I don’t have any measurement equipment, how can I get started designing speakers without it?

Reid Towsley - Sept 30, 2021

Revision History:

Date	**Description**
Sept 30, 2021	Initial Release
Nov 8, 2021	Added clarity of recommendation for real measurements

Let's assume you have manufacturer data, and the manufacturer has measured on an infinite baffle, so the response is truly a 2pi response, or "half space". If the frequency response data you have was measured on a baffle (non-infinite), there are a few more steps involved. See appendix A for additional steps for non-infinite baffle data.

For woofers and mid-bass drivers, following the steps below will process the manufacturer data to align with a response that is representative of our specific cabinet design. The manufacturer data will be processed to include some off-axis information, as well as the cabinet model.

For tweeters, There is no cabinet to model as the tweeter includes a chamber from the factory (usually). Only step 1 and 4 need to be completed for tweeters. Make note of step 4, as this process only applies to normal tweeters with flat face plates. Horns and wave-guides cannot be simulated using these tools.

It’s important to understand the limitations of this process. Mathematical simulations are not perfect, so there is some uncertainty in the accuracy of these results. Manufacturer data is often inaccurate. Diffraction models have accuracy limitations, as well any off-axis simulation here operates based on a “piston model”, assuming the driver is a perfect piston, which it of course isn’t, so the simulation is lacking the complex breakup behaviours of the driver. Additionally, the frequency response tracing process creates a minimum phase approximation, so acoustic delays between multiple drivers cannot be determined. You may make some assumptions of acoustic delay by observing the differences in driver depth, using the point where the cone meets the voice coil as the reference point. For all of these reasons, **it is not recommended to use this simulated data for design, but rather this process in intended to help provide an understanding of the acoustic principles and response processing process**. Measuring the drivers in the intended cabinet with a 2 channel measurement system is always the recommended process for design. Read the VituixCAD help file “How to start working with VituixCAD”, which includes links to measurement process for ARTA, REW, and SoundEasy.

Step 1 - Tracing the manufacturer data

VituixCAD includes a tracing tool that we can use to create the data sets we need. With the manufacturer's PDF open, the simplest method is to us the Windows snipping tool. Simply press Windows Key + Shift + S, then draw a box around the chart.

In VituixCAD, go to tools -> SPL Trace. Then under the edit menu, select paste. The tool is fairly straight forward from there, you simply mark some low and high known reference points on the image for the X and Y axis. For SPL charts, the y axis amplitudes are on the left, for impedance, the y axis amplitude is on the right. Then simply click the trace button, then on the line to trace it. If the image is black and white, you may need to erase some grid lines around the plot line for the tracing feature to succeed.

Figure 1 Trace Example

Once you have traces each SPL and impedance, simply export the result.

Step 2 - Cabinet model

For this simulation process, we will treat the cabinet model as our "near field" measurement. Start by opening the enclosure tool, create a new driver and enter the T/S Parameters.

