Two Drivers in a Transmission Line

Manipulating the Waves

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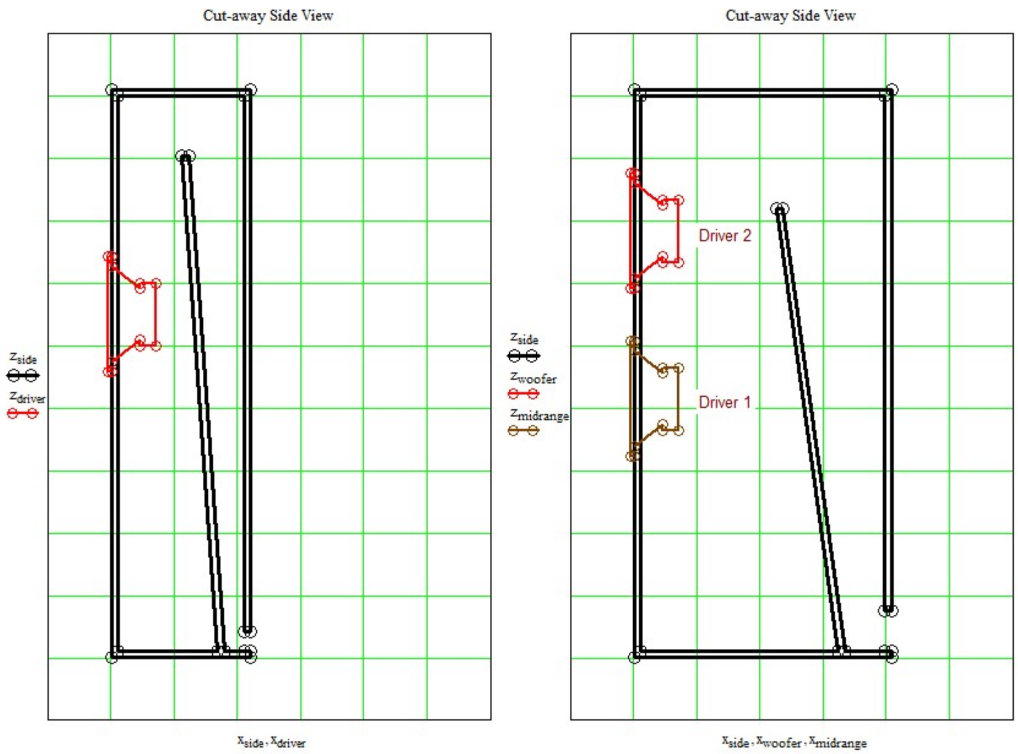
January 24, 2026

Introduction

In the previous presentation, “Modeling Method for Two Drivers in a Transmission Line”, it was noted that modeling two discrete drivers seemed to eliminate/reduce some of the higher frequency peaks and dips seen in the single driver model. This was pointed out on slides 19 and 20 in the presentation. The question becomes, is this real and why did it happen?

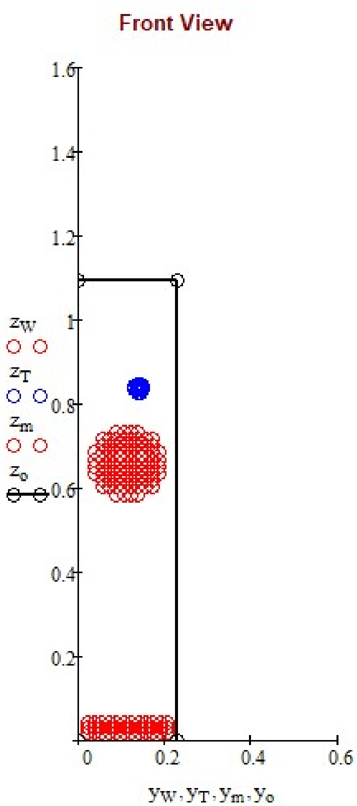
The intent of this presentation is to look a little closer at my latest MathCad models for multiple drivers loading a common acoustic volume and investigate this observation. Understanding why this happens might lead to yet another design tool that can be used to optimize a TL’s low frequency response and eliminate some of the higher frequency standing waves.

