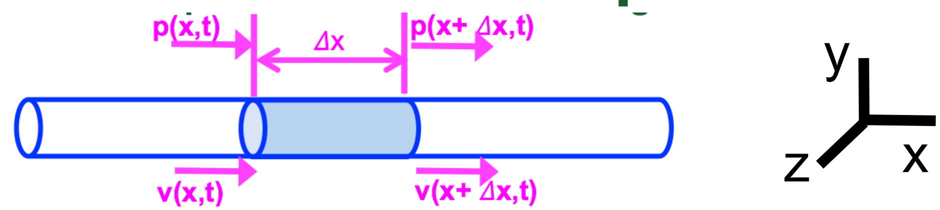
Collected examples

Acoustic Pipe Transmission Lines Example: Air

$$\frac{\partial^2 p(x,t)}{\partial x^2} = \rho_R \kappa_R \frac{\partial^2 p(x,t)}{\partial t^2}$$



- Consider the air-filled pipe at 300 °K and static pressure p_0=100 kPa, with mass-density ρ=1.2 kg/m^3.
- Then, the adiabatic compressibility κ_R in Pa^{-1}, for air (N_2, O_2) with γ=7/5 for diatomic gas:

$$\text{for ideal gas: } \kappa_R = ???\ \ \text{Pa}^{-1},$$

- Then, phase velocity v_p and characteristic impedance Z_0 is

$$v_p = ???\ \text{m/s}$$

$$Z_0 = ???\ \text{N s/m}^3$$

NOTE: v_p is in m/s, and Z_0 is in rayl = N s/m^3 = Pa s/m

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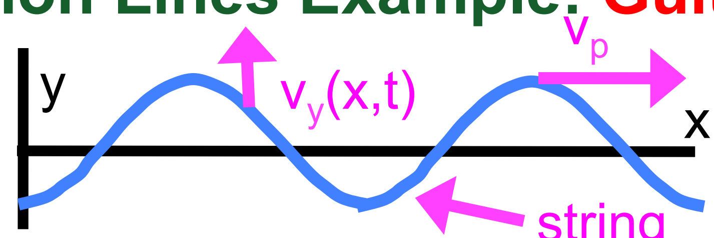
Transverse String Transmission Lines Example: Guitar

$$\frac{\partial^2 v_y(x,t)}{\partial x^2} = \frac{\rho_R}{T_s}\frac{\partial^2 v_y(x,t)}{\partial t^2}$$



- Consider low E-string on a guitar with 66 cm string length
  - mass-density ρ_R=0.007 kg/m,
  - Find the tension if low E is 83 Hz

$$\omega_n = ???? \quad \rightarrow T_s = ??? \text{ N}$$

- Then, phase velocity v_p and characteristic impedance Z_0 is

$$v_p = ??? \text{ m/s}$$

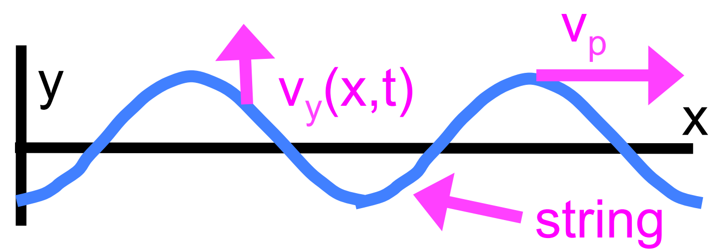
$$Z_0 = ??? \text{ N/(m/s)}$$

- Finally, find the length of the string in wavelengths

$$\lambda = ??? \text{ m}, \qquad = ??? \text{ wavelengths}$$

Transverse String Transmission Lines Example: Guitar

$$\frac{\partial^2 v_y(x,t)}{\partial x^2} = \frac{\rho_R}{T_s}\frac{\partial^2 v_y(x,t)}{\partial t^2}$$



