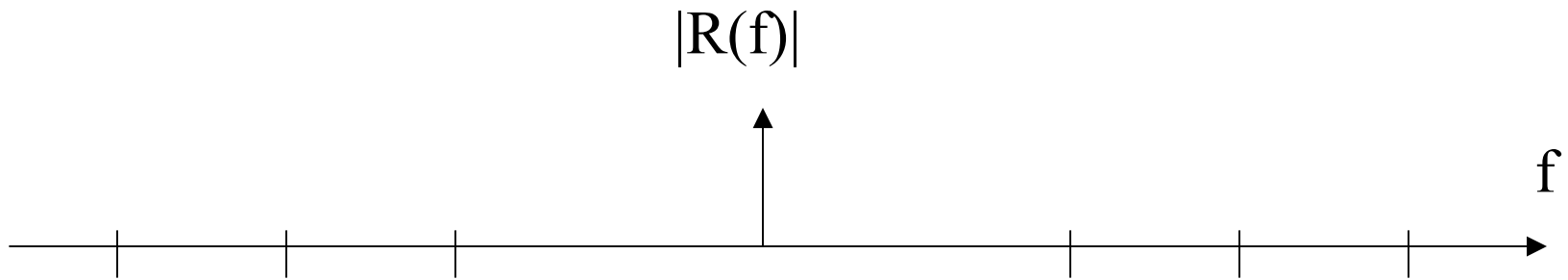
What Does the RF Spectrum of One Radio Station Look Like?

- How can we find $R(f) = X(f) \ast C(f)$?
- $C(f)$ carrier spectrum looks like: 2 impulses
- Given $X(f)$, what is $R(f)$?



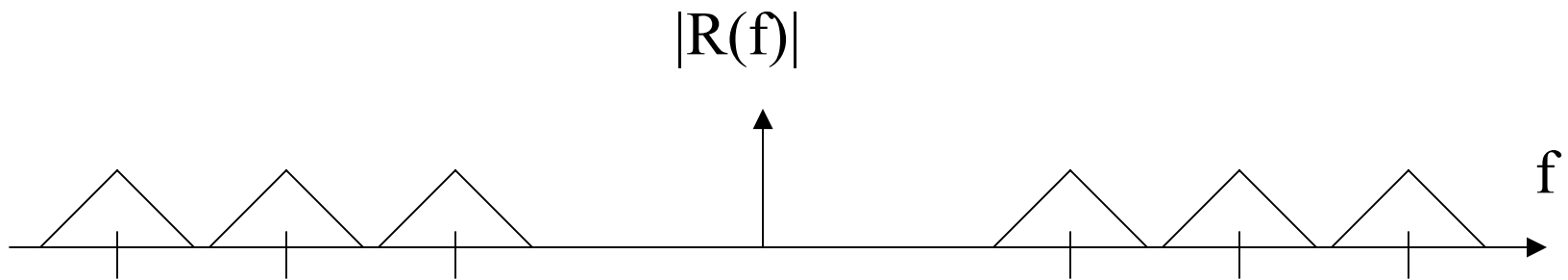
Application

What Does the RF Spectrum of Many Radio Stations Look Like?



Application

What Does the RF Spectrum of Many Radio Stations Look Like?



- What other communication system packs many signals into a single medium, for distribution around town? (Use frequency multiplexing).
 - Packed side-by-side in spectrum.
 - Medium: Coax
 - Most students have it!

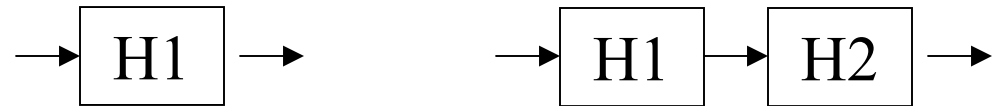
Application

Only Positive Frequencies Exist In Real Life!

