Two Way Transmission Line - Acoustic and Electrical Response

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Line Configuration : Near End Closed -> Driver in the Line -> Far End Open

Corrected Offset and Terminus Position

Passive Crossover

3 m SPL

Unit and Constant Definition

$cycle := 2 \cdot \pi \cdot rad$ $Hz := cycle \cdot sec^{-1}$

Air Density : $\rho := 1.205 \cdot kg \cdot m^{-3}$

Speed of Sound : $c := 344 \cdot m \cdot sec^{-1}$

Part 1 : Thiele-Small Consistent Calculation

Detailed User Input (Edit This Section and Input the Parameters for the System to be Analyzed)

Cable Series Resistance

$R_{add} := 0.5 \cdot \Omega$

Input Power

$Power := 1 \cdot watt$ (Input Power) Applied Voltage Reference ---> $R_{ref} := 8 \cdot \Omega$

Tweeter Thiele / Small Parameters : SB Acousitcs Satori TW29R Updated

$f_d := 671.7 \cdot Hz$ $V_{ad} := 0.022 \cdot liter$

$R_e := 3.05 \cdot \Omega$ $Q_{ed} := 1.375$

$L_{vc} := 0.02 \cdot mH$ $Q_{md} := 2.214$

$Bl := 1.758 \cdot \frac{newton}{amp}$ $Q_{td} := \left(\frac{1}{Q_{ed}} + \frac{1}{Q_{md}} \right)^{-1}$

$S_d := 9.6 \cdot cm^2$ $Q_{td} = 0.848$

Bass Driver Thiele / Small Parameters : Satori WO24P-4 Woofer

$f_d := 32.81 \cdot Hz$ $V_{ad} := 48.31 \cdot liter$

$R_e := 3.3 \cdot \Omega$ $Q_{ed} := 0.545$

$L_{vc} := 0.372 \cdot mH$ $Q_{md} := 7.637$

$R_p := 0.74 \cdot \Omega$

$L_p := 0.595 \cdot mH$

$Bl := 7.524 \cdot \frac{newton}{amp}$ $Q_{td} := \left(\frac{1}{Q_{ed}} + \frac{1}{Q_{md}} \right)^{-1}$

$S_d := 255 \cdot cm^2$ $Q_{td} = 0.509$

Enclosure Geometry Definition

$0.71 \cdot \frac{\text{cycle}}{4} \cdot \frac{c}{f_d} = 73.268\,\text{in}$

$L := 74 \cdot \text{in}$ (Length)

Driver Distance

$\xi := 0.338285$ (Driver Position Ratio : 0.001 < ξ < 0.999)

$\xi \cdot L = 25.033\,\text{in}$

$S_0 := 2.520 \cdot S_d$ (Area of the Driver End)

$1.5 \cdot V_{ad} = 72.465\,\text{liter}$

$S_L := 0.2 \cdot S_0$ (Area of the Open End)

$0.5 \cdot (S_0 + S_L) \cdot L = 72.470\,\text{liter}$

$S_T := 8 \cdot \text{in} \cdot 2.5 \cdot \text{in}$ (Area of the Terminus)

$\text{Density} := 0.5 \cdot \text{lb} \cdot \text{ft}^{-3}$ (Stuffing Density : 0 lb/ft^3 < D < 1 lb/ft^3)

Instructions :

1. A Zobel, Trap, and L-Pad are available for adjusting the Extended Range Driver's SPL output.
2. Select the crossover frequencies, orders, and types below.
3. Scroll down to the applicable crossover sections below and fill in the values of the circuit components.
    a. The theoretical values are shown to the right of each schematic.
    b, Theoretical values are calculated using only the driver's DC resistance, a textbook solution.
    c. Enter the actual component values, these should correspond to available components.
    d. Iterate the actual component values to optimize the crossover responses.
    e. You can mix the crossover orders and types by using only half of each pair of schematics.
4. Purchase the optimized actual component values and construct the crossover per the schematics.

Crossover Definition

For Even Order Crossovers :

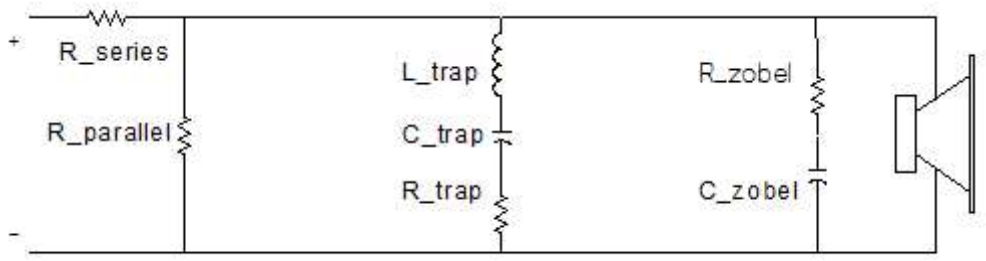
Type 1 = Linkwitz-Riley
Type 2 = Bessel
Type 3 = BEC
Type 4 = Butterworth

Low Pass Filter	High Pass Filter	
$f_{LP} := 1000 \cdot \text{Hz}$	$f_{HP} := 2100 \cdot \text{Hz}$	(Filter Frequency)
$LP_{order} := 2$	$HP_{order} := 2$	(Filter Order : 0, 1, 2, 3, or 4)
$LP_{type} := 4$	$HP_{type} := 4$	(Filter Type : 1, 2, 3, or 4 for even order only, for odd order this entry is ignored)

Crossover Phase Connection and Extended Range Driver Attenuation

$LP_{phase} := 1$	$HP_{phase} := 1$	(Phase : 1 = in phase, -1 = out of phase)
	$H\_Pad := -10$ dB	(L Pad Attemuation of Tweeter)
	$L\_Pad := 0$ dB	(L Pad Attemuation of Woofer)

Compensation Circuits (Default Actual Values **Remove** Circuits)



Tweeter Circuit Elements

Zobel Components

User Specified Compensation Circuit Values

Suggested Values $R_{zobel} = 3.813\,\Omega$

Actual Values $R_{zobel} := 10^{10}\cdot\Omega$

$C_{zobel} = 1.376\,\mu F$

$C_{zobel} := 10^{-10}\cdot\mu F$

Resonance Trap Components

Suggested Values $R_{trap} = 4.944\,\Omega$

Actual Values $R_{trap} := 10^{10}\cdot\Omega$

$C_{trap} = 56.499\,\mu F$

$C_{trap} := 10^{-10}\cdot\mu F$

$L_{trap} = 0.994\,mH$

$L_{trap} := 10^{10}\cdot mH$

L-Pad Components

Suggested Values $R_{parallel} = 1.411\,\Omega$

Actual Values $R_{parallel} := 1.5\cdot\Omega$ PE Part #005-1.5 $6.98

$R_{series} = 2.086\,\Omega$

$R_{series} := 2.5\cdot\Omega$ PE Part #005-2.5 $6.98

Woofer Circuit Elements

Zobel Components

Suggested Values

$R_{zobel} = 4.125\,\Omega$

$C_{zobel} = 21.862\,\mu F$

User Specified Compensation Circuit Values

Actual Values

$R_{zobel} := 10^{10}\cdot\Omega$

$C_{zobel} := 10^{-10}\cdot\mu F$

Resonance Trap Components

Suggested Values

$R_{trap} = 3.535\,\Omega$

$C_{trap} = 2.697 \times 10^{3}\,\mu F$

$L_{trap} = 8.724\,mH$

Actual Values

$R_{trap} := 10^{10}\cdot\Omega$

$C_{trap} := 10^{-10}\cdot\mu F$

$L_{trap} := 10^{10}\cdot mH$

L-Pad Components

Suggested Values

$R_{parallel} = 1.000 \times 10^{10}\,\Omega$

$R_{series} = 0.000\,\Omega$

Actual Values

$R_{parallel} := 10^{10}\cdot\Omega$

$R_{series} := 0\cdot\Omega$

End of Abbreviated User Input

Internal Geometry Plot

$242 \cdot mm = 9.528\,in$ driver OD

$height := 37.75 \cdot in$ exterior height

$210 \cdot mm = 8.268\,in$ hole OD

$width := 11 \cdot in$ exterior width

$thick := 0.5 \cdot in$ wood thickness

$0.5 \cdot (width - 2 \cdot thick - 210 \cdot mm) = 0.866\,in$ web

$\theta := atan\left[\left(S_0 - S_L\right) \cdot [(width - 2 \cdot thick) \cdot L]^{-1}\right]$ $\theta = 6.146\,deg$

$depth := \left(S_0 + S_L\right) \cdot (width - 2 \cdot thick)^{-1} + 2 \cdot thick + thick \cdot (\cos(\theta))^{-1}$ exterior depth

$depth = 13.455\,in$

$depth := 13.5 \cdot in$

$L_1 := 30.5 \cdot in$ vertical height of divider

$(height - 2 \cdot thick) \cdot (depth - 2 \cdot thick) \cdot (width - 2 \cdot thick) - L_1 \cdot \cos(\theta)^{-1} \cdot (width - 2 \cdot thick) \cdot thick = 72.765\,liter$