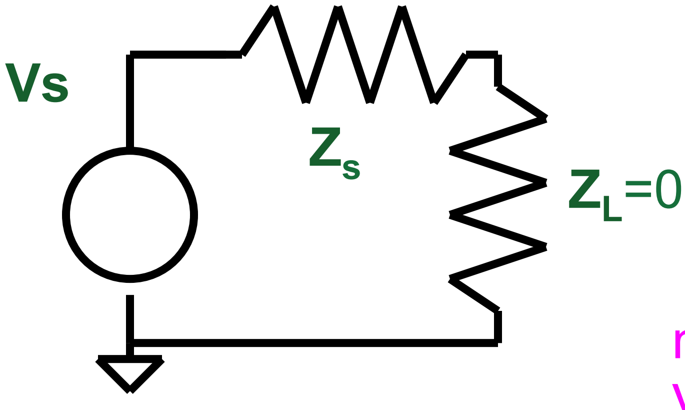
- Consider low E-string on a guitar with 66 cm string length
  - mass-density ρ_r=0.007 kg/m^3,
  - If low E is tuned to exactly 82.41 Hz, what must the string length become at the first fret with note F being exactly at 87.31 Hz

$$\frac{\omega_E}{\omega_F} = ??? \quad \frac{L_F}{L_E} = ????$$

$$so \quad L_F = ???\text{ m, and fret length} = ???\text{ m}$$

Simple Examples Without a Line

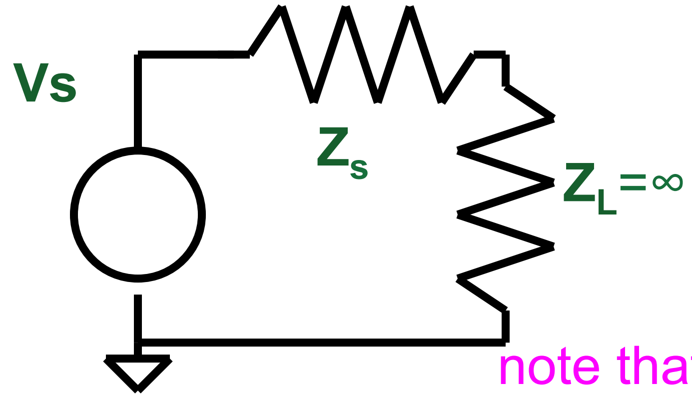
- Short circuit load



note that:
$V_T/I_T=Z_L=0$

$\Gamma = ???$

- Open circuit load



note that:
$V_T/I_T=Z_L=\infty$

$\Gamma = ???$

Example 1

- Find Z_{in} of an acoustic transmission line with length 3 m, Z_0=410 N s/m^3 and phase velocity v_p=300 m/s at a frequency of 10 Hz, terminated by a closed end (hard termination).

$$Z_{in} = ??? \ \ \mathrm{N\ s/m^3}$$

Example 2

- Find the fundamental and second harmonic mode of an acoustic transmission line with both ends open, with length 0.3 m, Z_0=410 N s/m^3, and phase velocity v_p=330 m/s.

$$\text{modes for both ends open: } l = n\lambda/2 = n\lambda/2$$

$$and \quad \lambda = ???$$

$$\text{then} \quad l = ???$$

$$so \quad f = ???\ \text{Hz}$$

$$\rightarrow ???\ \text{Hz and } ???\ \text{Hz}$$

Example 3

- Find the reflection coefficient and input impedance Z_{in} of an acoustic transmission line with length 5 m, Z_0=410 N s/m^3 and phase velocity v_p=300 m/s at a frequency of 10 Hz, terminated by an acoustic load of Z_L=200+j10 N s/m^3 .

$$\Gamma_{in} = ???5\ e^{j???} = ???\ + j\ ???$$

$$Z_{in} = ??? + j??? \text{ N s/m}^3$$

- Example:
    - What is the bit rate of a POTS channel?
    - bitrate=??? kbits/s

