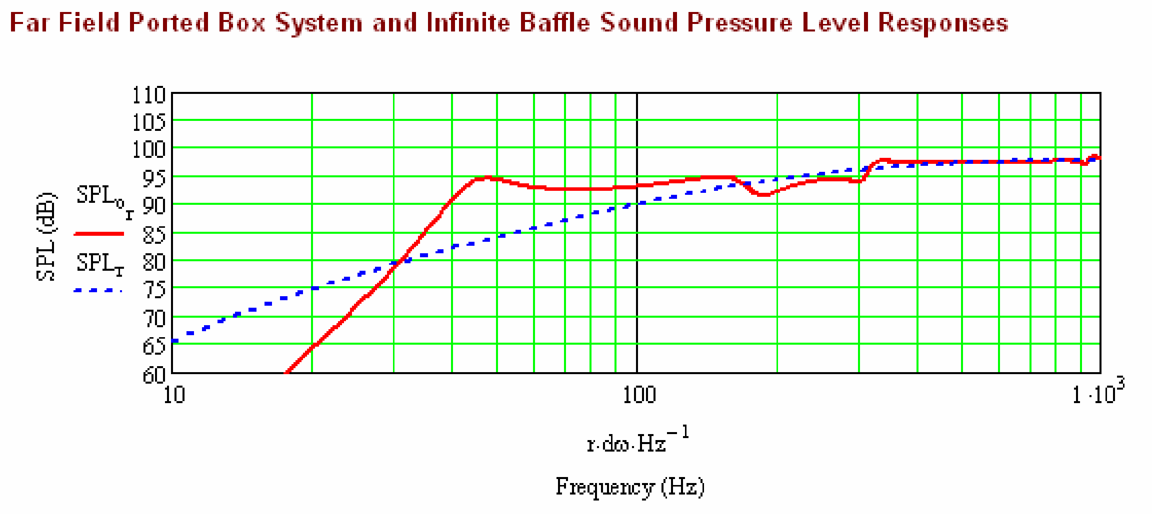
Using the New MathCad Worksheets to Diagnose SPL Response Curves
By Martin J. King, 7/05/06

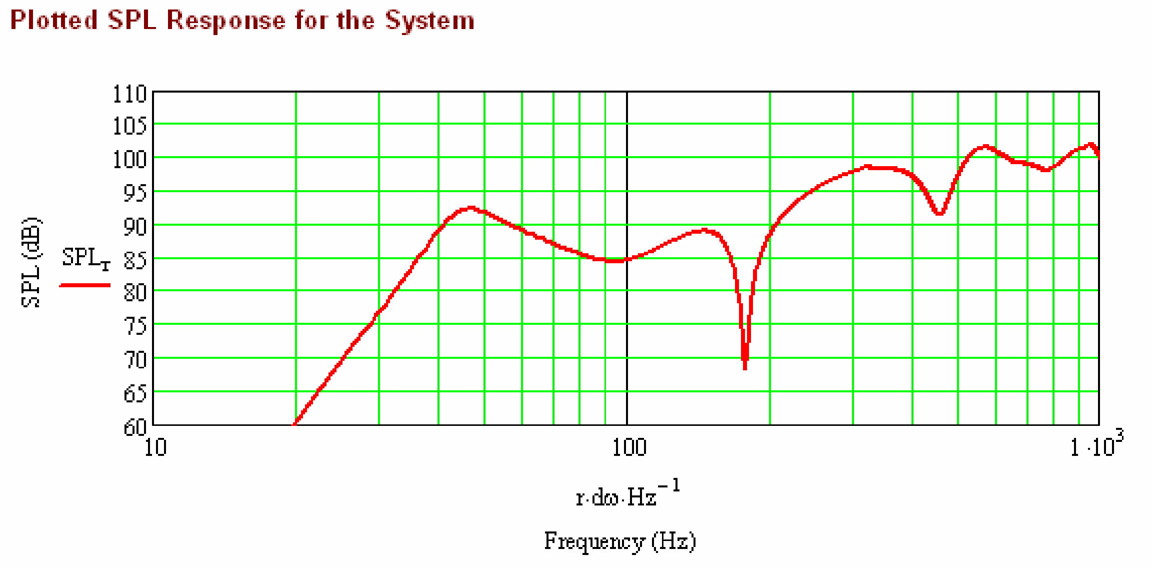
Introduction :

The latest MathCad worksheets retain most of the original calculations from the earlier versions but add the influence of the enclosure geometry and two room reflections. The additional calculations take into account the relative positions of the driver and the terminus/port, the size and shape of the front baffle, and the distance to the floor and rear wall. By adding these more detailed calculations, the response is no longer as smooth and can exhibit multiple peaks and nulls.