Definition of One and Two Woofer TL Speakers

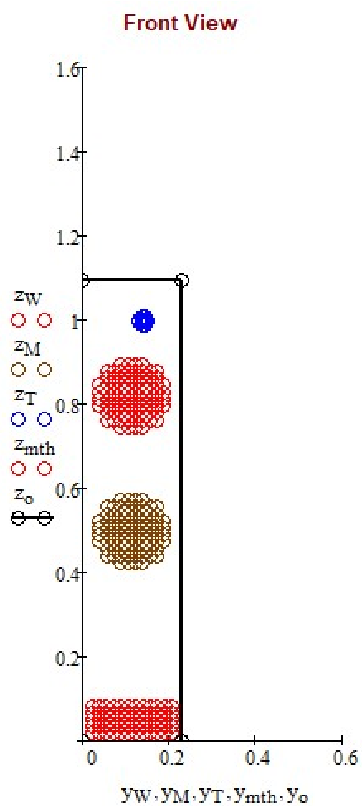


- On the left is a single 8” woofer in a 5:1 tapered transmission line. On the right is a pair of the same 8” woofers in an equivalent 5:1 tapered transmission line.
- For the two-driver enclosure, the tuning frequency (length and profile) is the same while the internal volume doubled. Increasing the volume was accomplished by adding depth while leaving the front baffle dimensions constant.
- The two TL design lengths are approximately equal.
- The single woofer was offset 30% along the length while the average position of the dual woofers was also offset the same 30% along the length.
- No damping material was used in the initial simulations to allow peaks and dips in the acoustic impedance and SPL response plots to be easily observed.
- Both TL speaker systems include a 1” tweeter and an active crossover to complete the design.