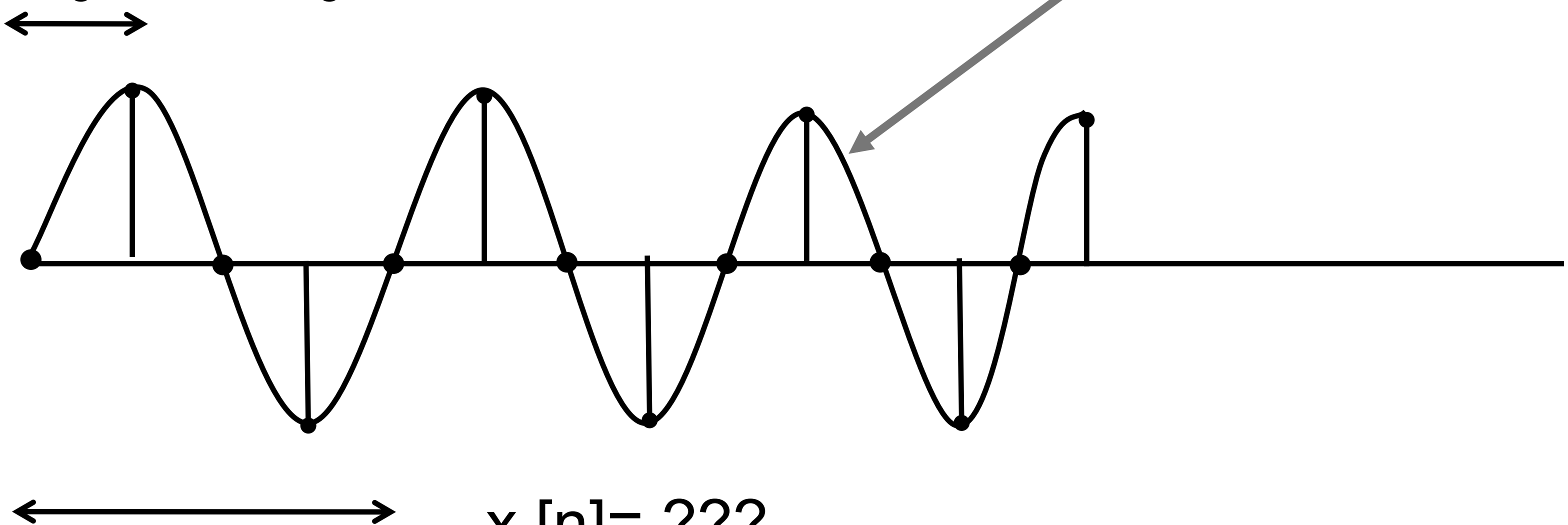
- Example: compute the frequencies of Amajor at 220 Hz
    - =???, and ??? Hz

- Example: if $y(t) = g^2(t)$ what frequencies are in $y(t)$ if $f_1 = 20$ kHz and $f_2 = 30$ kHz?
- ??? kHz and ??? kHz

Plot of Sampled Sinusoid

$$x(t) = \sin(\Omega_c t) = \sin(2\pi f_c) = \sin\left(\frac{2\pi t}{T_c}\right)$$

$T_s = 1/2$, $f_s = 2$ samples/second



$x[n] = ???$

$T_c = 1/f_c = 2$

$\omega_c = ???$ rad/sample

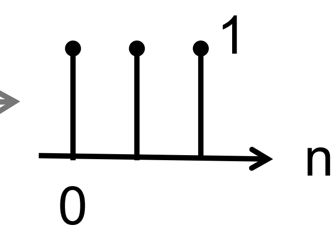
How many radians between each sample?

DTFT Example

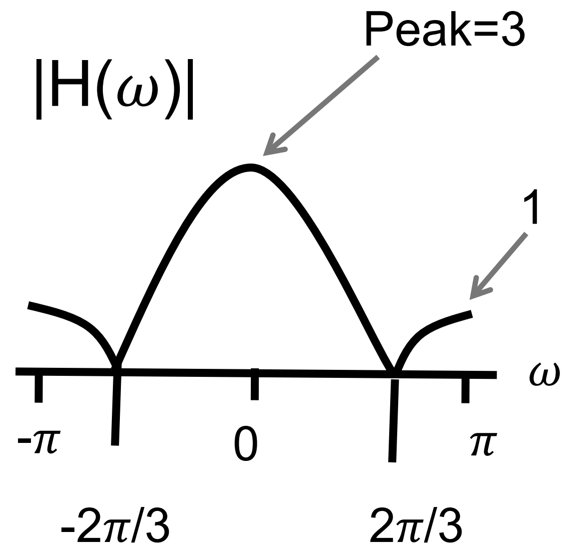
- Find DTFT of 3-point moving sum h[n]={1, 1, 1}

  y[n]=x[n] + x[n-1] + x[n-2]

  Note: h[n]=u[n]-u[n-3]



$$H(\omega) = \mathcal{F}\{h[n]\} = \sum_{n=-\infty}^{\infty} h[n]e^{-j\omega n} = ???$$