- However, note that Fourier's methods predict the spectrum of a modulated signal correctly!
- Another explanation:
$$\cos(A) \cos(B) = \cos(A+B) + \cos(A-B)$$

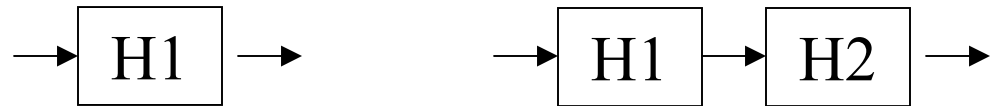
If A is the carrier then multiplication results in the upper and lower 'sidebands'.
- Fourier needs negative frequencies to properly synthesize real signals.
- Negative frequencies OK in discrete domain ☺

Models of Subsystem Blocks Permit Concatenation



- Concatenating H2 leaves H1 unchanged.
- Hence, No loading effects!
- What conditions (inside block, associated with inputs and outputs) are needed for no loading?

Models of Subsystem Blocks Permit Concatenation



- Concatenating H2 leaves H1 unchanged.
- Hence, No loading effects!
- What conditions (inside block, associated with inputs and outputs) are needed for no loading?
 - Hi-Z input, Low-Z output
 - (Consider a voltage divider).

Generally Avoid Differentiation Operation as a Subsystem Block

- Property of Fourier Transform:
Given the FT pair: $x(t) \leftrightarrow X(f)$
Then: $x'(t) \leftrightarrow j 2 \pi f X(f)$
- How is $X(f)$ affected by differentiation?
- Why is this bad? (Consider that noise is typically present at all frequencies).
- Integral generally safer... Any problem frequencies?

Generally Avoid Differentiation Operation as a Subsystem Block

- Property of Fourier Transform:
Given the FT pair: $x(t) \leftrightarrow X(f)$
Then: $x'(t) \leftrightarrow j 2 \pi f X(f)$
- How is $X(f)$ affected by differentiation?
Magnitude increased with frequency, f .
- Why is this bad? (Consider that noise is typically present at all frequencies).
Amplifies high frequency noise considerably!
- Integral generally safer... Any problem frequencies?
Integral $\{x(t) dt\} \leftrightarrow X(f) / j 2 \pi f + 0.5 X(0) \delta(f)$

Speech Recognition Via Correlation

- Even with an identical speaker, still must accommodate signal delay.



Introduce Correlation: $r(\tau) = \int x_1(t) x_2(t + \tau) dt$

Compare to convolution? _____

When does $r(\tau)$ have a peak? _____

Speech Recognition Via Correlation

- Even with an identical speaker, still must accommodate signal delay.



Introduce Correlation: $r(\tau) = \int x_1(t) x_2(t + \tau) dt$

Compare to convolution? No time-reversal

When does $r(\tau)$ have a peak?

When "Hello"s aligned, (and hence recognized)

Can We Eliminate the Time Shift Problem for Recognition ?

- Consider property of Fourier Transform

$$x(t - \tau) \underset{FT}{\Leftrightarrow} e^{-j2\pi f \tau} X(f)$$

- How is $X(f)$ changed? _____
- How can we employ this for recognition?

Can We Eliminate the Time Shift Problem for Recognition ?

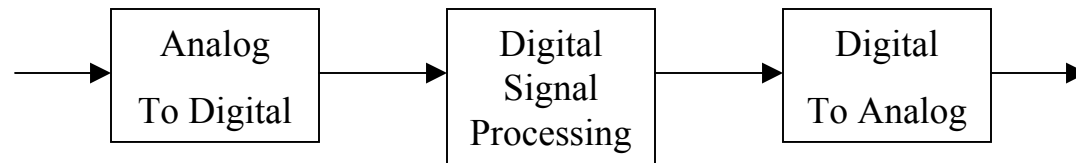
- Consider property of Fourier Transform

$$x(t - \tau) \underset{FT}{\Leftrightarrow} e^{-j2\pi f \tau} X(f)$$

- How is $X(f)$ changed? Phase only.
- How can we employ this for recognition?

Compare magnitudes. No shifting. Do need both
"Hello"s within range of transform integration.