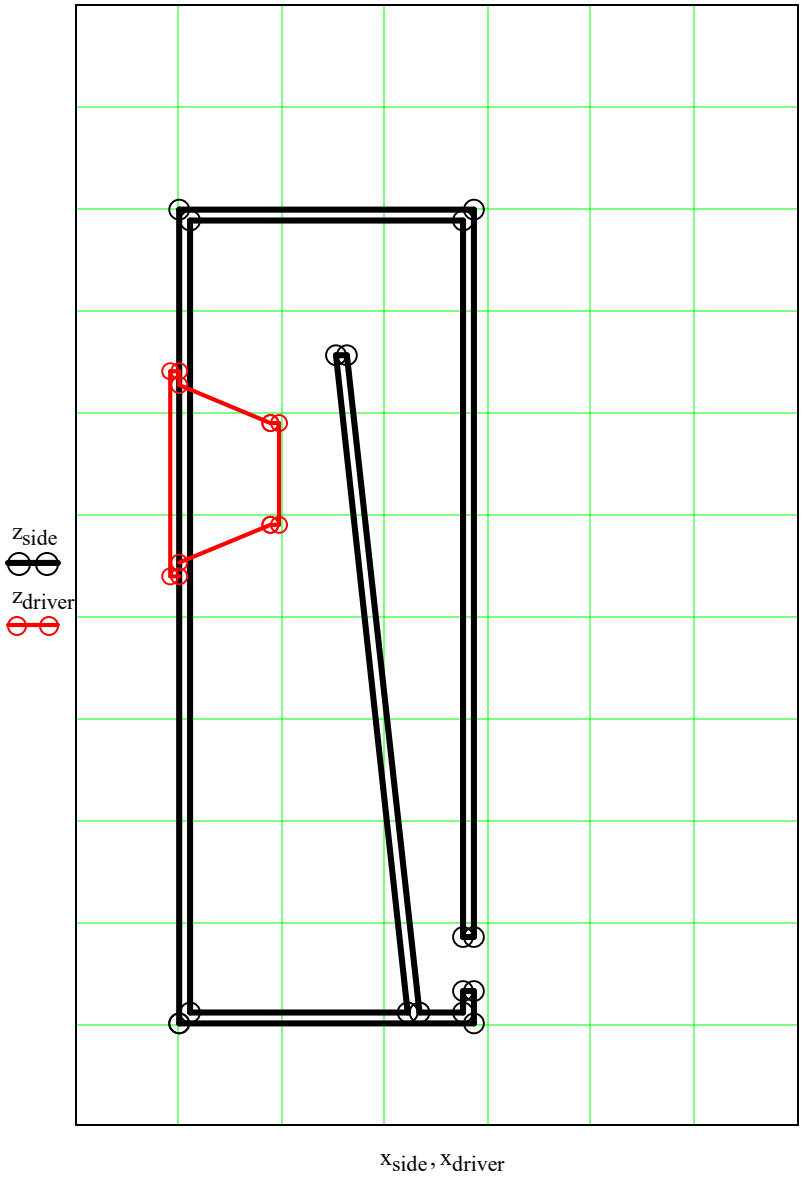
Checks

$$\frac{\sqrt{\left(x_{side_7} - x_{side_8}\right)^2 + \left(z_{side_7} - z_{side_8}\right)^2} \cdot (width - 2 \cdot thick)}{S_0} = 1.000$$

$$\frac{\left(x_{side_{12}} - x_{side_{11}}\right) \cdot (width - 2 \cdot thick)}{S_L} = 1.000$$

$$\frac{\left(z_{side_3} - z_{side_{13}}\right) \cdot (width - 2 \cdot thick)}{S_T} = 1.250$$

Cut-away Side View



Total Length of the Transmission Line

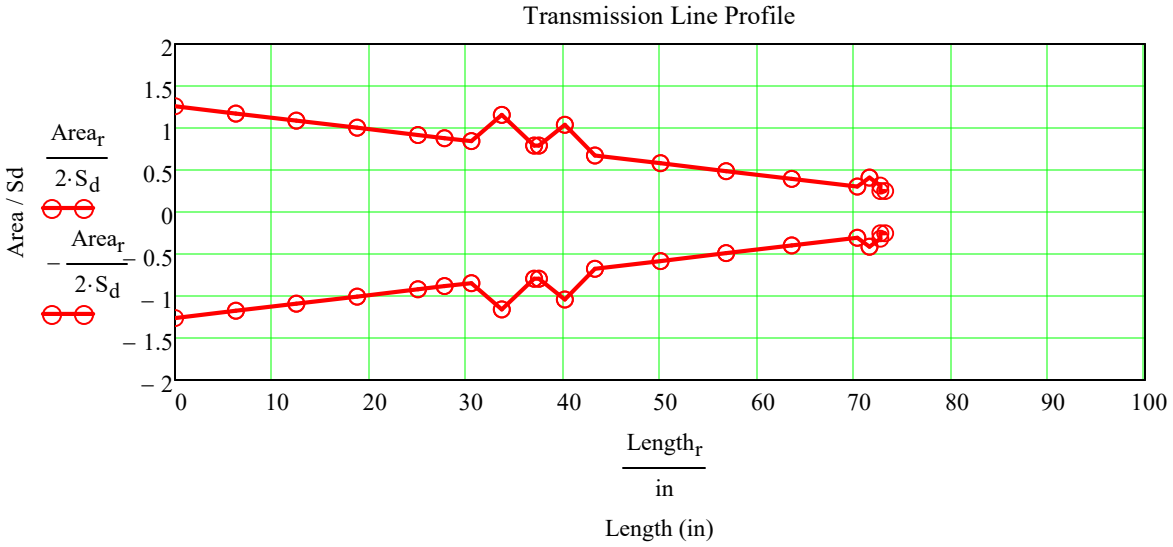
$$\sum_{i=0}^{n\_closed} L_{c_i} + \sum_{i=0}^{n\_open} L_{o_i} = 73.203\ \text{in} \qquad L = 74.000\ \text{in} \qquad \text{checks}$$

Total Amount of Stuffing

$$\sum_{r=0}^{n\_closed} \left(\frac{S_{c_{r,0}} + S_{c_{r,1}}}{2} \cdot L_{c_r} \cdot D_{c_r} \right) + \sum_{r=0}^{n\_open} \left(\frac{S_{o_{r,0}} + S_{o_{r,1}}}{2} \cdot L_{o_r} \cdot D_{o_r} \right) = 538.141\ \text{gm}$$

Total Volume

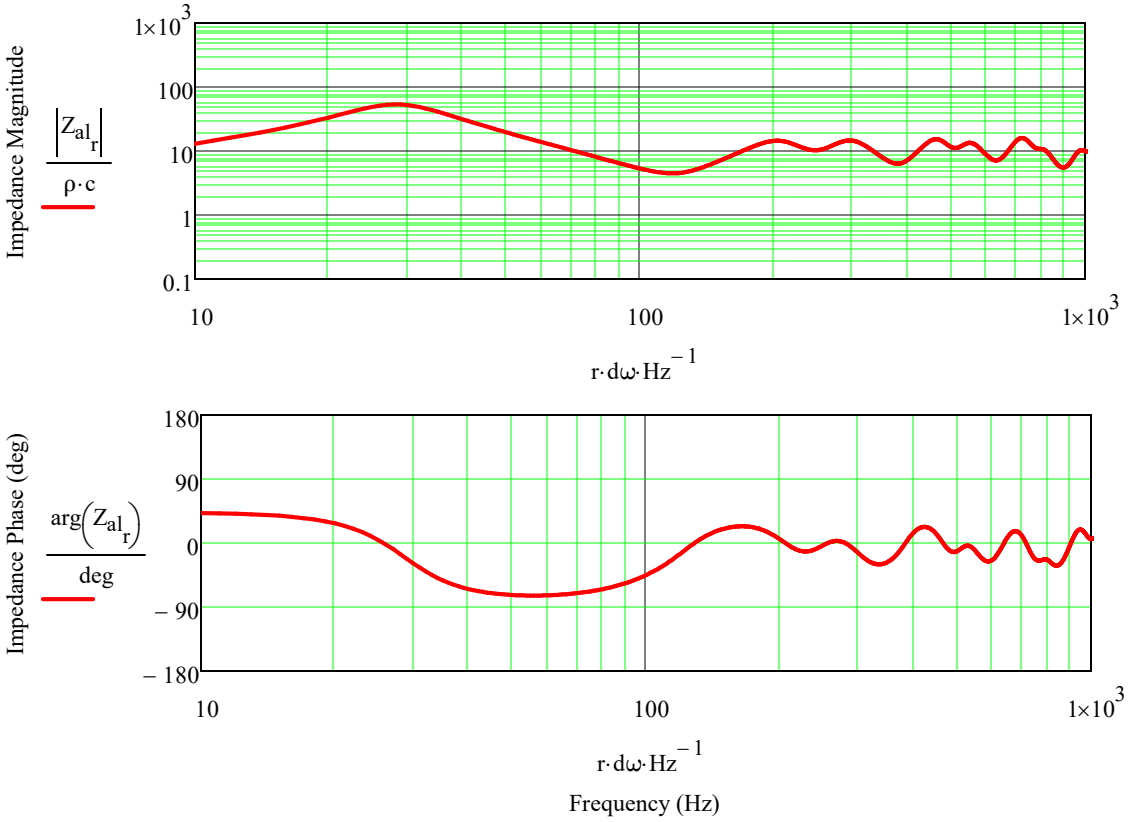
$$\sum_{r=0}^{n\_closed} \left(\frac{S_{c_{r,0}} + S_{c_{r,1}}}{2} \cdot L_{c_r} \right) + \sum_{r=0}^{n\_open} \left(\frac{S_{o_{r,0}} + S_{o_{r,1}}}{2} \cdot L_{o_r} \right) = 75.414\,\text{liter} \qquad 1.5 \cdot V_{ad} = 72.465\,\text{liter}$$