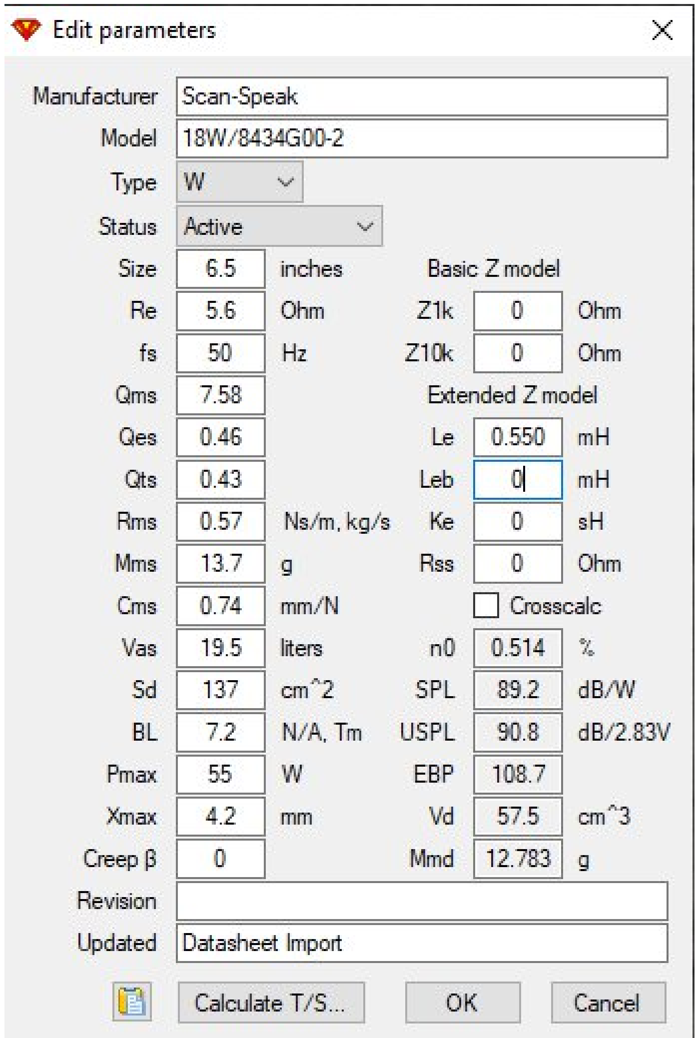

Figure 2 T/S Parameters Example

We can take the driver parameters a step further and use the traced impedance to determine a extended Z model for more accurate representation of the driver impedance in simulation. Select “Calculate T/S”, then load the traced impedance file under “Free air impedance response”. Provided that you have entered all the other T/S parameters already, simply press the “solve” button under the Extended Z model section. You will see a trace that should overlap the loaded impedance with a high degree of accuracy. Pressing the solve button a few times may achieve a slightly better result.

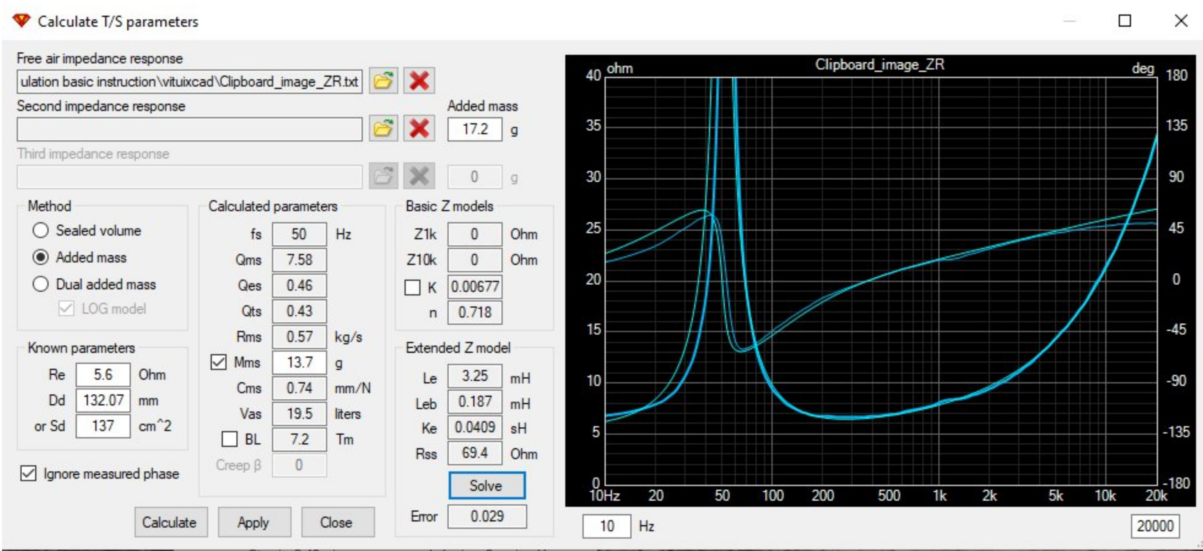

Figure 3 Extended Z model calculation

To use the extended inductance model in simulation, simply right click on the SPL chart and select “show effect of inductance”.

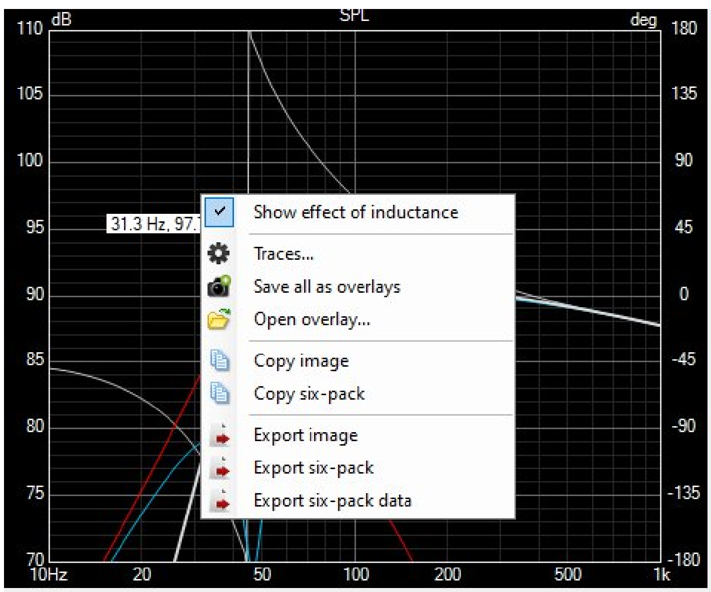

Figure 4 Show effect of inductance

When your cabinet model is complete, ensure the cabinet simulation is set to 2.83V, then export the SPL to file.