Fourier Transform Popular For Digital Signal Processing



- A/D samples signals (44.1KHz for CD)
- Processing via arithmetic, not RLC. Can be implemented in software, firmware, hardware.
- FFT is Fast Fourier Transform. Computationally efficient.
- FFT permits processing in frequency domain
Compression, Voice Recognition, Display Spectrum, Phased Array

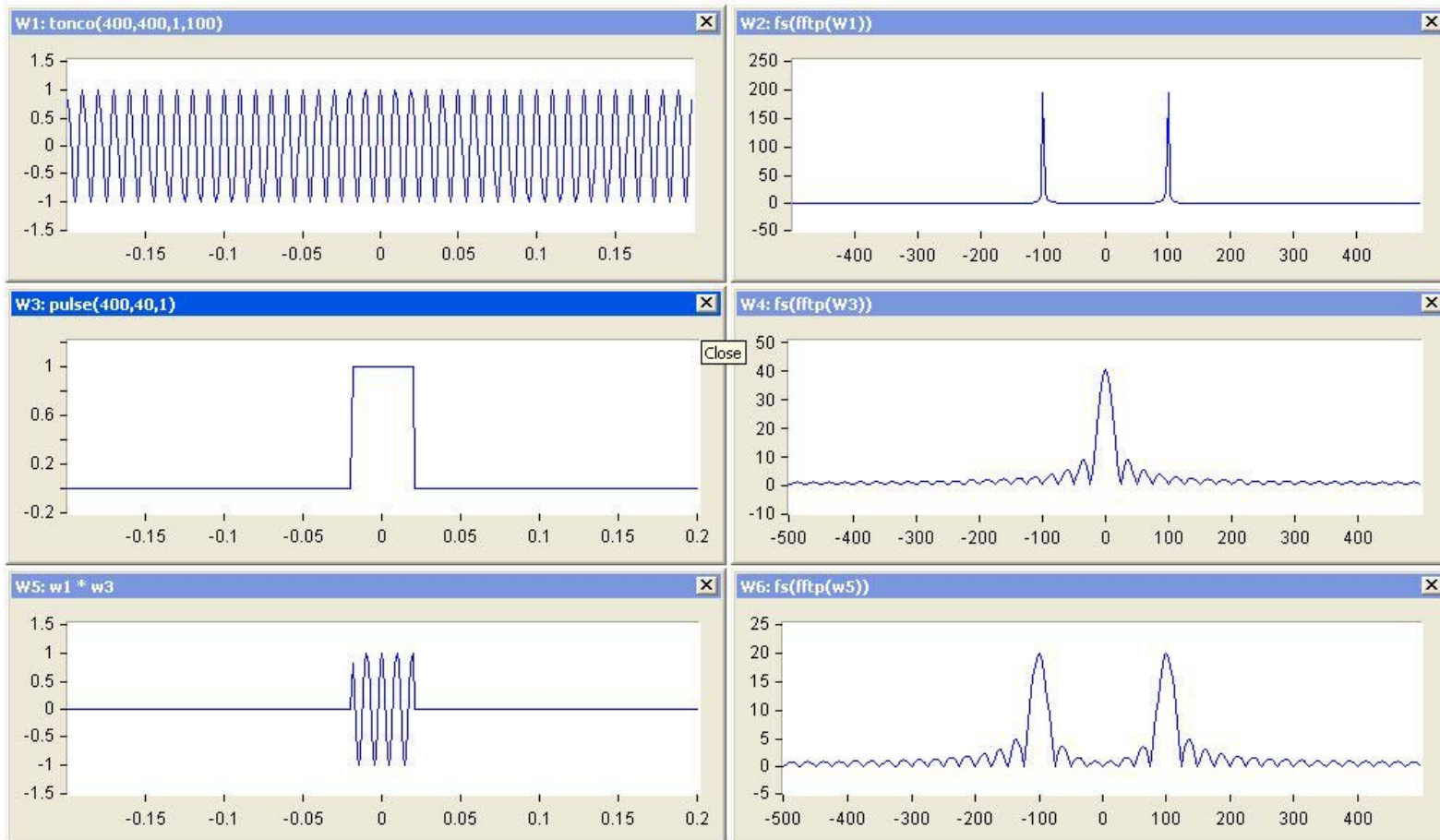
What is the Spectrum Of a Tone Burst?