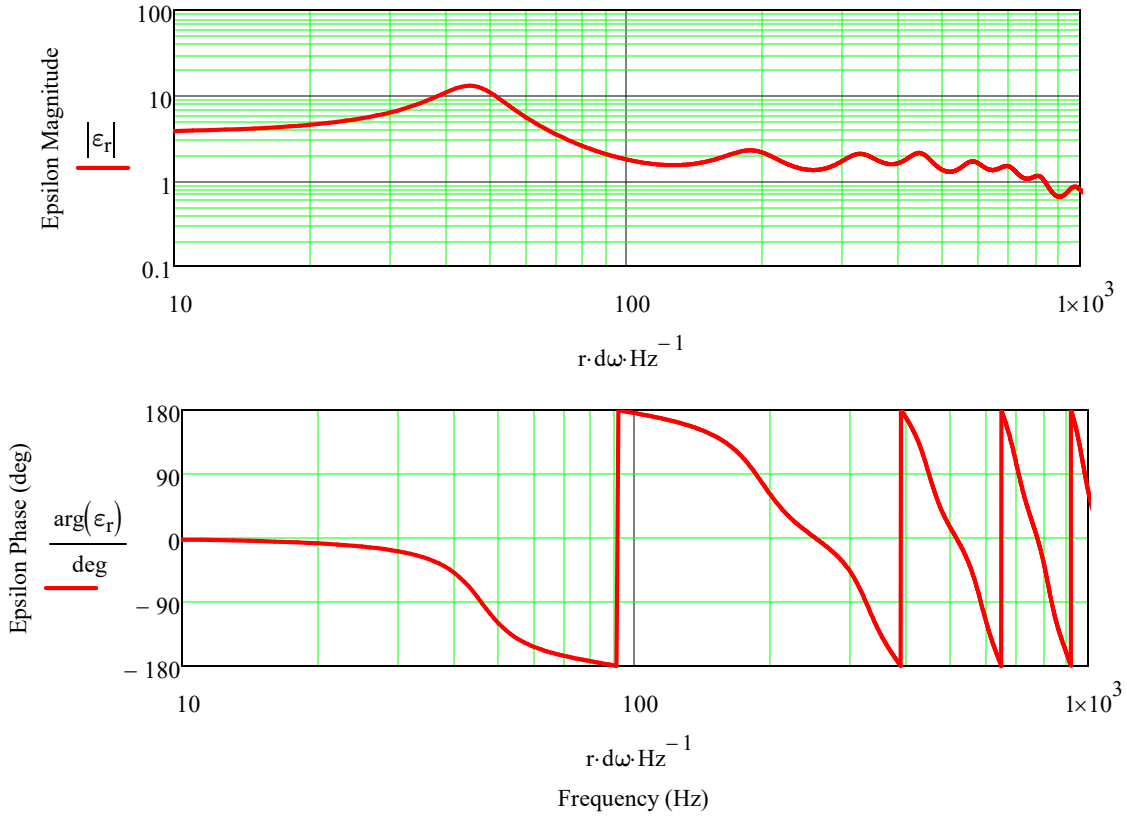
End of Detailed Input

End of Part 1 Input

Resulting Acoustic Impedance for the Transmission Line



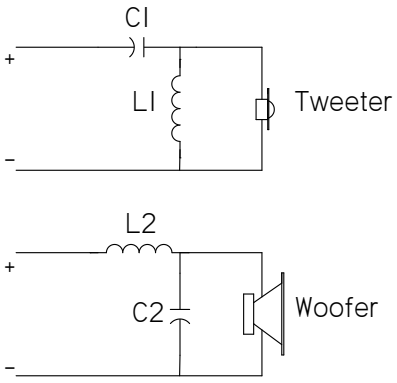
Velocity at the Terminus of the Transmission Line for a 1 m/sec Excitation at the Driver



Crossover Definition - 1st Order High and Low Pass

Crossover Definition - 2nd Order High and Low Pass

Schematic



Theoretical Values

$C_1 = 17.568\,\mu F$

$L_1 = 0.327\,mH$

$L_2 = 0.743\,mH$

$C_2 = 34.098\,\mu F$

Enter Actual Component Values Below

High Pass

$C_1 := 18\cdot\mu F$ $R_{C1} := 0\cdot\Omega$ PE Part #027-580 Solen 18uF $10.69

$L_1 := 0.33\cdot mH$ $R_{L1} := 0.1\cdot\Omega$ PE Part #266-317 ERSE 14 AWG Perfect Lay $15.74

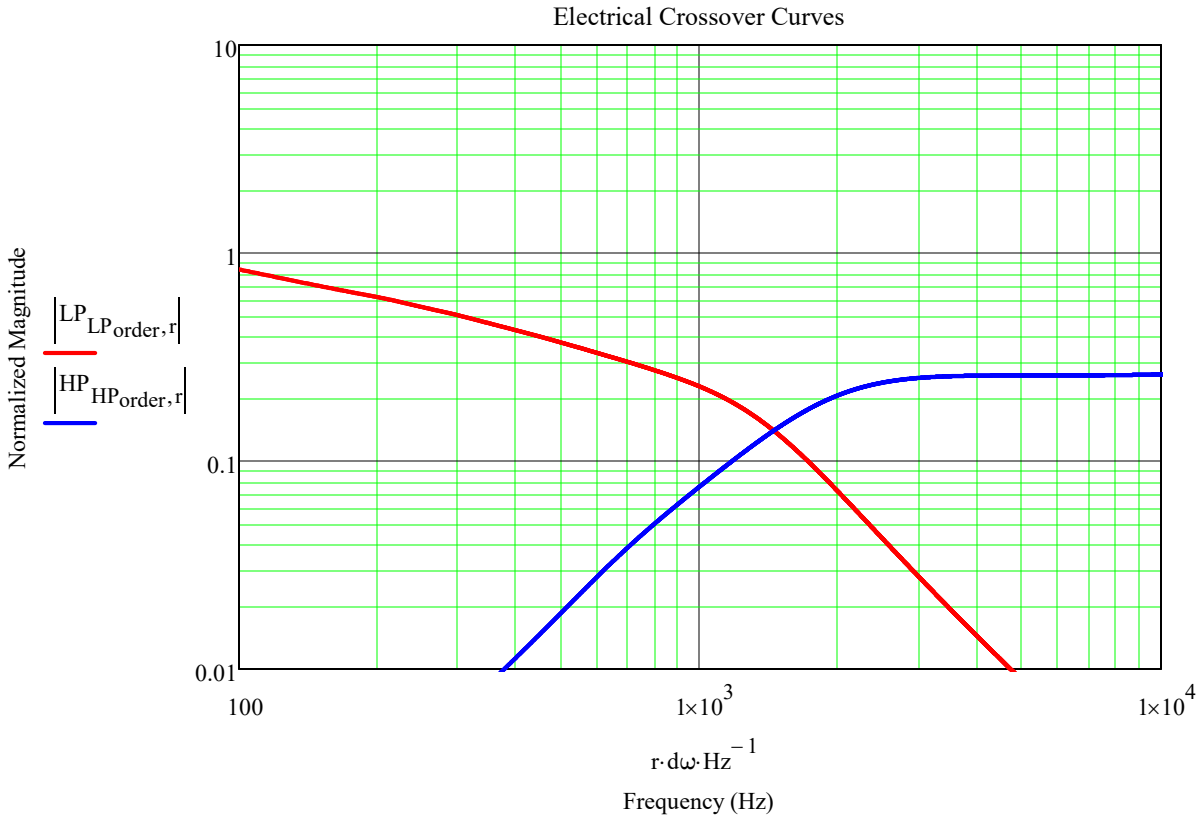
Low Pass

$L_2 := 3.38\cdot mH$ $R_{L2} := 0.81\cdot\Omega$ ERSE Super Q 18 AWG Perfect Lay