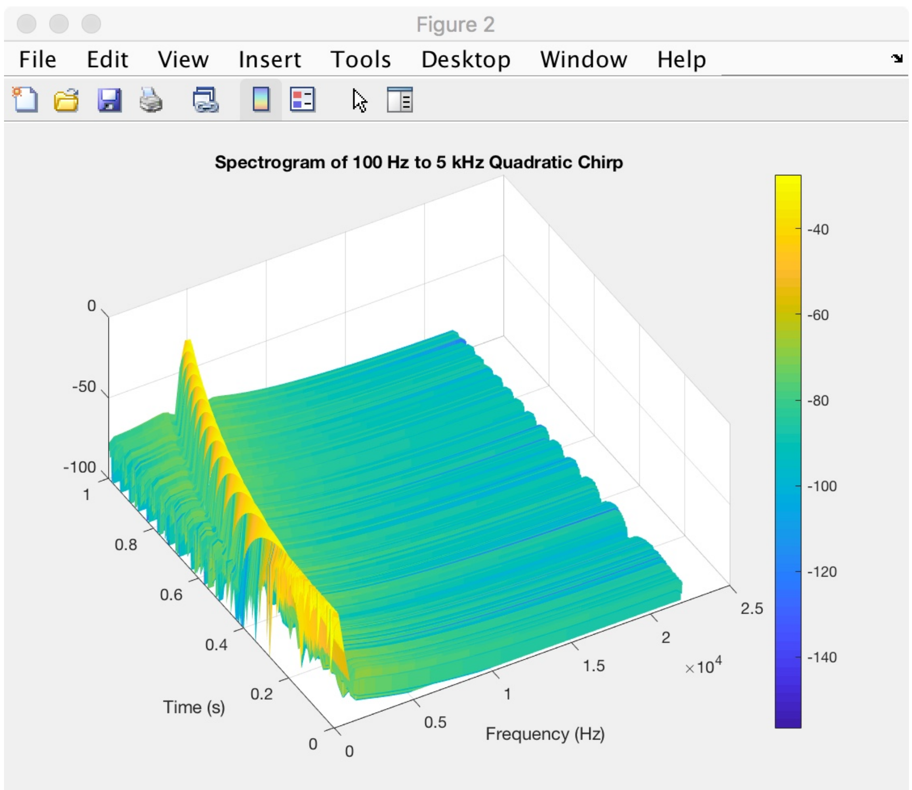
$$\text{using} \sum_{k=N_1}^{N_2} \alpha^k = \frac{\alpha^{N_1} - \alpha^{N_2+1}}{1-\alpha} \quad ; \; N_2 > N_1$$

Why does peak=3?
Note: plot is periodic
Period=?
Is this a lowpass filter?
What is dc response?

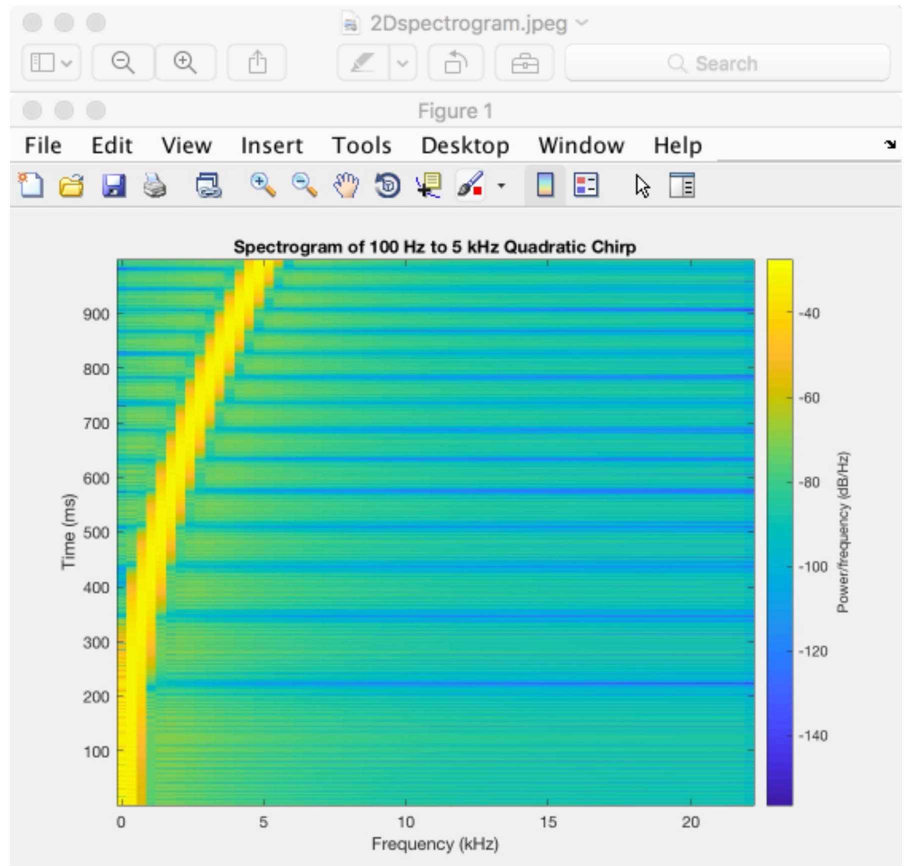
From the difference equation, if the input is x[n]=2, what is the output?