- How can we model a short (time-limited) sinusoidal signal? _____
- How can we find the spectrum of the time-limited signal? _____

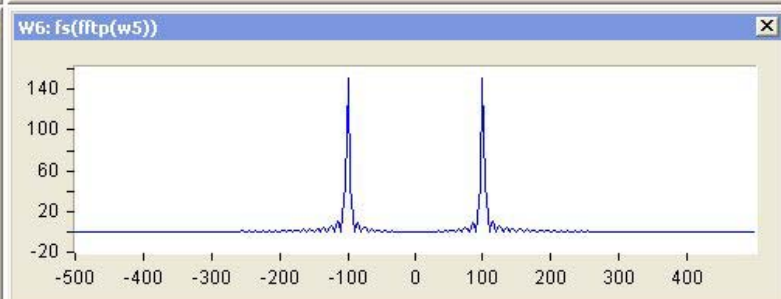
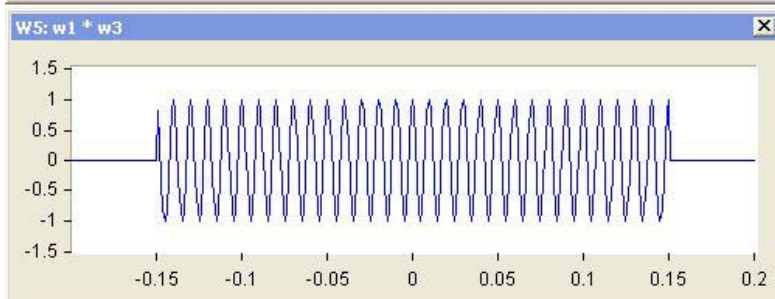
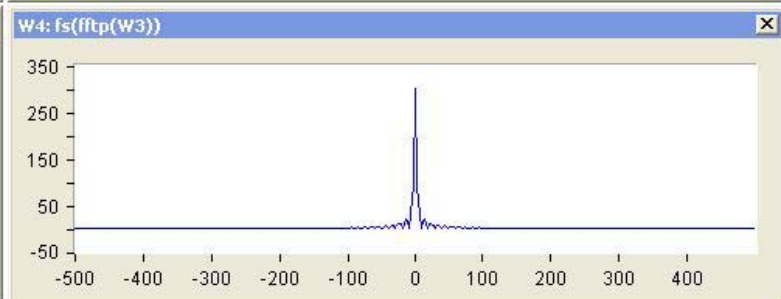
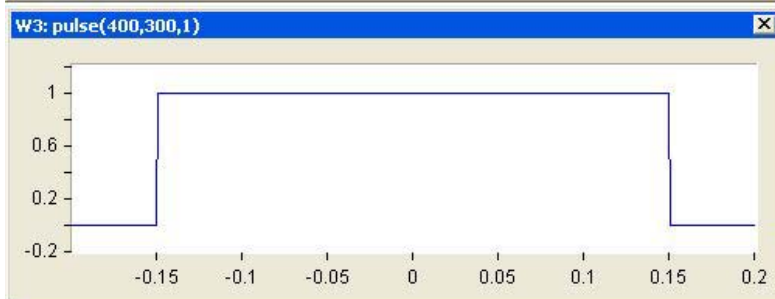
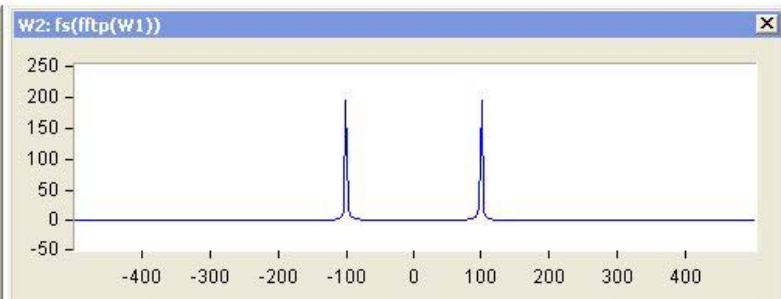
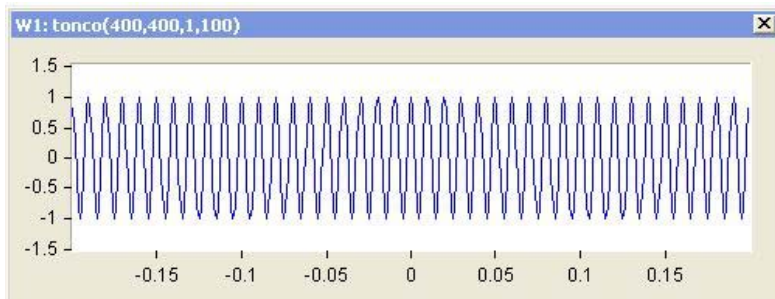
What is the Spectrum Of a Tone Burst?