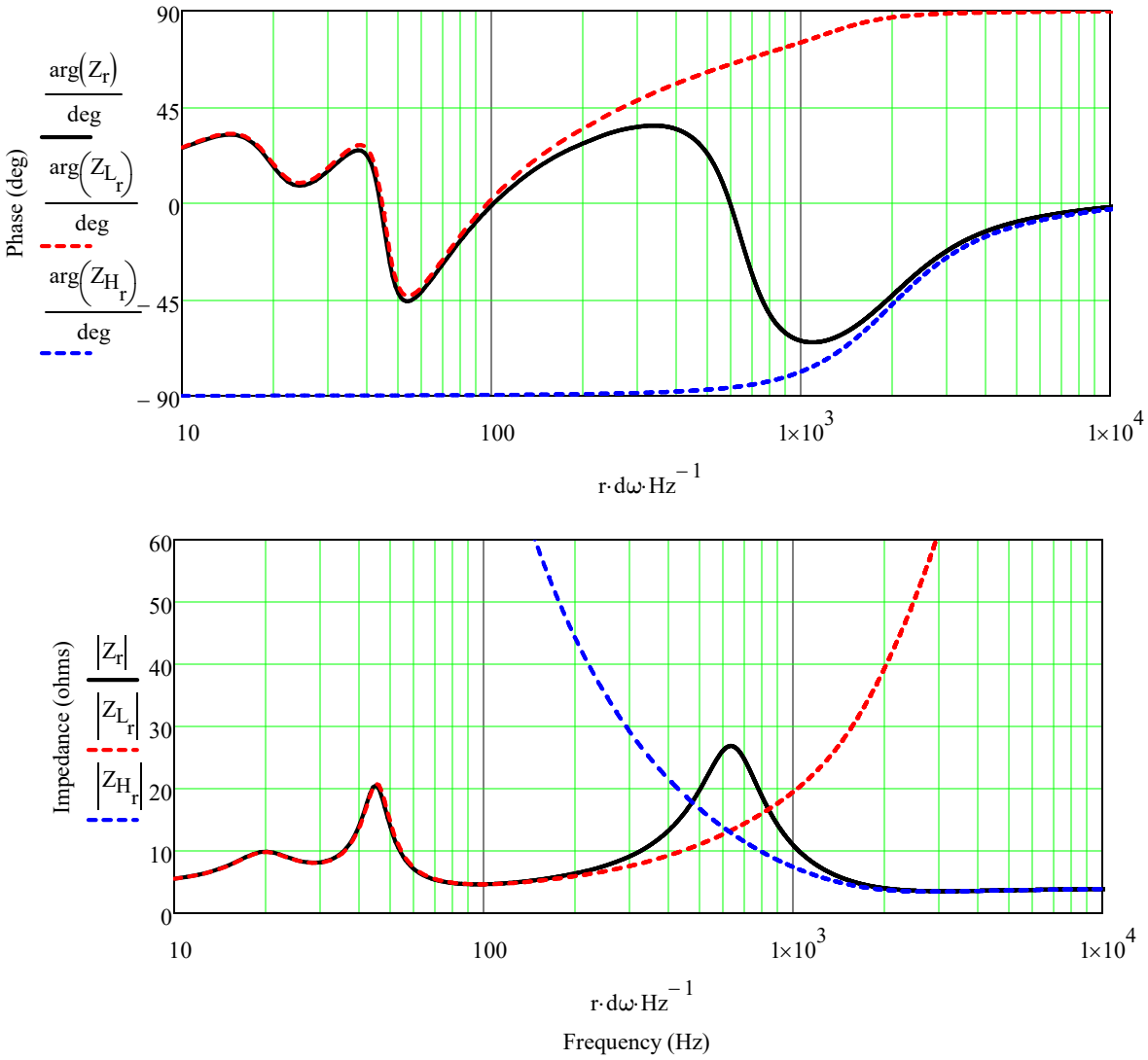
$C_2 := 36.7\cdot\mu F$ $R_{C2} := 0\cdot\Omega$ PE Part #027-594 Solen 37uF $18.98

Crossover Definition - 3rd Order High and Low Pass

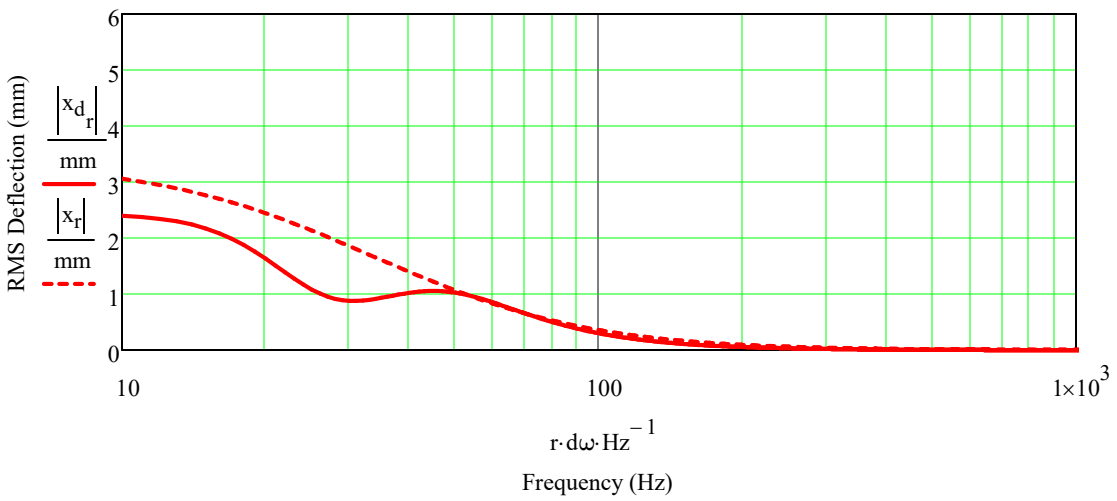
Crossover Definition - 4th Order High and Low Pass


Electrical Crossover Curves
10
1
0.1
0.01
Normalized Magnitude
|LP LPorder, r|
|HP HPorder, r|
100
1×10^3
1×10^4
r·dω·Hz^−1
Frequency (Hz)

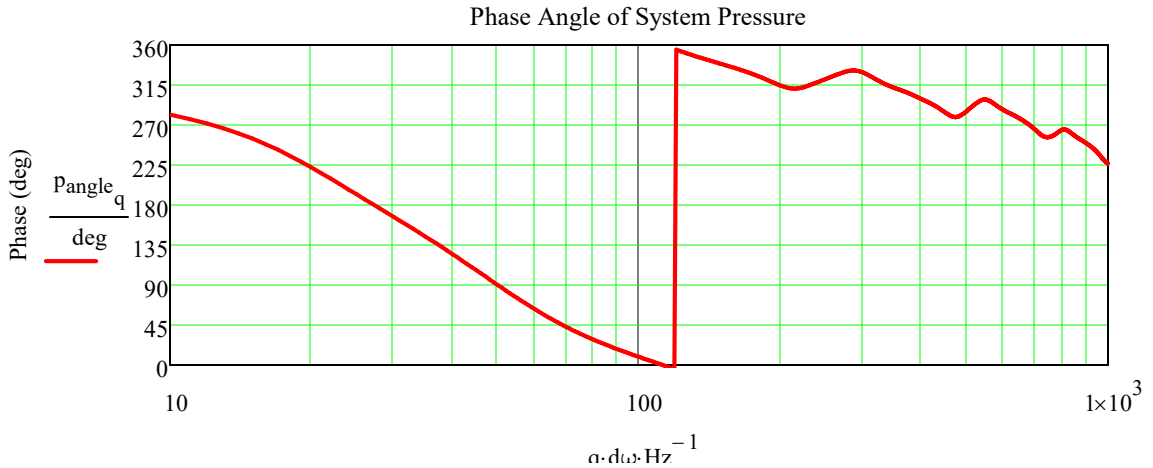
Transmission Line System and Infinite Baffle Impedance

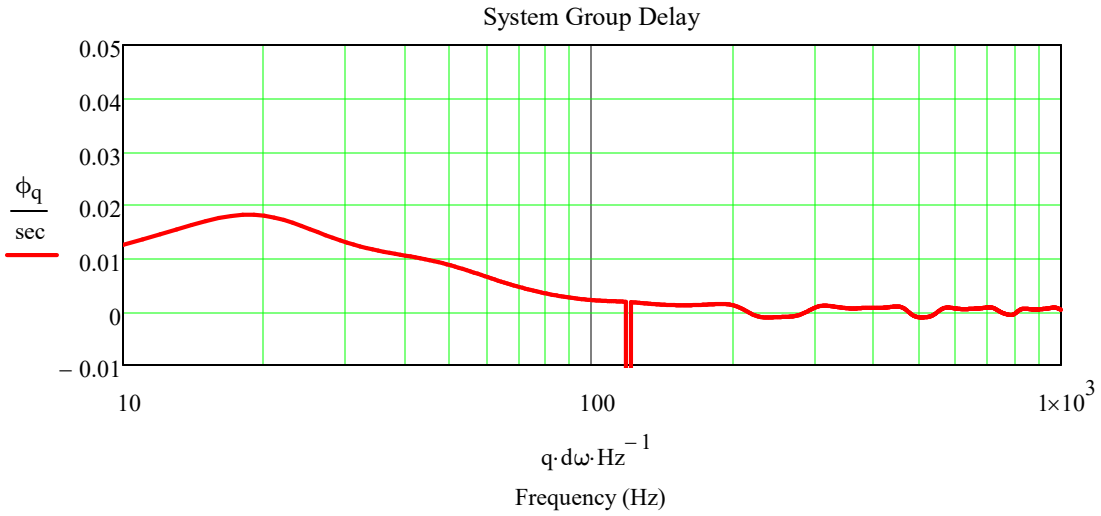


Woofer RMS Displacement

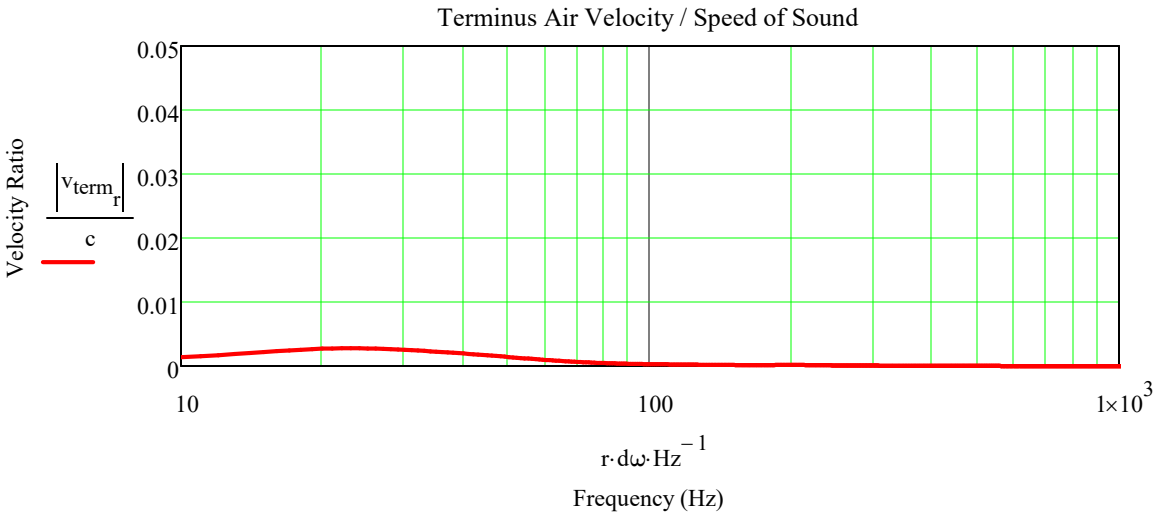


System Group Delay





Terminus Air Velocity (should be < 17 m/sec / 344 m/sec = 0.05)



Part 2 : Detailed SPL Response Calculation

Calculation Includes :
Position of the Drivers and the Terminus on the Baffle.
Baffle Step of the Drivers and the Terminus.
Room Reflections for the Drivers and the Rear Terminus.