Spectrogram

- See maatlab spectrogram function
- Basic idea: take small FFT's in "time chunks"
- Examples below show frequency chirp 200 Hz to 5 kHz



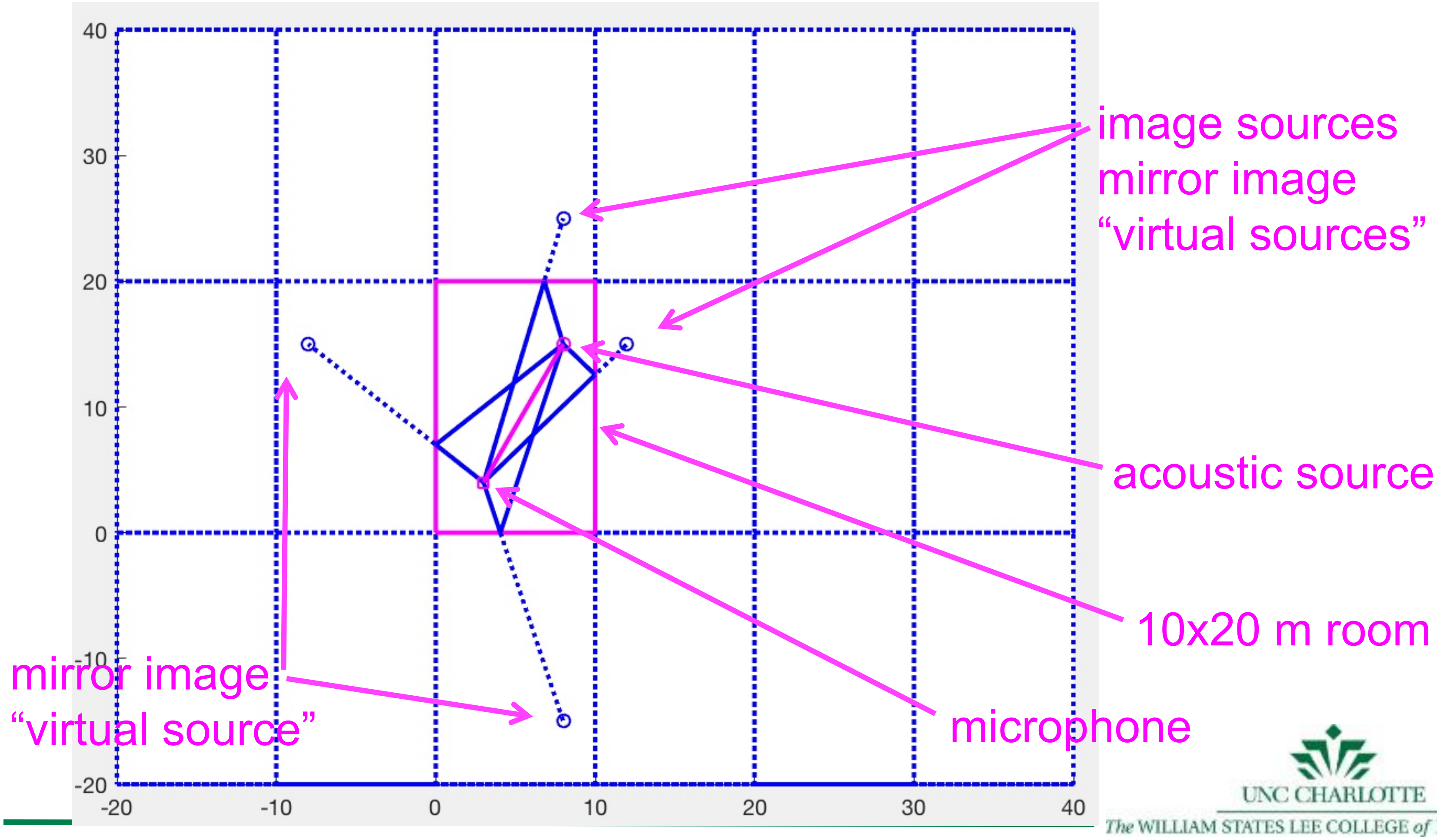
3D Format



2D Format

Example: 2D Ray-Tracing (1-bounce reflections)