Figure 1 compares the original lumped parameter model result in the upper plot, where the driver and terminus/port are assumed to be mounted coincident on an infinite baffle, and the new calculated result in the lower plot that includes the enclosure geometry. The top plot is typical of results obtained with various freeware speaker design packages. So what causes some of these dramatic differences? Some of the answers follow along with a short discussion.

Figure 1 : ML TL Calculated Responses


Far Field Ported Box System and Infinite Baffle Sound Pressure Level Responses


Plotted SPL Response for the System

Discussion :

There are now two versions of a couple of the updated MathCad worksheets. The first one treats the enclosure as a floor standing tower while the second assumes the enclosure is mounted on a stand some specified distance above the floor. By using the ported box versions of these worksheets, I will add and remove different geometric influences to study the impact on the final system SPL response for my Lowther ML TL design. In all of these plots, a correction circuit has not been applied to balance the SPL results.

Before going too far, the first step is to reproduce the infinite baffle response by setting the enclosure geometry and the distances to the room boundaries large enough to simulate an infinite baffle while making the driver and port coincident. Figure 2 shows the geometry entered into the stand mounted ported box worksheet and the calculated SPL response. Comparing the response in Figure 2 with the upper curve in Figure 1 verifies that the infinite baffle result has been reproduced.

The next step is to position the driver and the port on the infinite baffle to assess how this non coincident geometry impacts the SPL response curve. Figure 3 includes the geometry used in the stand mounted worksheet and the new calculated SPL response. The small peak originally at 40 Hz is attenuated slightly due to the additional distance the contribution from the port must travel to the listening position. Also, a null just below 200 Hz appears where the port and driver contributions arrive at the listening out of phase.

The baffle geometry was added into the stand mounted calculation as shown in Figure 4. The baffle geometry introduces the baffle step phenomenon into the SPL response and can be seen as a rising response above 200 Hz. The response below 200 Hz is depressed an additional 6 dB since the speaker system is now radiating into 4π space at low frequencies. This effect is typically not calculated by most freeware speaker design packages and is the cause of unexpectedly weak bass output from some inexperienced DIYer’s first projects.

In Figure 5, the floor is added into the response by using the floor standing ported box worksheet. The floor reflections accentuate the null just below 200 Hz by effectively increasing the port output, you should visualize a mirror image of the driver, the port, and the front baffle below the floor all adding to the summed SPL response at the listening position. A second set of artifacts produced by floor reflections (sometimes referred to as floor bounce) can be seen as a series of rolling peaks and shallow nulls starting above 400 Hz.

Finally, in Figure 6 the rear wall influence is added back into the simulation to produce an identical SPL response curve to what was already seen in the lower plot in Figure 1. Reflections from the rear wall typically appear below the baffle step frequency, in this case below 200 Hz, and produce an additional series of rolling peaks and shallow nulls similar to the floor reflections above 400 Hz.

Using the New MathCad Worksheets to Diagnose SPL Response Curves
By Martin J. King, 7/05/06

Figure 2 : Stand Mounted Result to Check for the Infinite Baffle Solution

Enclosure Geometry Input

$width := 100\cdot m$ (Front Baffle Width)

$height := 100\cdot m$ (Front Baffle Height)

$depth := 100\cdot m$ (Depth of Enclosure)

$dist := 100\cdot m$ (Front Baffle Distance from Rear Wall > Depth, to Eliminate Rear Wall use 100 m)

$stand := 100\cdot m$ (Height from Floor to Bottom Edge of Front Baffle, to Elimnate Floor use 100 m)

$num\_r := 9$ (Number of Points per Quadrant of Baffle Edge)

Driver Geometry Input

$x_{dc} := 50\cdot m$ (Driver Center x Coordinate)

$y_{dc} := 50\cdot m$ (Driver Center y Coordinate)

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

Port Geometry Input

$x_{mc} := 50\cdot m$ (Port Center x Coordinate)

$y_{mc} := 50\cdot m$ (Port Center y Coordinate)

$n\_mth := 4$ (Number of Points Across Diameter)