Geometry

Coordinate System :
Origin is the lower left corner of the front baffle
y = horizontal direction
z = vertical direction

The variables num_r, n_drv, and n_mth control the number of simple sources used in the calculations. Increasing each will improve accuracy at the expense of longer calculation times. Increase each variable until final plotted SPL stops changing at which point the solution has converged.

Enclosure Geometry Input

$X_0 := 3 \cdot ft$ (Front Baffle Distance from Rear Wall > Depth of Enclosure)

$Y_0 := 2 \cdot ft$ (Front Baffle Distance from Side Wall)

$\theta_0 := 30 \cdot deg$ (Rotation Towards Room Center)

$Z_0 := 8 \cdot ft$ (Floor to Ceiling Distance)

$stand := 0.001 \cdot in$ (Height from Floor to Bottom Edge of Front Baffle)

$num\_r := 60$ (Number of Points per Unit Length of Baffle Edge)

Corner Coordinates

Y coordinate	Z coordinate	
$yo_0 := width$		(Bottom Right Corner)
$yo_1 := width$	$zo_1 := height$	(Top Right Corner)
$yo_2 := 0 \cdot in$	$zo_2 := height$	(Top Left Corner)
$yo_3 := 0 \cdot in$		(Bottom Left Corner)

$depth = 13.500\,in$ (Depth of Enclosure)

Driver Geometry Input

$y_{wc} := 0.5 \cdot width$ (Woofer Center y Coordinate)

$z_{wc} := z_{woofer}$ (Woofer Center z Coordinate)

$z_{wc} + stand = 25.498\,in$

$w\_dvr := 12$ (Number of Points Across Diameter)

$\xi \cdot L \cdot \cos(0.5 \cdot \theta) + thick = 25.497\,in$

$y_{tc} := 0.5 \cdot width + 1 \cdot in$ (Tweeter Center y Coordinate)

$z_{tc} := z_{woofer} + 8 \cdot in$ (Tweeter Center z Coordinate)

$z_{tc} + stand = 33.498\,in$

$t\_dvr := 5$ (Number of Points Across Diameter)

$height - z_{tc} = 4.253\,in$

$\Delta_{centers} := -42 \cdot mm$ (Acoustic Center Offset, Negative is Woofer Behind Tweeter)

Terminus Geometry Input

$y_{mc} := 0.5 \cdot width$ (Terminus Center y Coordinate)

$z_{mc} := 2.75 \cdot in$ (Terminus Center z Coordinate)

$w_{mth} := 8 \cdot in$ (Terminus Width)

$thick + 1.in + \frac{1}{2} \cdot \frac{S_T}{width - 6 \cdot thick} = 2.750\,in$

$n\_mth := 15$ (Number of Points Across the Width)

$width - 6 \cdot thick = 8.000\,in$

$Locate := 1$ (0 = Front Baffle Terminus, 1 = Rear Baffle Terminus)

Listening Position

n_listen = 0	(Listening Position Relative to Speaker)
$radius := 3 \cdot m$	(Calculation Radius Along Axis of the Extended Range Driver)
$\theta := 0 \cdot deg$	(0 deg is along the Driver's Axis, -80 deg < θ < 80 deg)
$z_p := 33 \cdot in$	(Default Height is Equal to Seated Height)
n_listen = 1	(Listening Position Relative to the Room Corner)
$X_p := 10ft$	
$Y_p := 7 \cdot ft$	
$Z_p := 33 \cdot in$	(Default Height is Equal to Seated Height)
$n\_listen := 0$	(Method Selection)

Floor Condition

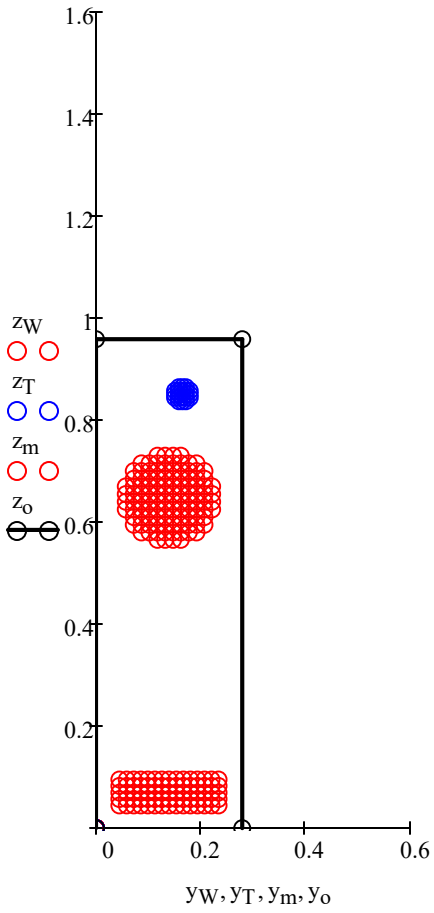
$Reflect := 1$	(0 = hardwood or concrete, 1 = carpeted)

Refective Surface Selections (if 1 reflective surface is included, if 0 reflective surface is removed)

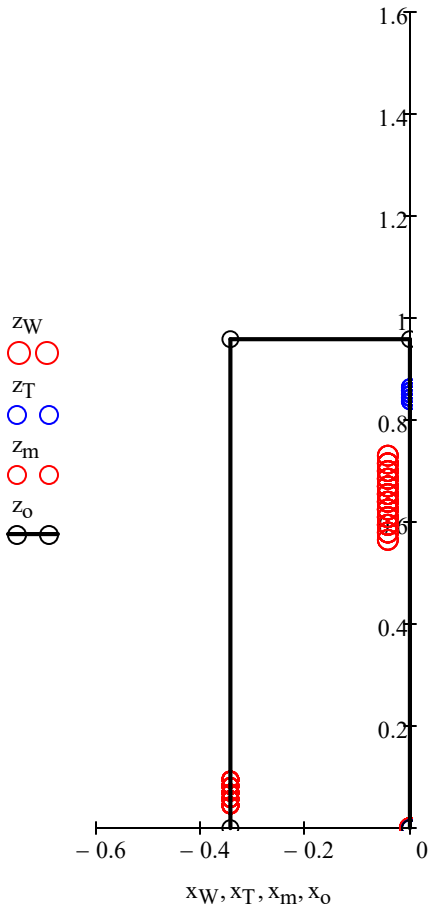
$Inc\_floor := 0$	(Floor, Z = 0)
$Inc\_rear := 0$	(Rear Wall, X = 0)
$Inc\_side := 0$	(Left Side Wall, Y = 0)
$Inc\_ceiling := 0$	(Ceiling)

Circular Driver and TL Terminus Simple Source Pattern with Baffle Edge Outline

Front View



Side View

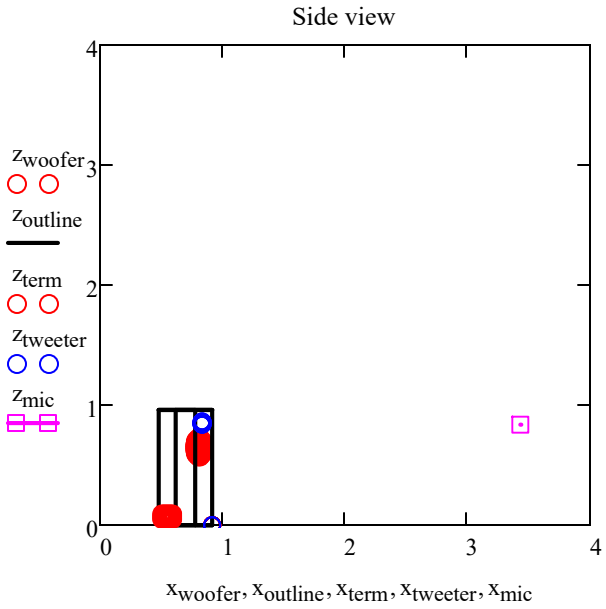


Red sources represent the woofer and terminus.
Blue sources represent the tweeter.
Black outline represents the baffle edge.
Origin is at the bottom front left corner of the enclosure.