Single Woofer

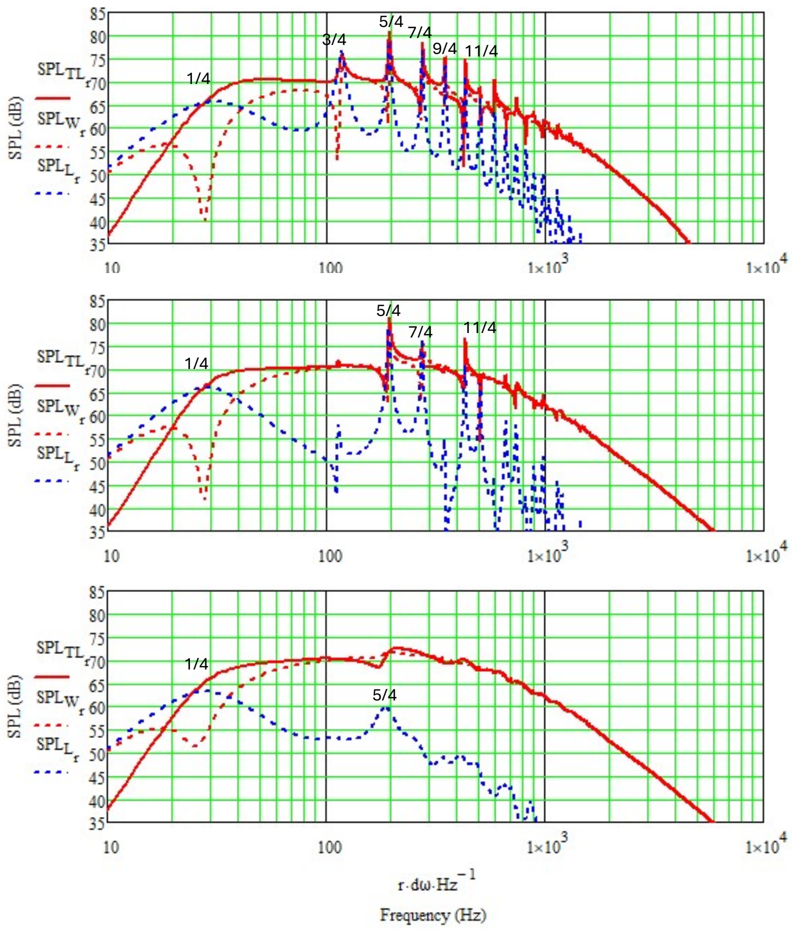


Dual Woofers



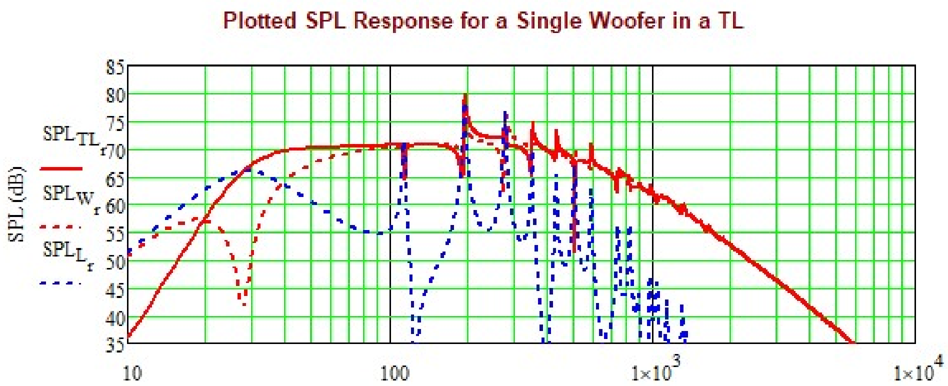
- Front views of the single and dual woofer TL speaker systems are shown on the left.
- Front baffle dimensions are the same.
- The tweeter position on the dual woofer baffle was shifted up to accommodate the second woofer.
- The active crossover properties were the same except for the amount of padding applied to the tweeter, 6 dB less for the dual woofer system.
- The open-end is located on the bottom of the rear baffle for both speakers.
- While the fronts of the two TL speaker systems are very similar, the terminus size and depth location is larger in the dual woofer speaker. This had a minimal impact on the results.
- Comparing the SPL responses for these two speaker systems was a reasonable comparison and a valid indicator of the performance similarities and differences.