- How can we model a short (time-limited) sinusoidal signal? *Multiply by rect()*
- How can we find the spectrum of the time-limited signal? *Convolution of sinc with impulses.*

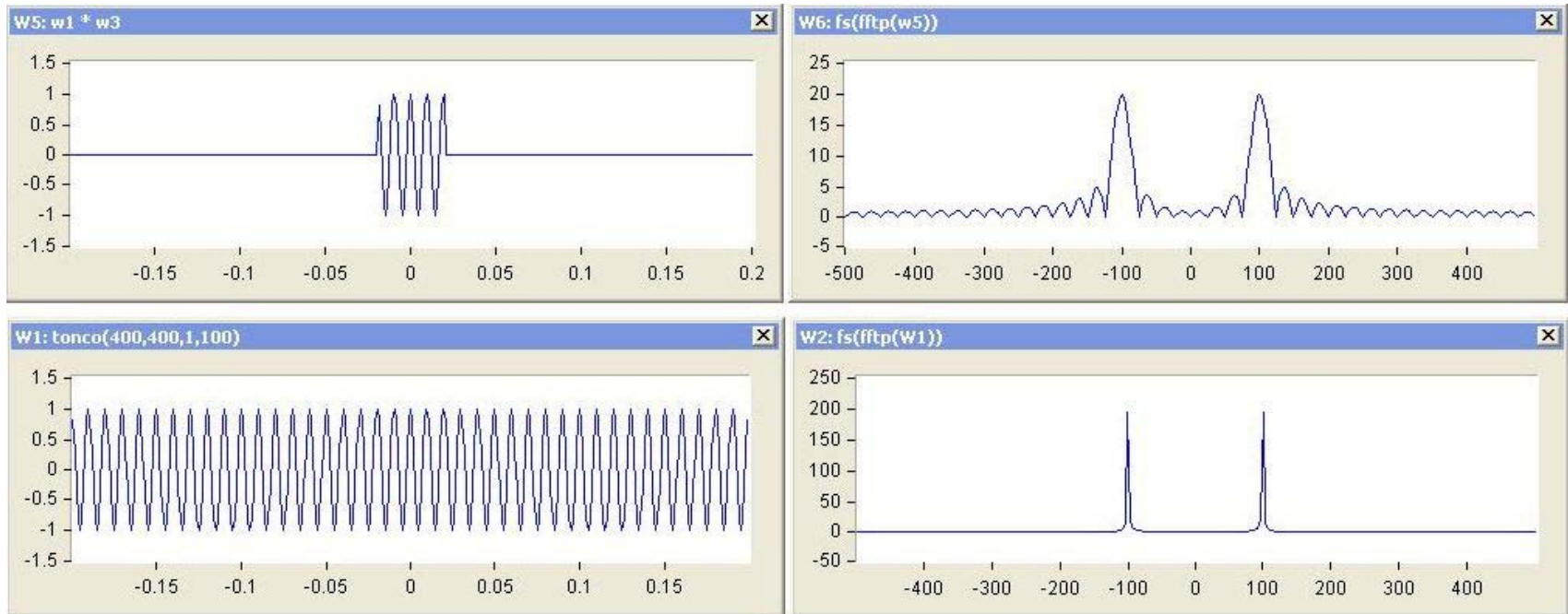
Short Tone Burst Has 'Spectral Leakage' Effect