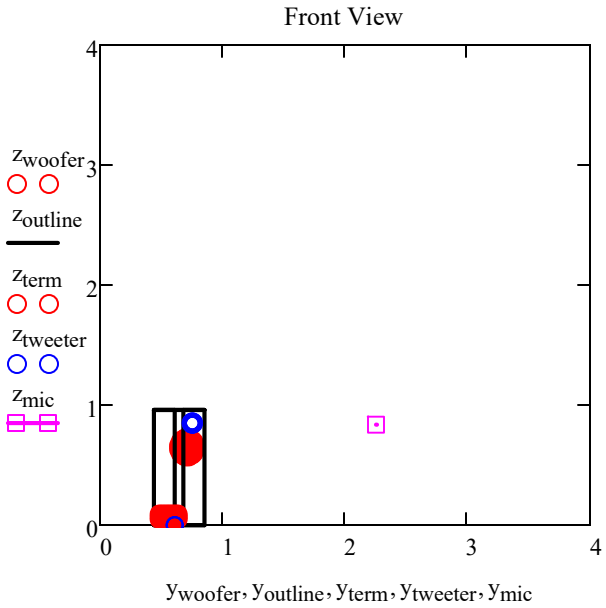
Three Dimensional View

Axis Length (m) axis := 4 <---- Change value of "axis" to rescale plots

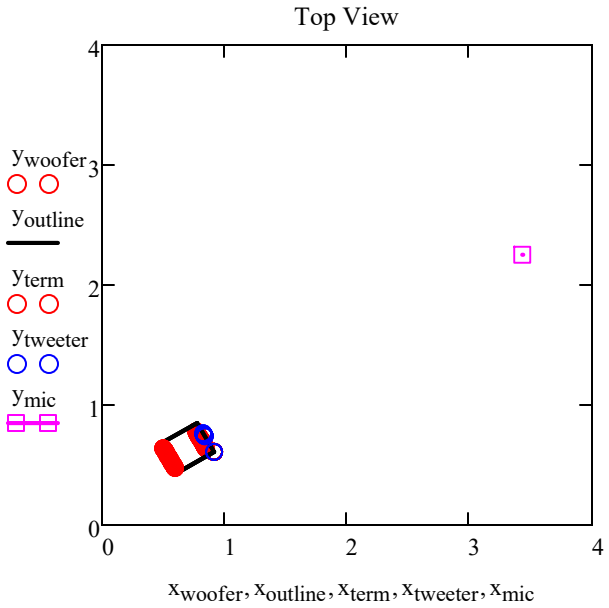
Room Corner is the Origin



Side View - looking out from side wall

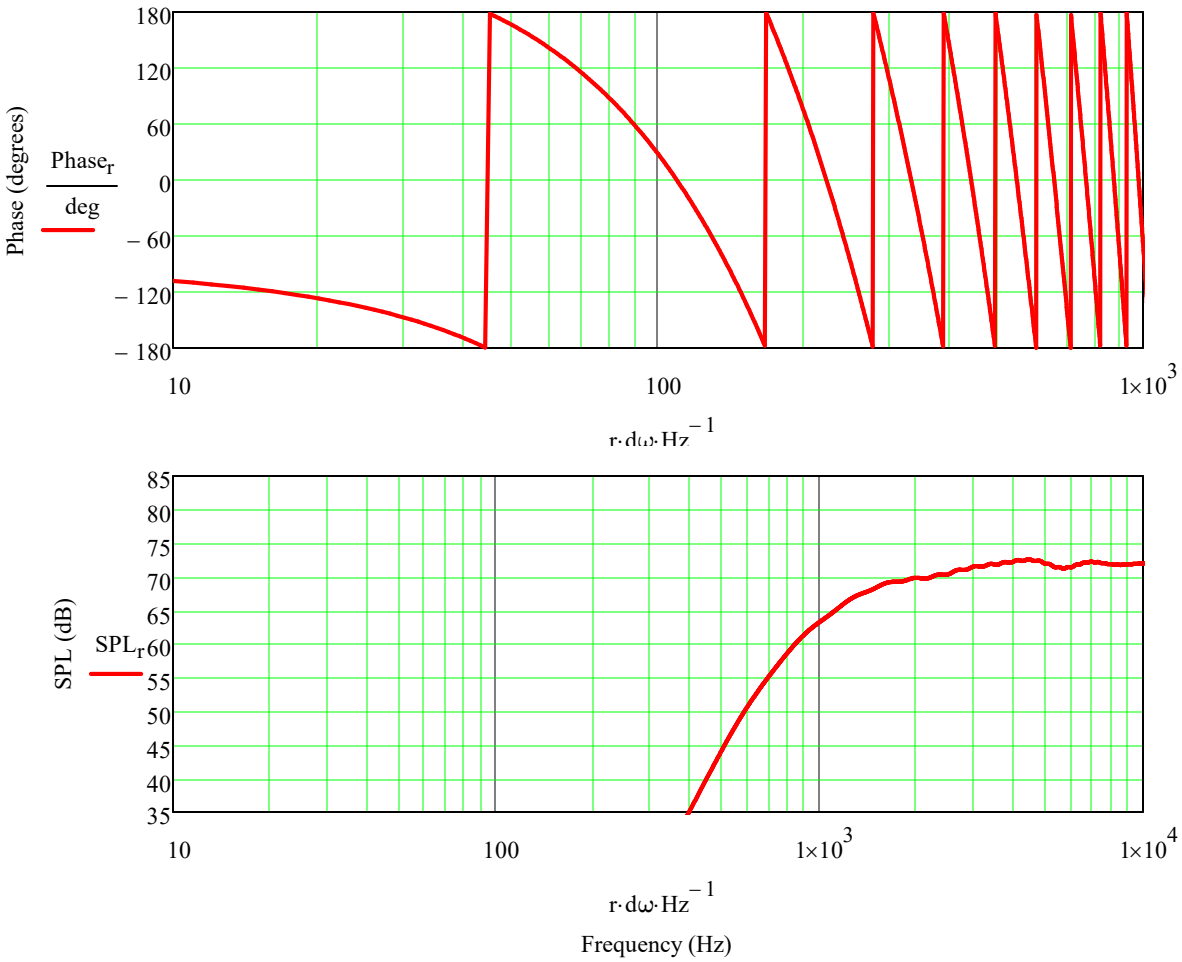


Front View - looking towards rear wall

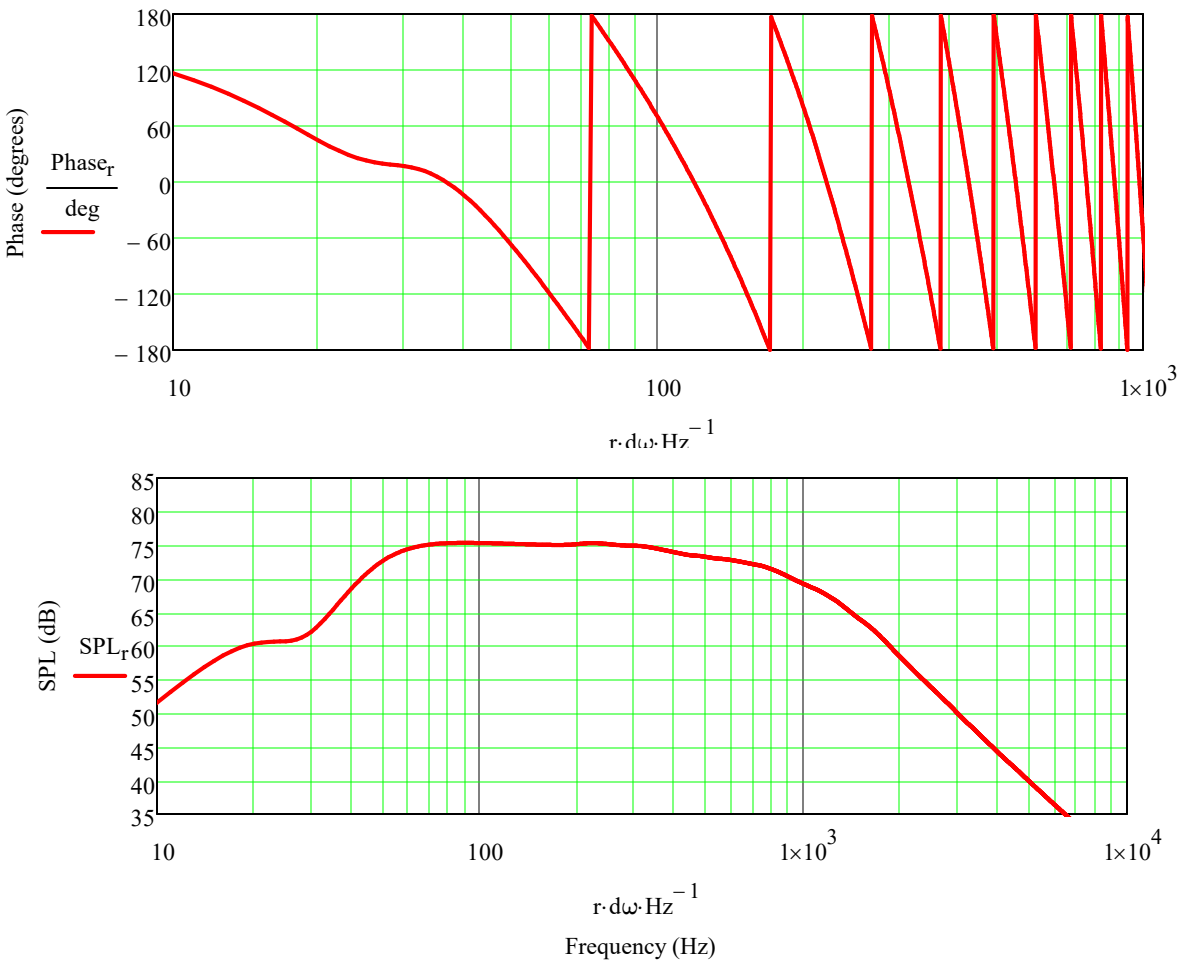


Top View - looking down from ceiling

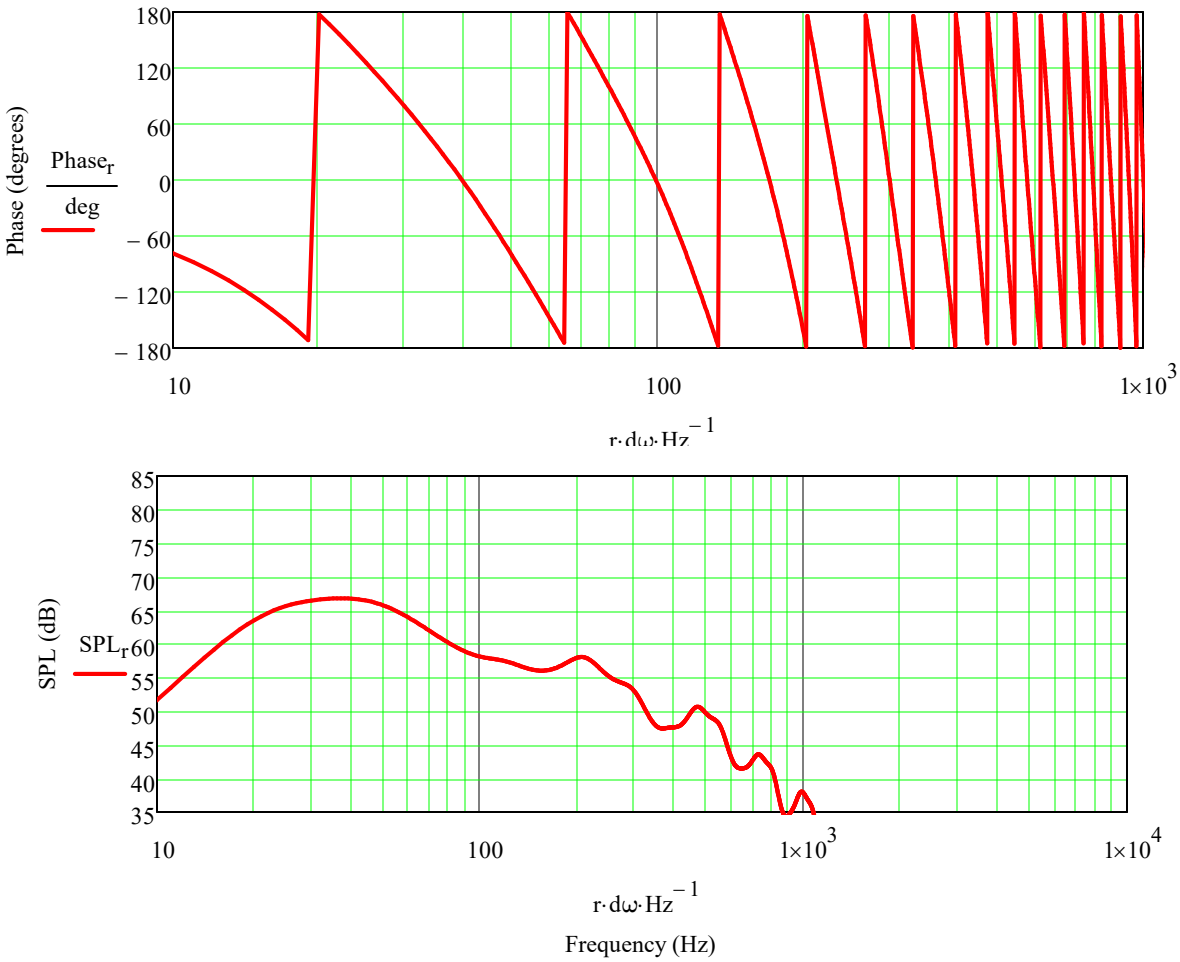