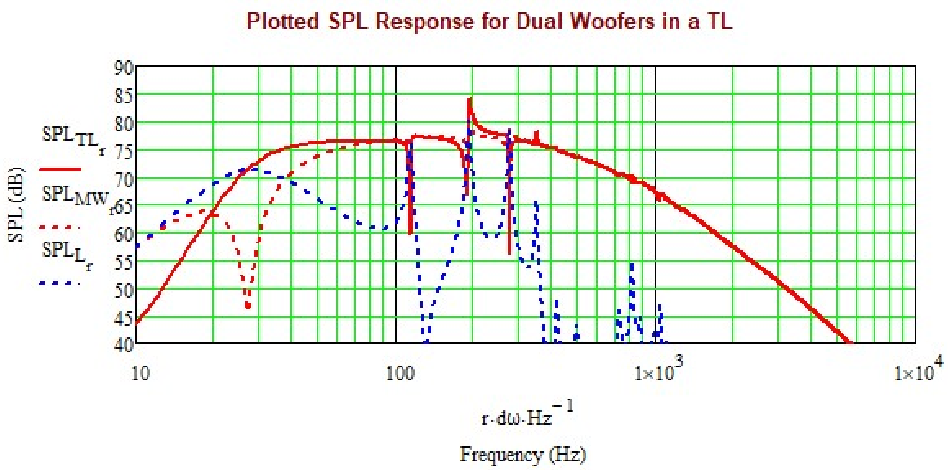
Typical Single Woofer TL Optimization



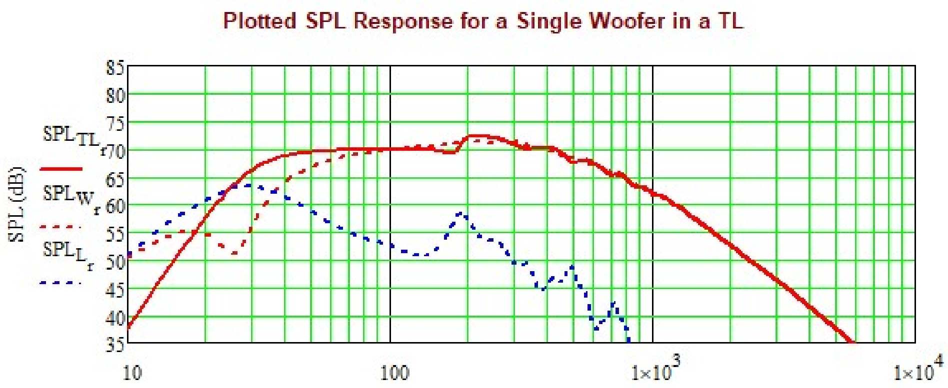
- On the left are the SPL responses of a single woofer in a 5:1 tapered transmission line.
- The typical optimization steps are shown starting from the top plot and progressing down to the bottom plot.
- The top plot locates the woofer at the closed end without any fiber stuffing in the line. This configuration maximizes the excitation of all standing waves. The peaks in the terminus SPL output (blue dashed curve) correspond to the 1/4, 3/4, 5/4, 7/4, 9/4, 11/4 … standing waves.
- In the middle plot, the woofer has been offset to 33% of the TL's length. This woofer position eliminates the 3/4, 9/4, 15/4, … standing waves, every third standing wave.
- And finally in the bottom plot, 0.5 lb/ft^3 of fiber stuffing was added to the first 2/3 of the TL's length. This completes the typical optimization process; all that's left is some minor tweaking. The SPL ripple created by undesirable standing waves has pretty much been brought under control.