Wider Pulses \leftarrow FT \rightarrow Narrow Sinc

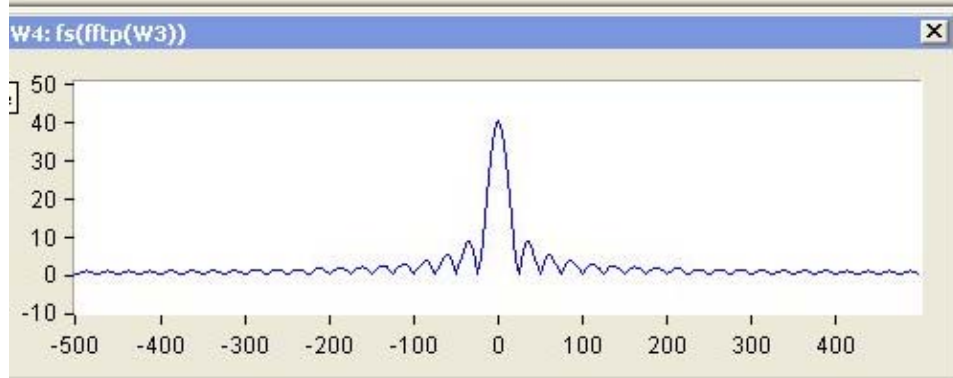
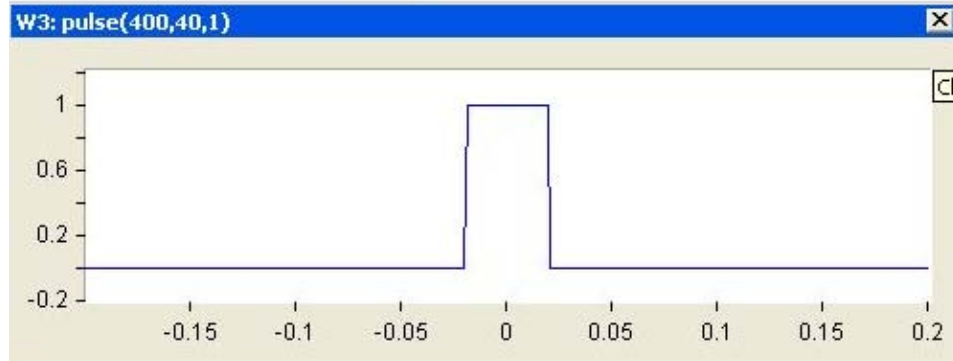
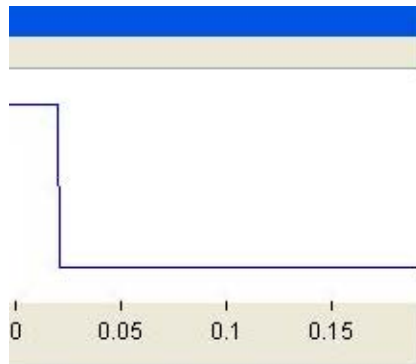


No Signal Can Be Simultaneously Limited in Both Time and Frequency



Can't make both duration and bandwidth arbitrarily small!

Impulse Response $h(t)$ of Ideal LPF Filter is a Sinc



- $H(\omega) \xleftrightarrow{\text{FT}} h(t)$
- These signals are duals of previous examples.

Ideal Filter Not Realizable!

- What are problems associated with $h(t) = \text{sinc}()$?

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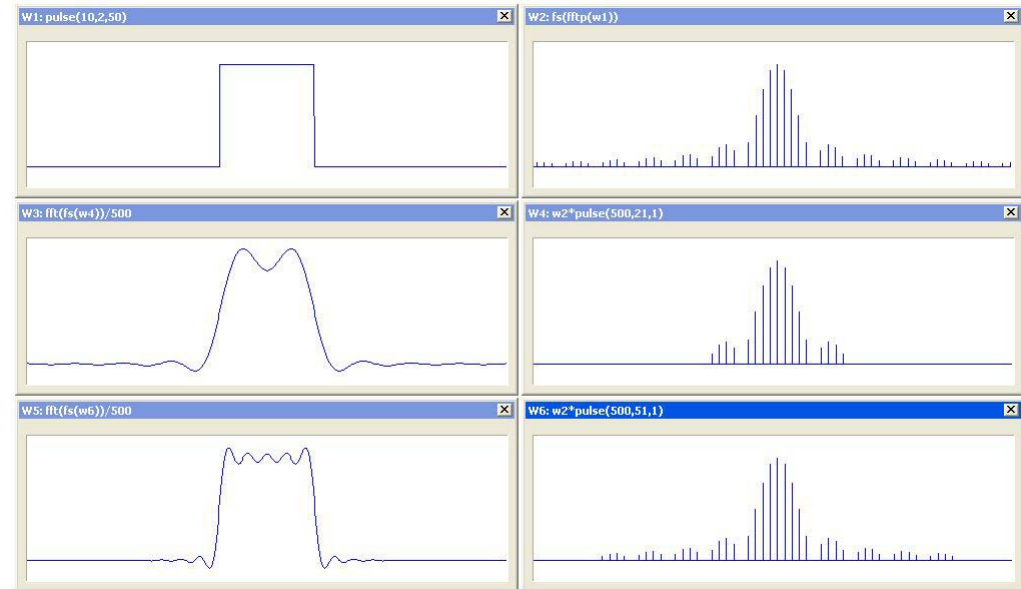
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Ideal Filter Not Realizable!