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

Plotted SPL Response for the System

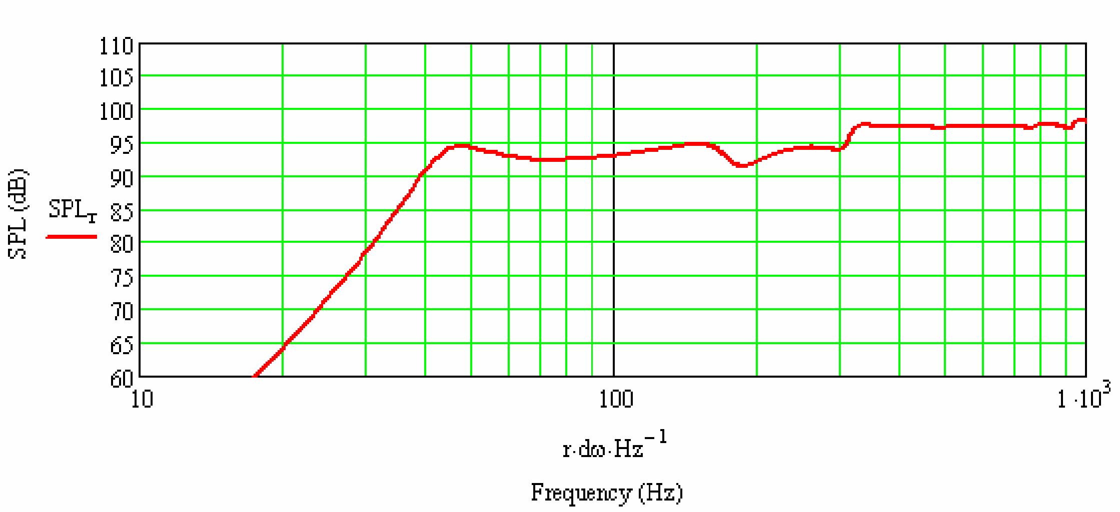
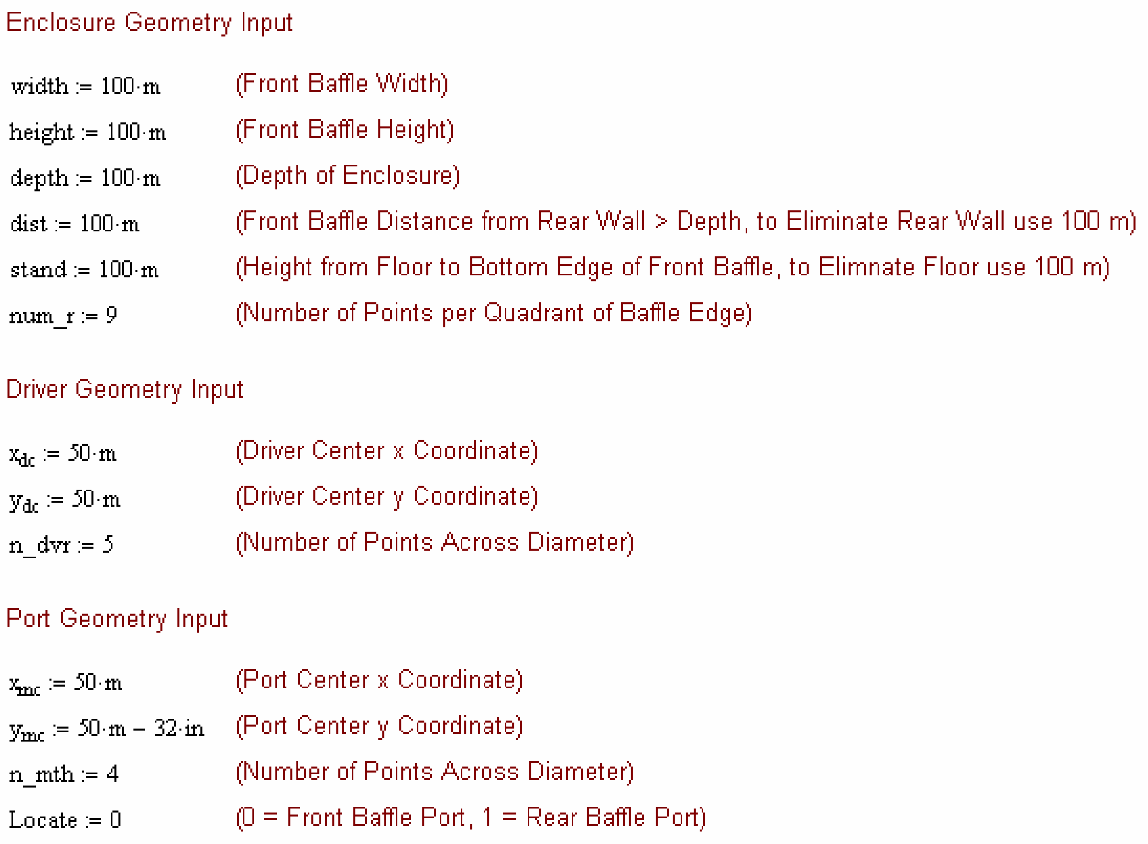