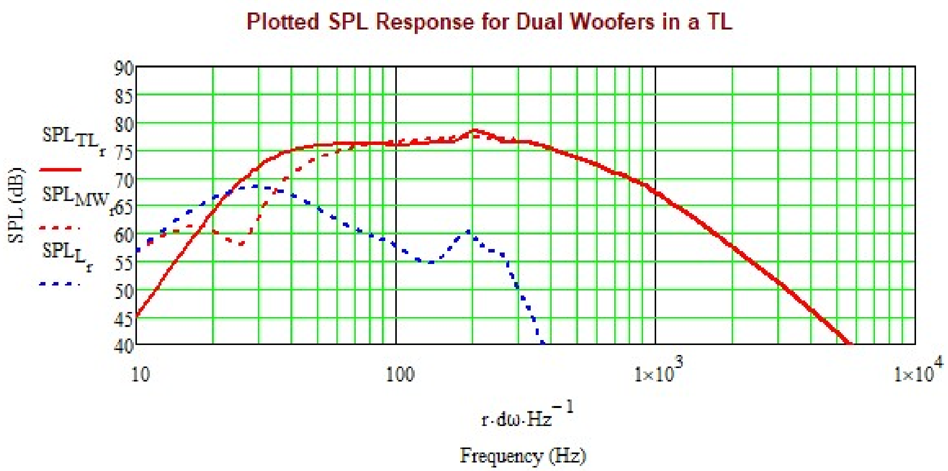
Single and Dual Woofer TL Responses





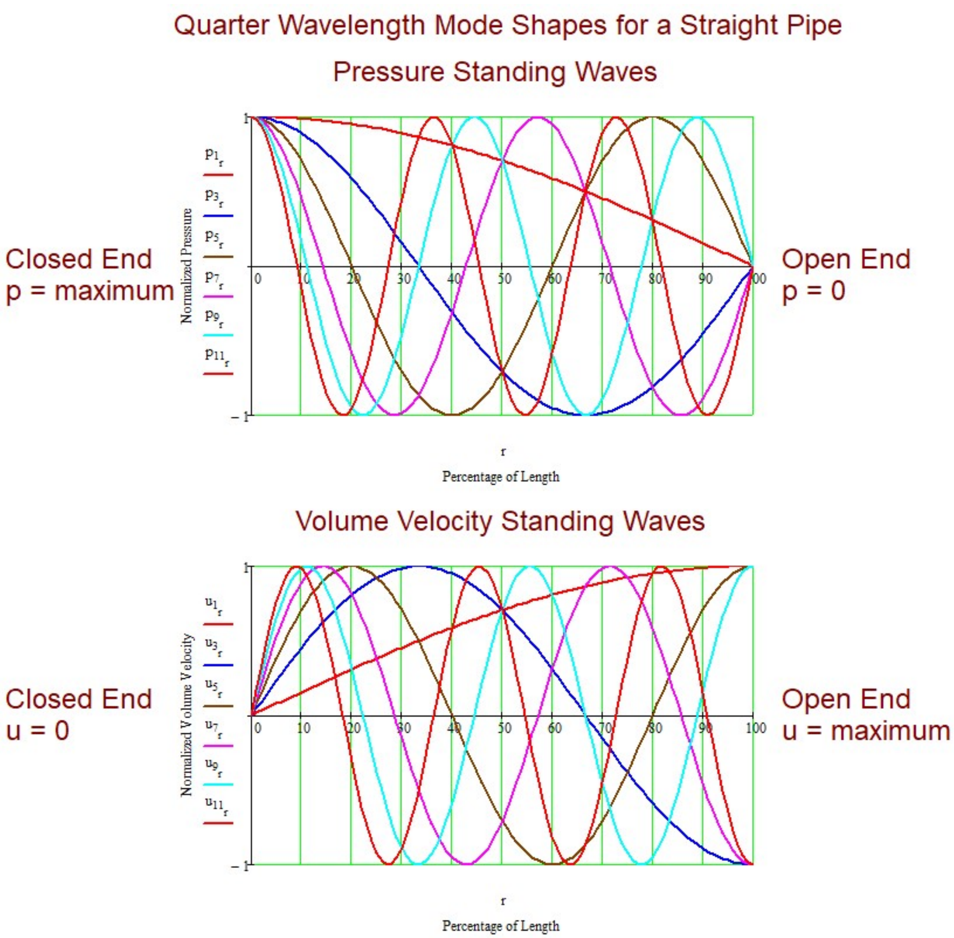
- The TL SPL responses at 3 m are plotted for the single woofer (top plot) and dual woofer (bottom plot) speaker systems shown on slides 3 and 4.
- The simulations do not include any fiber stuffing to damp the standing waves.
- The solid red curves are the summed responses while the dashed red and blue curves are respectively the woofer and terminus responses.
- The results are very similar at low frequencies; the dual woofer SPL is 6 dB higher as expected for two drivers wired in parallel.
- While the SPL responses are similar in shape below 200 Hz, above 200 Hz the dual woofer design has significantly fewer peaks and nulls.