- What are problems associated with $h(t) = \text{sinc}()$?
 - *Sinc is noncausal*
 - *Sinc has infinite absolute area, hence system unstable.*

High Frequency Content Needed to Construct Sharp Corners

- Sums of harmonic contributions to (one period of) square wave shown.
- More harmonics needed for sharper corners
- Note non-uniform convergence (varying amount of error).
- Note convergence to midpoint of discontinuity.



Choose Right Tool for Right Job

- Variety of tools to find the spectra of signals & systems.
- Fourier Series for periodic signals.
- Fourier Transform for non-periodic signals or to find Frequency Response, $H(f)$, $H(\omega)$. Steady state response.
- $H(\omega)$ also from Bode, via graphical evaluation using poles & zeros in s-plane, or substituting $H(s = j\omega)$.
- Laplace Transform need complete response, includes steady state and transient responses.

ROC Important for Analysis Of Non-Causal Systems Via Laplace

$$X(s) = \int_{0^-}^{\infty} x(t)e^{-st} dt$$

- Laplace Transform exists only for cases which are absolutely integrable. Hence $|x(t)e^{-st}| < \infty$
- For example, with $x(t) = e^{-\alpha t}$ the Laplace Transform $X(s)$ only exists – is finite valued – in part of the s-plane. Which portion? _____
- Formally, need jw axis to be within ROC for inverse Laplace operation to be possible.
- Not an issue for causal signals and systems.

ROC Important for Analysis Of Non-Causal Systems Via Laplace

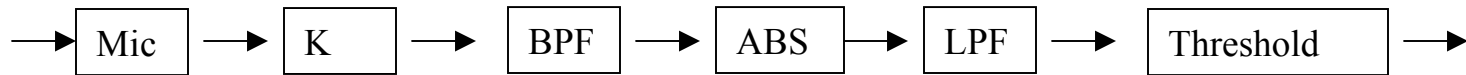
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- Formally, need jw axis to be within ROC for inverse Laplace operation to be possible.
- Not an issue for causal signals and systems.

Two-Sided Laplace Transform Handles Non-Causal Signals

- Signals must be absolutely integrable for all time. $\int_{-\infty}^{\infty} |x(t)e^{-st}| dt < \infty$
- Method: Multiply $Y(s) = H(s) X(s)$, then sort out the causal and non-causal parts and perform inverse Laplace separately on each.
- Typically a topic in graduate courses.

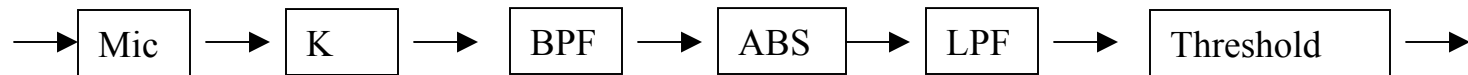
Whistle Detector Has Design Requirement: Delay & F-Discrimination



- Given: K , F_0 of BPF, V_t of Threshold.
- What other parameters affect off-delay?

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- Given: K , F_0 of BPF, V_t of Threshold.
- What other parameters affect off-delay?
BPF Q and LPF time constant
- What other parameters affect on-delay?
LPF time constant

Spell Check

- Bode: Engineer, Scientist and Mathematician
- Bodie: Ghost Town in Northern CA