Figure 3 : Stand Mounted Result with Driver and Port Relative Positions Added



Enclosure Geometry Input

$width := 100 \cdot m$	(Front Baffle Width)
$height := 100 \cdot m$	(Front Baffle Height)
$depth := 100 \cdot m$	(Depth of Enclosure)
$dist := 100 \cdot m$	(Front Baffle Distance from Rear Wall > Depth, to Eliminate Rear Wall use 100 m)
$stand := 100 \cdot m$	(Height from Floor to Bottom Edge of Front Baffle, to Elimnate Floor use 100 m)
$num\_r := 9$	(Number of Points per Quadrant of Baffle Edge)

Driver Geometry Input

$x_{dc} := 50 \cdot m$	(Driver Center x Coordinate)
$y_{dc} := 50 \cdot m$	(Driver Center y Coordinate)
$n\_dvr := 5$	(Number of Points Across Diameter)

Port Geometry Input

$x_{mc} := 50 \cdot m$	(Port Center x Coordinate)
$y_{mc} := 50 \cdot m - 32 \cdot in$	(Port Center y Coordinate)
$n\_mth := 4$	(Number of Points Across Diameter)
$Locate := 0$	(0 = Front Baffle Port, 1 = Rear Baffle Port)

Plotted SPL Response for the System

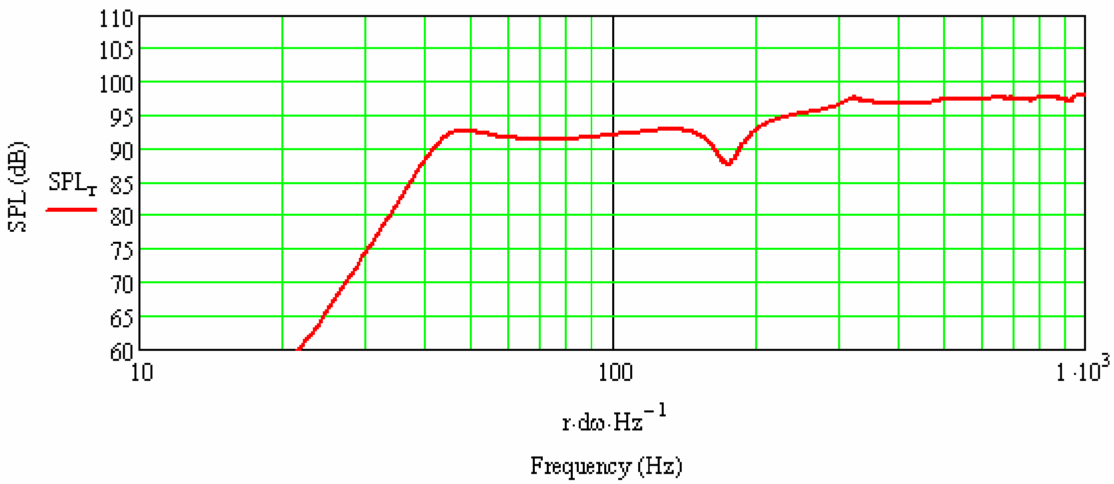


Figure 4 : Stand Mounted Result with Baffle Geometry Added

Enclosure Geometry Input

$width := 11 \cdot in$ (Front Baffle Width)
$height := 43.5 \cdot in$ (Front Baffle Height)
$depth := 100 \cdot m$ (Depth of Enclosure)
$dist := 100 \cdot m$ (Front Baffle Distance from Rear Wall > Depth, to Eliminate Rear Wall use 100 m)
$stand := 100 \cdot m$ (Height from Floor to Bottom Edge of Front Baffle, to Elimnate Floor use 100 m)
$num\_r := 9$ (Number of Points per Quadrant of Baffle Edge)

Driver Geometry Input

$x_{dc} := 5.5 \cdot in$ (Driver Center x Coordinate)
$y_{dc} := 36.75 \cdot in$ (Driver Center y Coordinate)
$n\_dvr := 5$ (Number of Points Across Diameter)