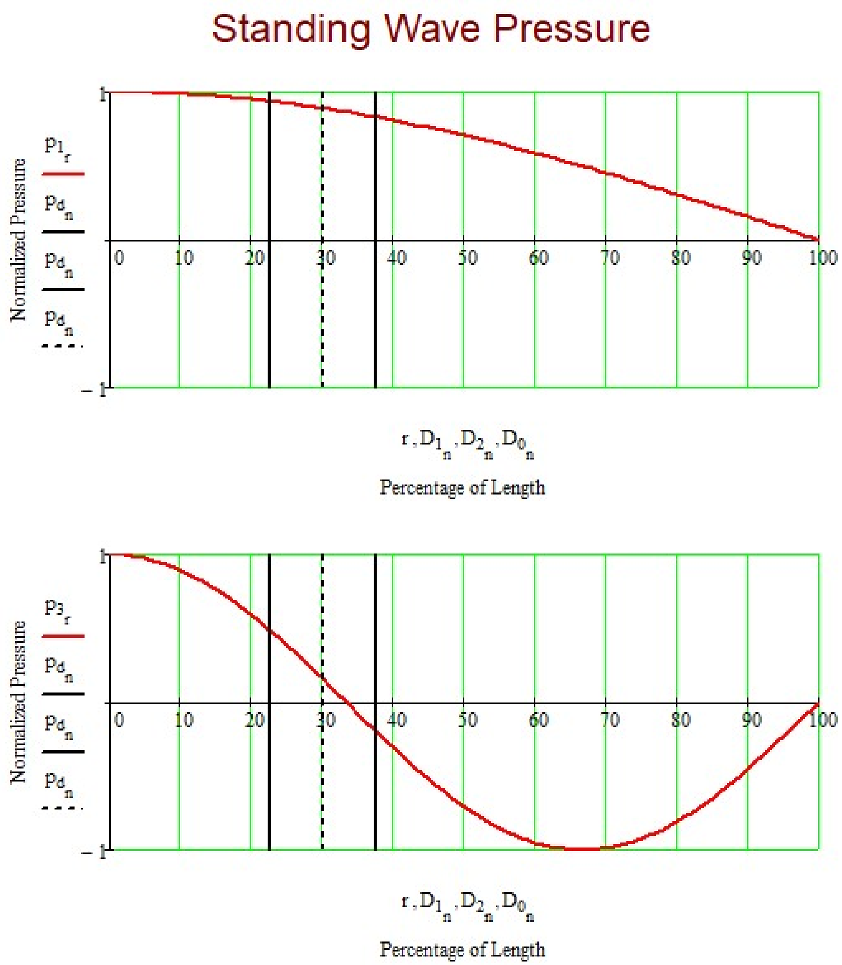


- The TL SPL responses at 3 m are again plotted for the single woofer (top plot) and dual woofer (bottom plot) TL speaker systems but with 0.5 lb/ft^3 of fiber stuffing added.
- The 0.5 lb/ft^3 of fiber stuffing occupies the first 2/3 of the length to damp the higher frequency standing waves.
- The results are again very similar at low frequencies; the dual woofer SPL is 6 dB higher as expected for two drivers wired in parallel.
- While the SPL responses are similar in shape below 200 Hz, above 200 Hz the dual woofer design is still smoother with less ripple.
- The faster roll-off of the terminus output (blue dashed curve) above 200 Hz is easily seen in the dual woofer configuration (lower plot).

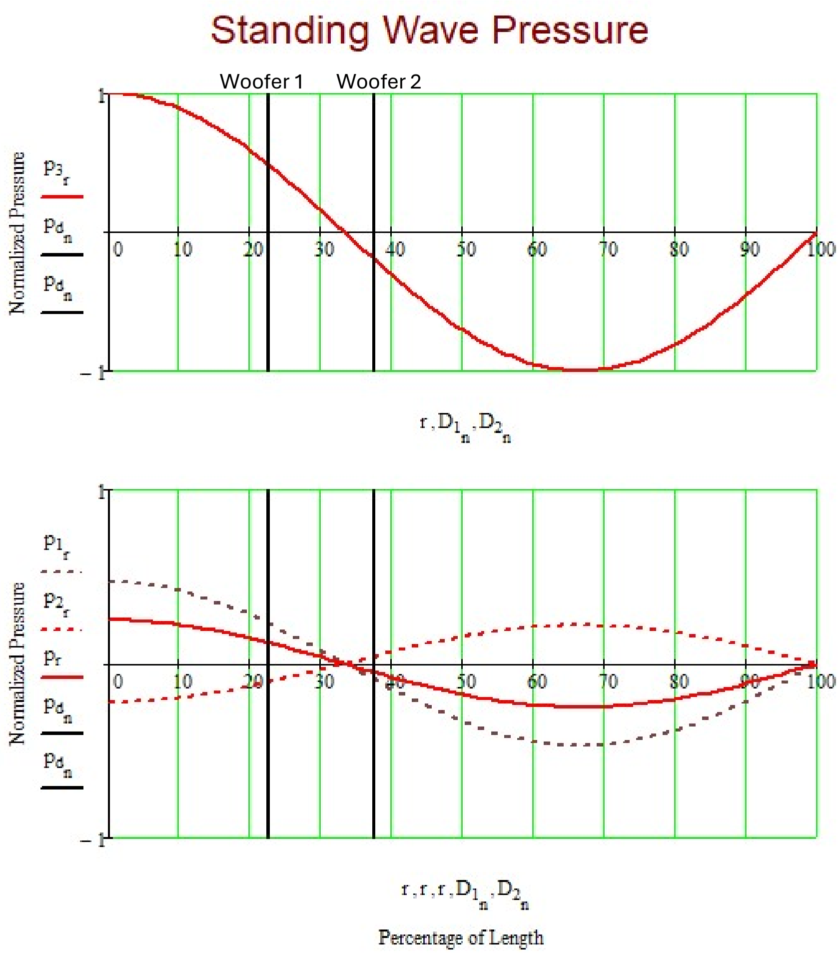
Why does this happen?



- To understand the differences between a single woofer and a pair of woofers located at the same average axial offset, the standing pressure (top) and volume velocity (bottom) profiles are presented in the two plots shown on the left.
- The x axis represents the percentage of TL length while the y axis is normalized to +/- 1.
- A standing wave will not be excited if a woofer is located axially at a zero pressure (maximum volume velocity) location.
- For example, placing the driver at 33% of the length for the 3/4 wave (blue curves) will eliminate it from the response. The blue pressure curve passes though the x axis while the blue volume velocity curve reaches a maximum at this percentage of axial position.
- Maximum excitation and SPL response occurs when the driver is placed at a pressure maximum (zero volume velocity) location like the closed end.
- Plotting individual standing waves along with the woofer's axial positions will be the key to understanding the differences in the terminus response for a single and a dual woofer TL configuration.