Plotted Baffle Step and Reflection SPL Response for the Tweeter



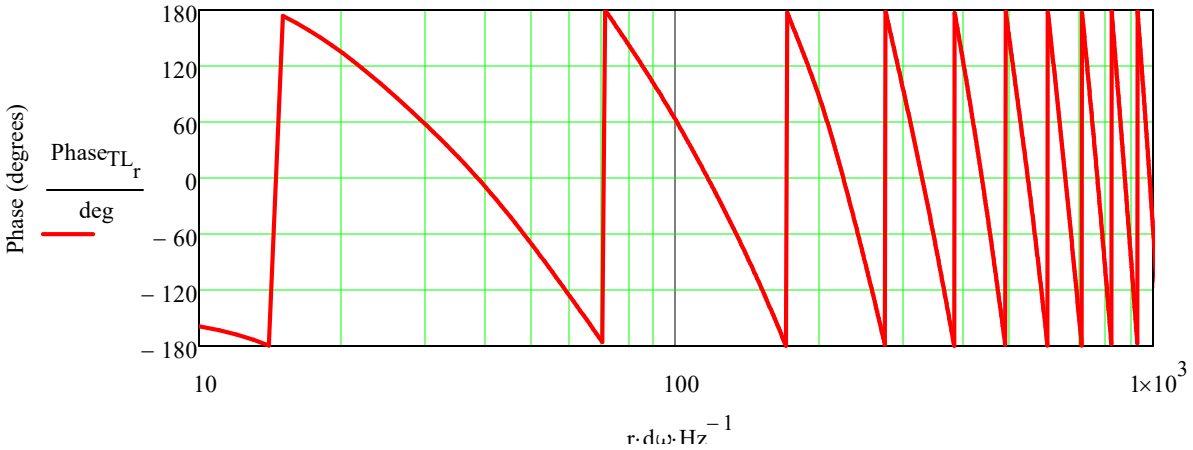
Plotted Baffle Step and Reflection SPL Response for the Woofer

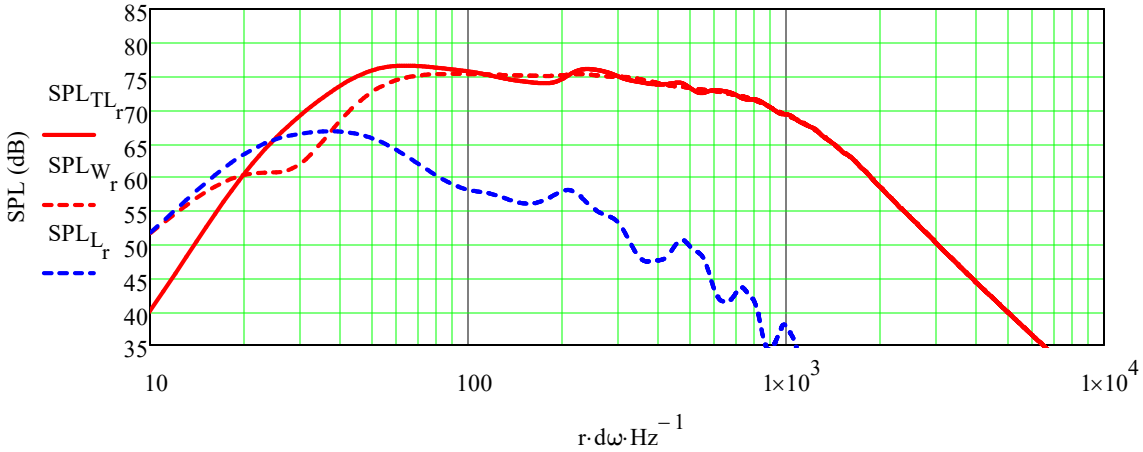


Plotted Baffle Step and Reflection SPL Response for the Terminus

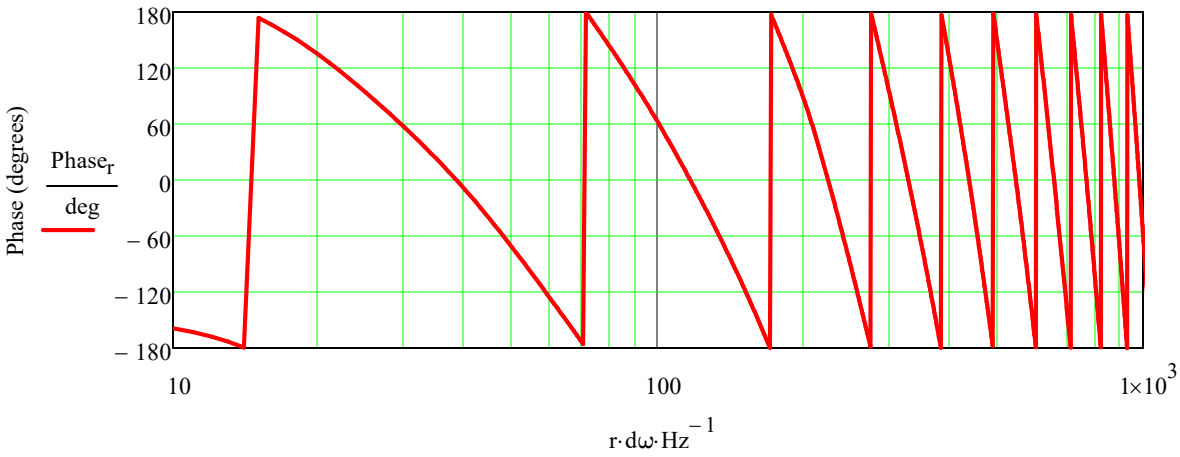


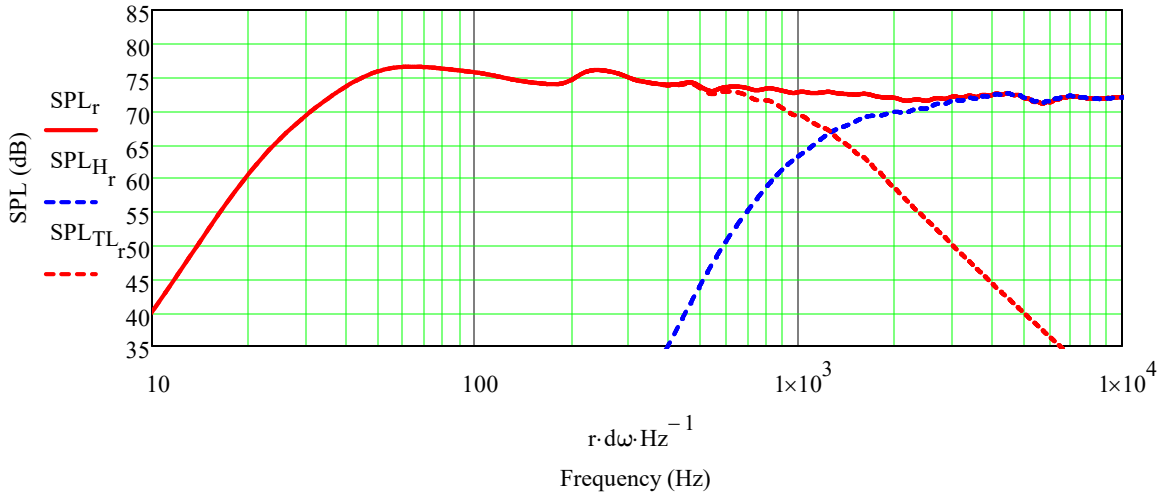
Plotted SPL Response for the Woofer in the TL