Port Geometry Input

$x_{mc} := 5.5 \cdot in$ (Port Center x Coordinate)
$y_{mc} := 4.75 \cdot in$ (Port Center y Coordinate)
$n\_mth := 4$ (Number of Points Across Diameter)
$Locate := 0$ (0 = Front Baffle Port, 1 = Rear Baffle Port)

Plotted SPL Response for the System

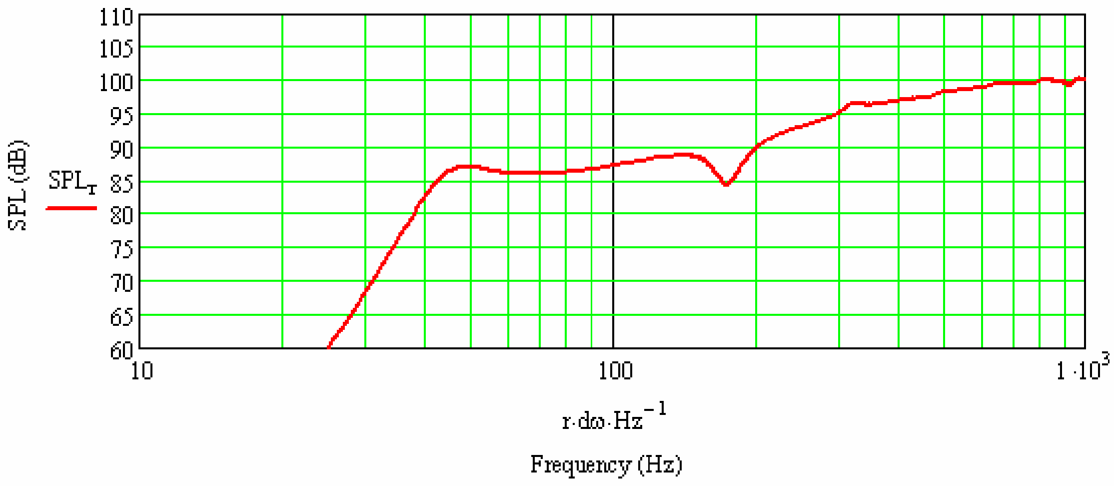


Figure 5: Floor Standing Result without Rear Wall

Enclosure Geometry Input

width := 11·in (Front Baffle Width)

height := 43.5·in (Front Baffle Height)

depth := 13.5·in (Depth of Enclosure)

dist := 100·m (Front Baffle Distance from Rear Wall > Depth, to Eliminate Rear Wall use 100 m)

num_r := 9 (Number of Points per Quadrant of Baffle Edge)

Driver Geometry Input

$x_{dc} := 5.5\cdot in$ (Driver Center x Coordinate)

$y_{dc} := 36.75\cdot in$ (Driver Center y Coordinate)

n_dvr := 5 (Number of Points Across Diameter)

Port Geometry Input

$x_{mc} := 5.5\cdot in$ (Port Center x Coordinate)

$y_{mc} := 4.75\cdot in$ (Port Center y Coordinate)

n_mth := 4 (Number of Points Across Diameter)

Locate := 0 (0 = Front Baffle Port, 1 = Rear Baffle Port)