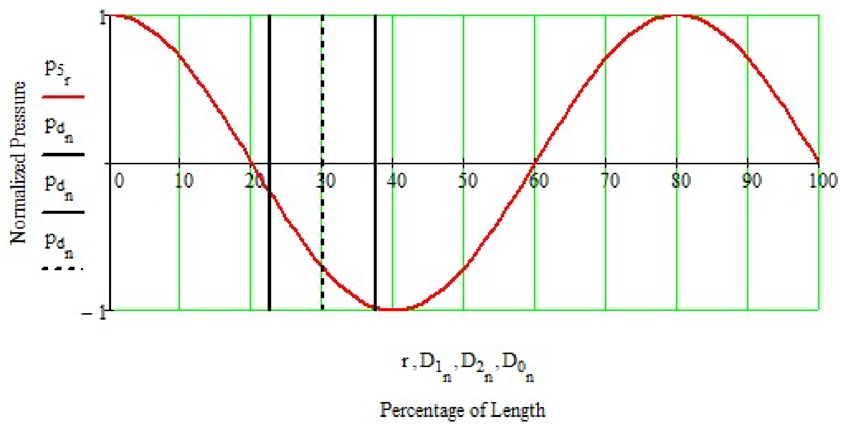


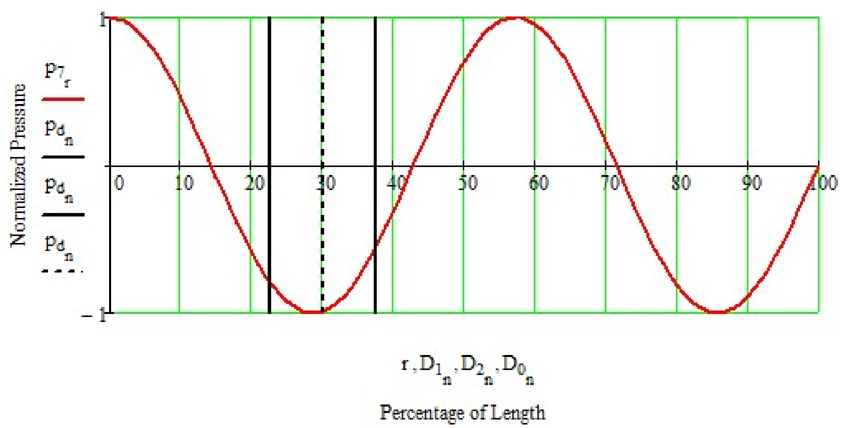
- The top and bottom plots show the 1/4 and 3/4 standing wave pressure profiles. The vertical dashed line is the single woofer axial position while the two solid lines are the dual woofer axial positions.
- For the 1/4 wave all driver positions act on the positive side of the pressure profile. This will generate strong excitation. From the plots in slides 6 and 7 the SPL curve shapes for the two TL configurations are the same around this frequency.
- For the 3/4 wave the single woofer position is near the zero-pressure crossing so this standing wave is weakly excited. The dual woofer positions excite the standing wave on both the positive and negative side of the x-axis which will tend to cancel the excitation, this standing wave is not strongly excited in either system.
- A more detailed look and attempt at explanation is provided on the following slide.



- A simplified explanation is shown in the two plots on the left. This is not 100% accurate but demonstrates the important concepts.
- The top graph is a repeat of the graph on the previous slide for the 3/4 standing wave acted on by the dual woofers.
- The lower graph scales the 3/4 wave at each of the two woofer positions to produce the brown dashed curve for woofer 1 and the dashed red curve for woofer 2. Each driver is assumed to act independently which is not completely correct. Notice that the 3/4 wave phase of woofer 2 is flipped, both woofers move in the same direction so the pressure on the back of each driver's cone should have the same sign.
- The solid red curve is the sum of the two woofer responses.
- Having the woofers acting on opposite sides of the x axis causes the response from one woofer to work against the response from the other woofer. The combined response is lowered if not almost completely attenuated.