- The image below shows a 10x20 m room (magenta box) with microphone at [x y]=[3 4] and source at [x y]=[8 15]
- Solid blue lines show 1-bounce reflections, with dashed blue line connecting to corresponding image sources (mirror image “virtual source”)
- Magenta line is the direct path from source to microphone



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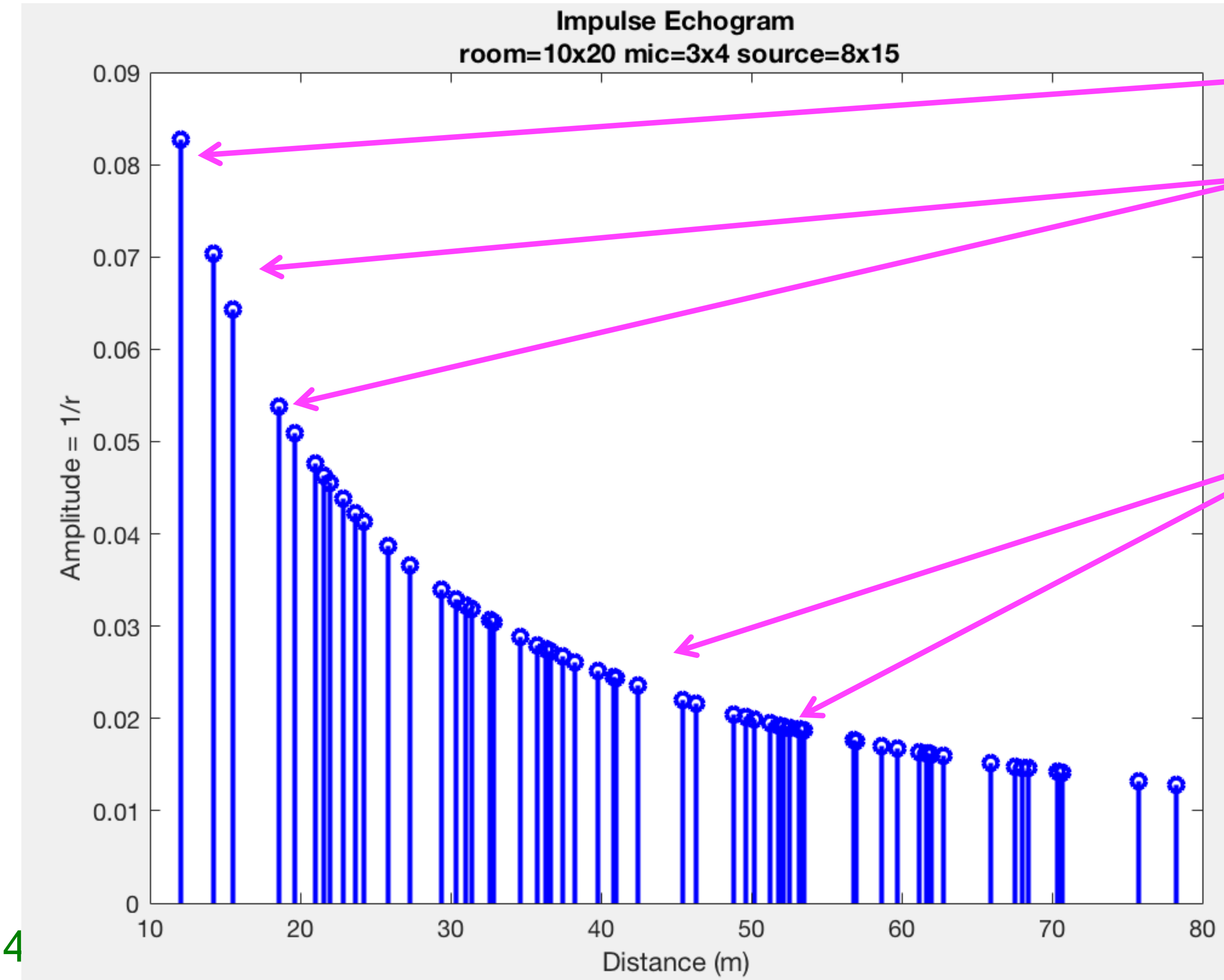
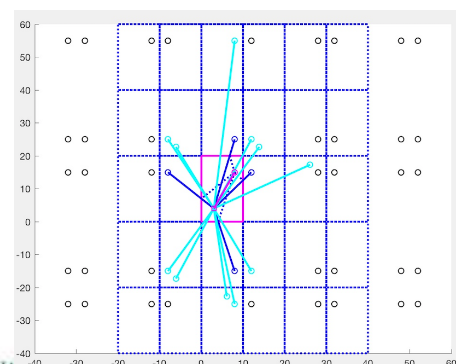
Example: 2D Ray-Tracing Impulse Echogram