Plotted SPL Response for the System

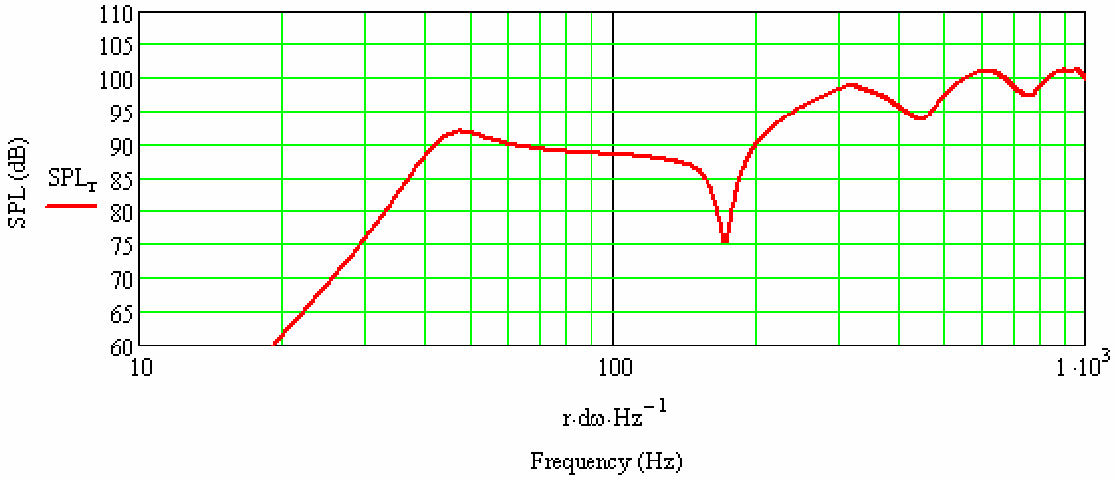


Figure 6 : Floor Standing Result with Rear Wall Added

Enclosure Geometry Input

$width := 11\cdot in$ (Front Baffle Width)

$height := 43.5\cdot in$ (Front Baffle Height)

$depth := 13.5\cdot in$ (Depth of Enclosure)

$dist := 32\cdot in$ (Front Baffle Distance from Rear Wall > Depth, to Eliminate Rear Wall use 100 m)

$num\_r := 9$ (Number of Points per Quadrant of Baffle Edge)

Driver Geometry Input

$x_{dc} := 5.5\cdot in$ (Driver Center x Coordinate)

$y_{dc} := 36.75\cdot in$ (Driver Center y Coordinate)

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

Port Geometry Input

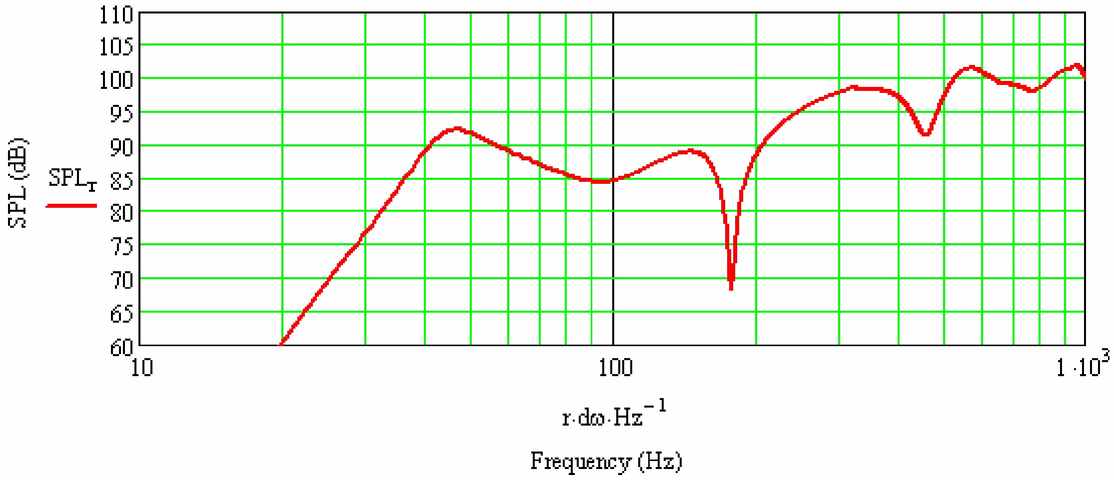
$x_{mc} := 5.5\cdot in$ (Port Center x Coordinate)

$y_{mc} := 4.75\cdot in$ (Port Center y Coordinate)

$n\_mth := 4$ (Number of Points Across Diameter)

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

Plotted SPL Response for the System



Conclusions :

At this point, I have hopefully identified the sources for the somewhat ragged response seen in the lower plot in Figure 1 and the contributors that are typically not accounted for but can influence the simulation that produced the nice smooth curve in the upper plot in Figure 1. If I had used the newer worksheets when I originally designed my Lowther ML TL, I would have had the advantage of diagnosing some of the response irregularities and possibly changing the design slightly to mitigate some of the peaks and nulls.

One other interesting outcome from this study is that the Lowther ML TL speaker design sounds very good and people who have built it, or the Fostex version, have provided very positive feedback despite this irregular SPL response. I have to conclude that these calculated response problems do not seem to ruin the system performance. As I work more and more with the new versions of the MathCad worksheets, the less I am concerned with obtaining a ruler flat calculated SPL response because I doubt it is achievable. So when I see DIYers sweating bullets over small wiggles in the SPL response they have calculated, with some other design program, I have to wonder if they are fooling themselves by unknowingly excluding the influences of the speaker geometry and the room boundaries. The combination of the floor standing and the stand mounted Mathcad worksheets is a powerful tool that can be used to further optimize the layout of your speaker design.