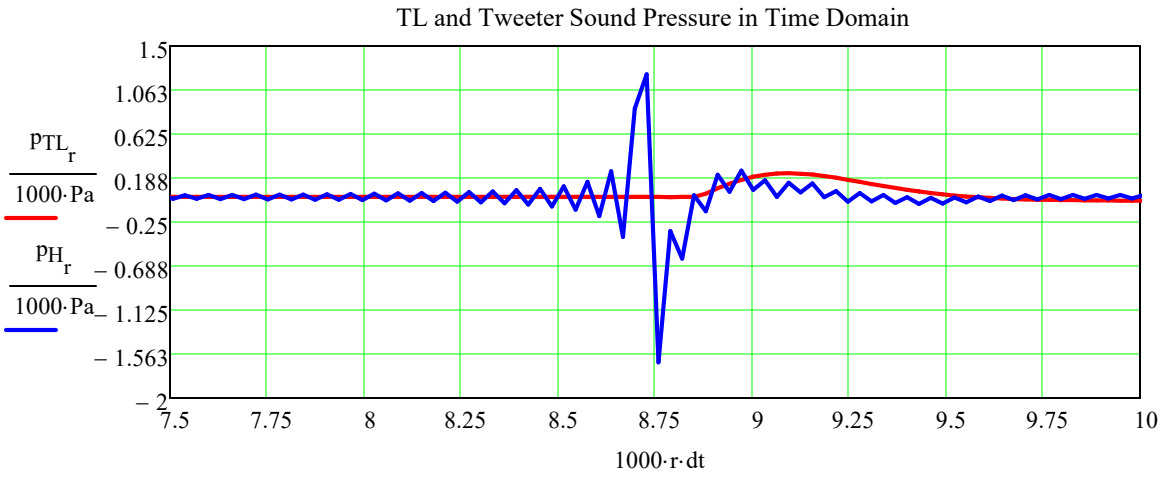


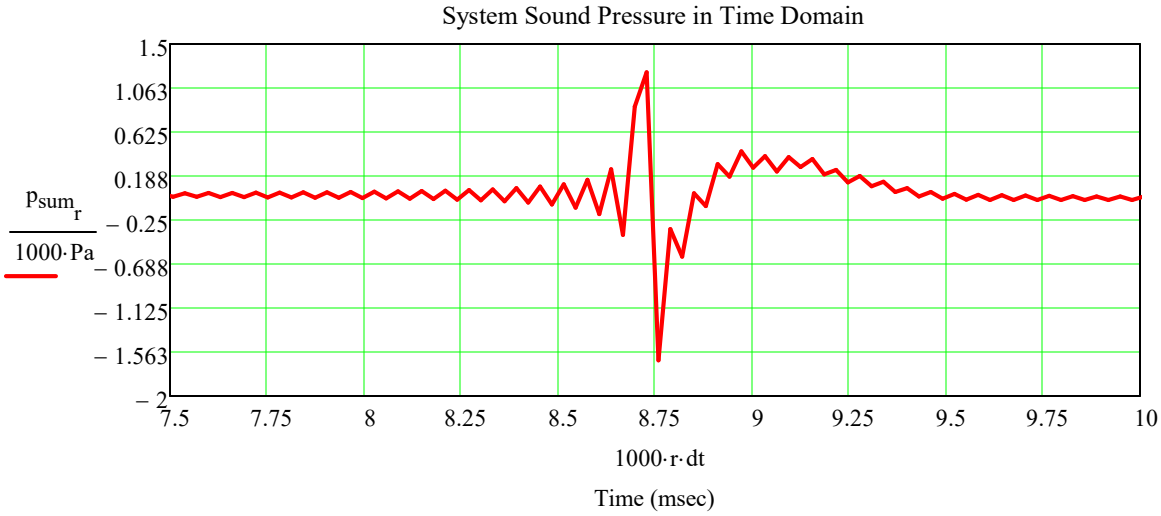
Plotted SPL Response for the System





System Time Response for an Impulse Input





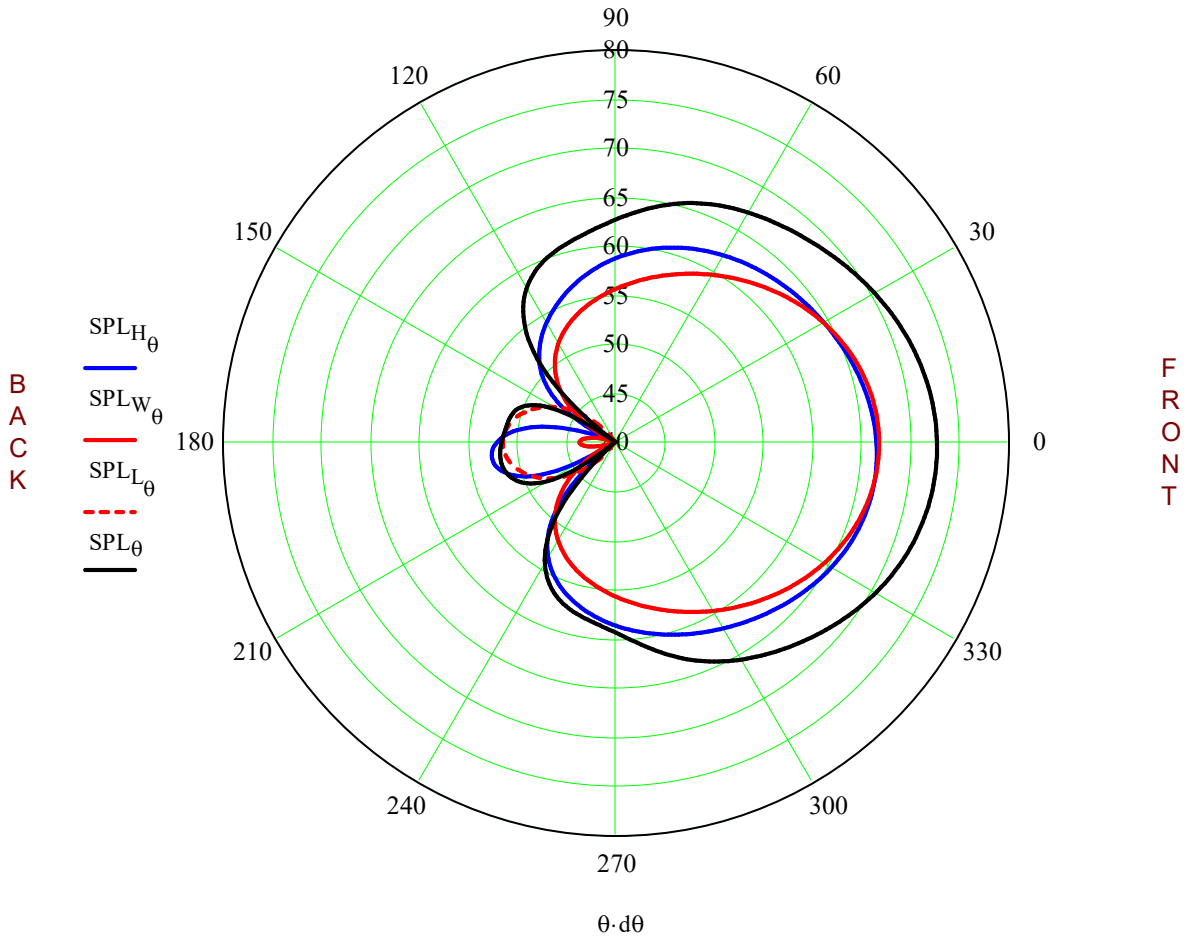
Anechoic Horizontal Polar Response - Free Space

Radius and Frequency Inputs

radius := 3·m (Calculation Radius Along the Driver's Axis)

ω := 1240·Hz (Calculation Frequency : 10 Hz < ω < 10000 Hz where ω must be an Integer Value)

TOP VIEW



Anechoic Vertical Polar Response - Free Space

Radius and Frequency Inputs

radius := 3·m (Calculation Radius Along the Driver's Axis)

ω := 1240·Hz (Calculation Frequency : 10 Hz < ω < 10000 Hz where ω must be an Integer Value)

SIDE VIEW