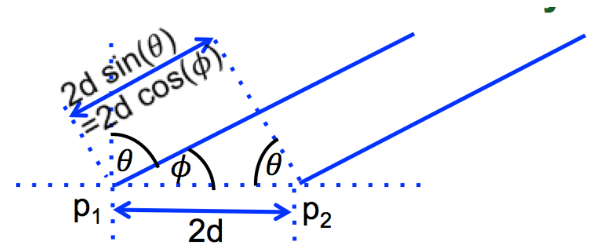
- The image below shows the impulse echogram for a 10x20 m room (magenta box) with microphone at [x y]=[3 4] and source at [x y]=[8 15]
- The 50 local image sources shown were used

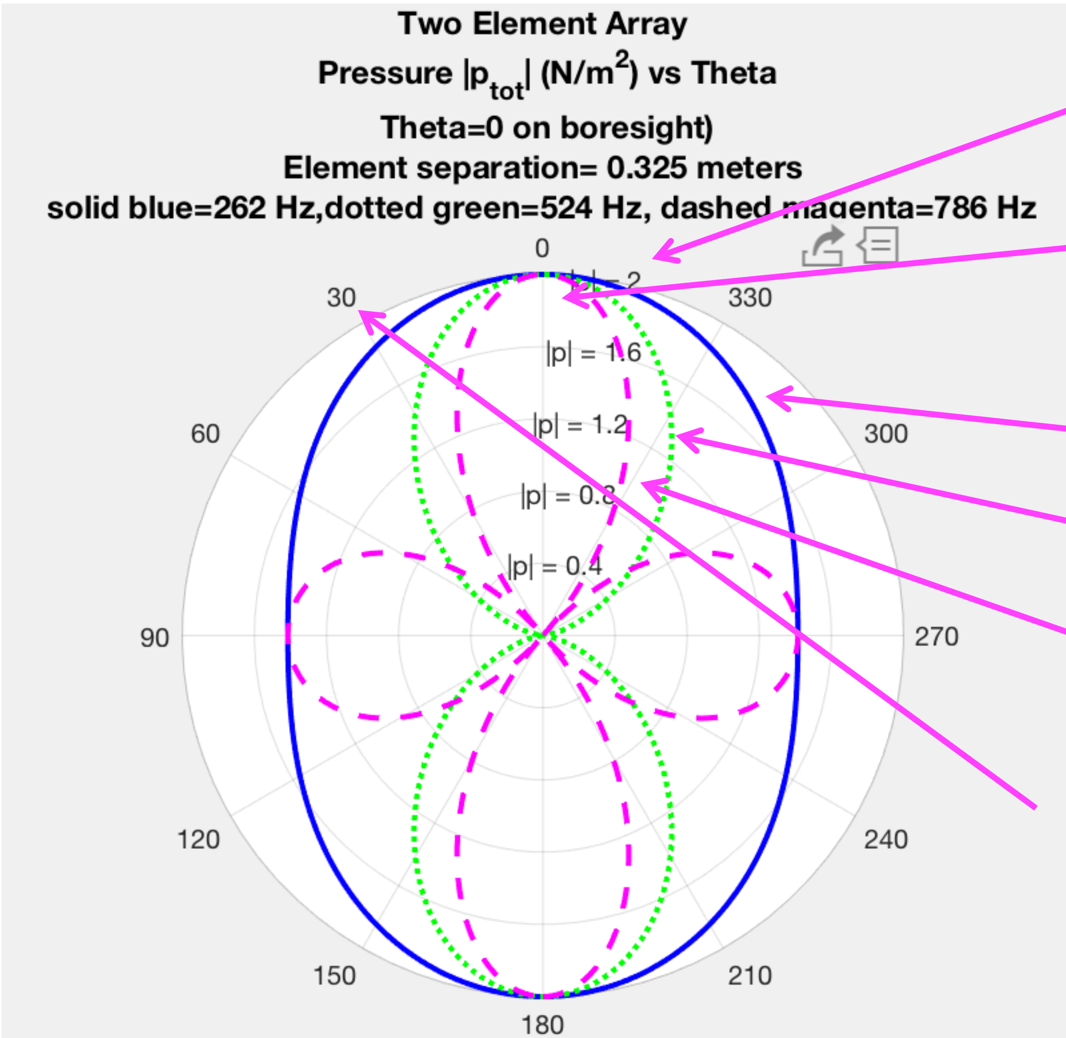




Two Element Array Frequency Dependence Example

- Simulation of the two-element array
- Separation between elements = 0.325 m





pressure doubles (6 dB power gain)

all frequencies have same value on boresight

262 Hz in blue

524 Hz in dotted green

786 Hz in dashed magenta

at 30° off boresight, levels are:
1.8 at 262 Hz
1.4 at 524 Hz
0.7 at 786 Hz

Examples:

- In a 4-element acoustic monopole source array, at a given distance r, what is the pressure level on boresight compared to a single element? How much greater in dB?
  - On boresight the pressure is ??? times larger
  - Power is greater by ??? dB

- For a 4-element array with $\lambda/2$ spacing of elements, calculate the FNBW

$$then: \quad FNBW = ??? \text{ degrees}$$

- Example: what is signal-to-noise for 10-bit ADC?

  ??? dB

- for example at 341 m/s, and middle C at 262 Hz, λ=???= 1.3 m, so speakers 0.325 m apart are at λ/???
  - However, an octave higher they are λ/??? apart, and at 786 Hz are ??? apart

Quiz Questions

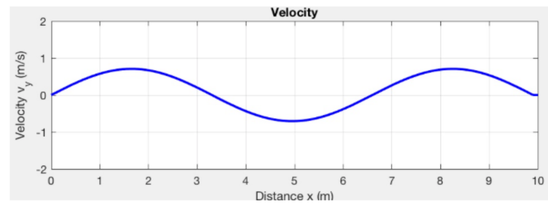
Question 1 — 5 pts

A 8 m long cable has a linear mass density ρ_R=0.5 kg/m and tension 3 , the transverse wave phase velocity in m/s (to 3 decimal places) is v_p=

Question 2 — 5 pts

A 6 m long cable has a linear mass density ρ_R=0.5 kg/m and tension 5 , the characteristic impedance in N/(m/s) (to 3 decimal places) is Z_0=

Question 3 — 5 pts



The figure above shows the velocity profile of a transverse standing wave on a string attached to walls at x=0 m and x=10 m. The mode of the standing wave is n=

- ◯ 3
- ◯ 1
- ◯ 2
- ◯ none above

Question 4 — 5 pts

A 8 m long cable is attached to walls at both ends and has a linear mass density ρ_R =0.5 kg/m and tension 3 N, the the frequency of the fundamental mode in Hz (to 3 decimal places) is f=

Quiz Questions

Question 1 5 pts

Find the fundamental mode of an acoustic transmission line with both ends open, with length 2 m, Z_0=353 N s/m^3 and phase velocity vp=478 m/s at a frequency of 100 Hz. The fundamental frequency in Hz (to 2 decimal places) is f =

Question 2 5 pts

Find the reflection coefficient Γ_L of a Z_L=516 N s/m^3 load driven by an acoustic transmission line with length 1 m, Z_0=244 N s/m^3, and phase velocity vp=9 m/s at a frequency of 400 Hz. The reflection coefficient (to 3 decimal places) is Γ_L =

Question 3 5 pts

The SWR observed an acoustic transmission line with length 5 m, Z_0=2 N s/m^3, and phase velocity vp=5 m/s is SWR=4. The magnitude of the reflection coefficient (to 3 decimal places) is $|\Gamma_L|$=

Quiz Questions

Question 1 5 pts

The FFT is a fast version of the DFT.

- True
- False

Question 2 5 pts

To avoid aliasing, a medical ultrasound system with a 5 Mhz signal would require a sample rate in MHz greater than

Question 3 5 pts

If the 4-point sequence $x[n]$ has a DFT $X[k]$={6, 3, 2, 3} then the dc component of the signal equals

Question 4 5 pts

If a musical note is at 252 Hz, then the frequency in Hz of a note 2 semitones higher is

Quiz Questions

Question 1 5 pts

Compared to a single acoustic source, the amplitude of the pressure p for an a 6-element array increases by a factor of

Question 2 5 pts

In the far field, doubling the distance from the source decreases the intensity in w/m^2 of the acoustic field by a multiplicative factor of 1/4.

- True
- False

Question 3 5 pts

If a far-field acoustic wave has an rms pressure of 0.04 Pa, at a distance of 200 m from the source, then the rms pressure in Pa at a distance of 4 m is p_{rms}=

Quiz Questions