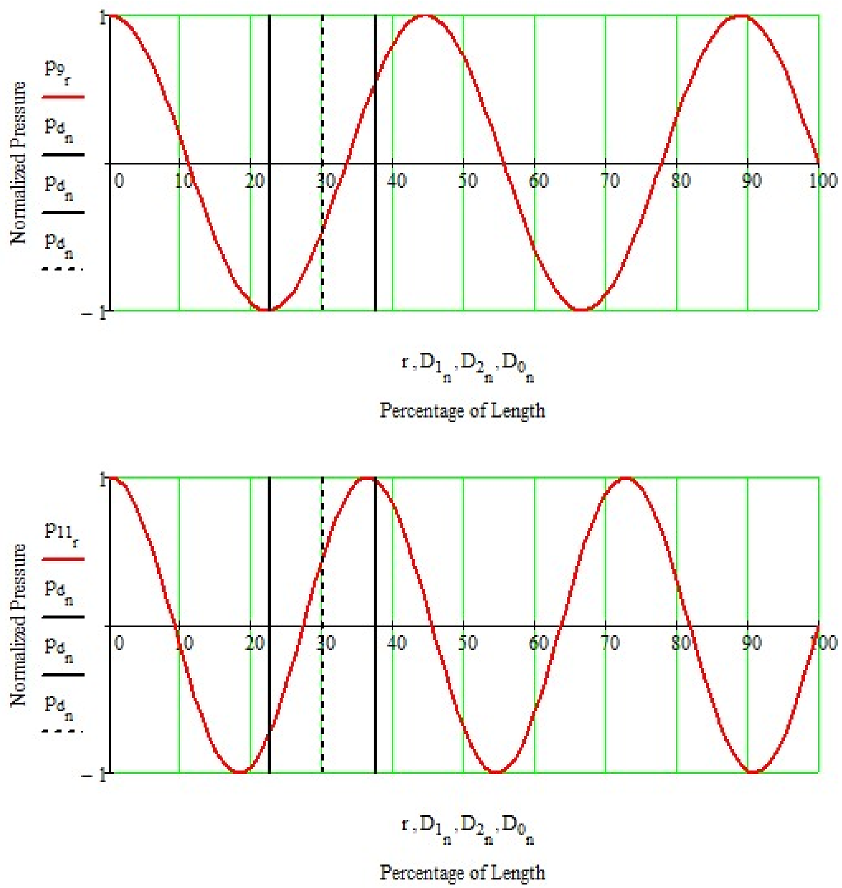
Standing Wave Pressure





- The top and bottom plots show the 5/4 and 7/4 standing wave pressure profiles, respectively.
- For both the 5/4 and 7/4 standing waves all woofer positions act on the negative side of the pressure profile. This will maximize the excitation. In the plots on slide 6, the SPL curve for both woofer configurations are similar around these standing wave frequencies.
- Both standing waves are strongly excited and are easily seen in the empty TL response plots shown on slide 6.

Standing Wave Pressure



- The top and bottom plots show the 9/4 and 11/4 standing wave pressure profiles.
- For both the 9/4 and 11/4 standing waves the single woofer will excite both standing waves but not strongly.
- For the dual woofer configuration, the woofers are far enough apart to act on the negative and the positive sides of the pressure profiles essentially cancelling any excitation of the standing waves. This will minimize the excitation and from the plots in slide 6 the SPL curve for the dual woofer configuration confirms that these modes have been mitigated.
- Both modes are weakly excited by the single woofer, and the excitation is essentially eliminated by the dual woofer configuration.

Take Aways

- The intent of this presentation was to examine in more depth the results obtained modeling two drivers sharing the same TL acoustic volume.
- The improvement in controlling the higher order quester-wave modes had been pointed out in the previous presentation and an explanation has been provided in the previous slides.
- Using two woofers, or two mid-woofers, in a TL design is another tool for controlling the higher order standing waves and associated ripple in the SPL response without resorting to damping materials and the associated loss of bass output.
- While the original approach of modeling dual woofers as a single equivalent woofer works at the tuning frequency, manipulating the enclosure's folded geometry to position a pair of woofers to manipulate the standing waves can maximize this benefit may be the next step forward in the TL design process.