Step 3 - Cabinet diffraction

The cabinet model includes “half space” data similar to a near-field measurement. To represent this as full space data, we must include the diffraction model of the speaker cabinet.

Open the diffraction tool in VituixCAD and enter the cabinet dimensions and driver size. The radiating surface area Sd specification is best used here, otherwise measure the radiating diameter as the cone diameter plus half of the surround diameter.

Place the mic in front of the speaker, and export the result

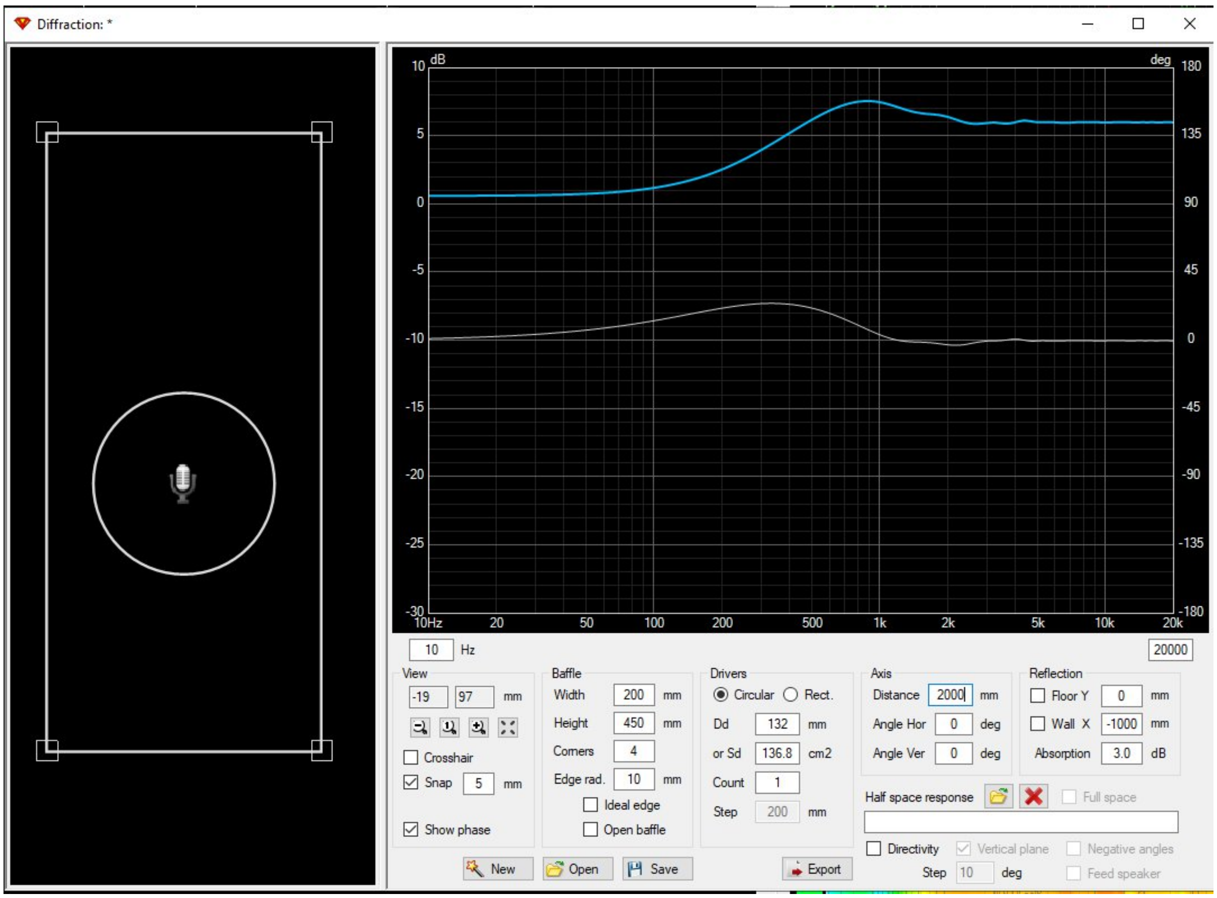

Figure 5 Cabinet diffraction simulation

Step 4 - Processing the traced frequency response

The frequency response that was traced in step 1 includes only a single axis of data, and is a half space measurement. The goal is to utilize this data to simulate the result in our designed cabinet. The diffraction tool can be used to process the measurement, applying the diffraction simulation in incremental steps at all angles. The limitation of this process is that the off-axis data includes the diffraction only, and the driver is simulated as a piston. For cone drivers, this means the complex cone breakup behaviour off-axis is not captured. As well, this simulation will not result in accurate data for horns or wave-guides.

With the diffraction simulation still open from Step 3, open the traced response under the “half space response” section. Check the “full space” box to include the measured data in the simulation. Check the box for “directivity” and “vertical plane” to export the off-axis data in incremental steps (10 degrees by default). Export the result as “far field” data.

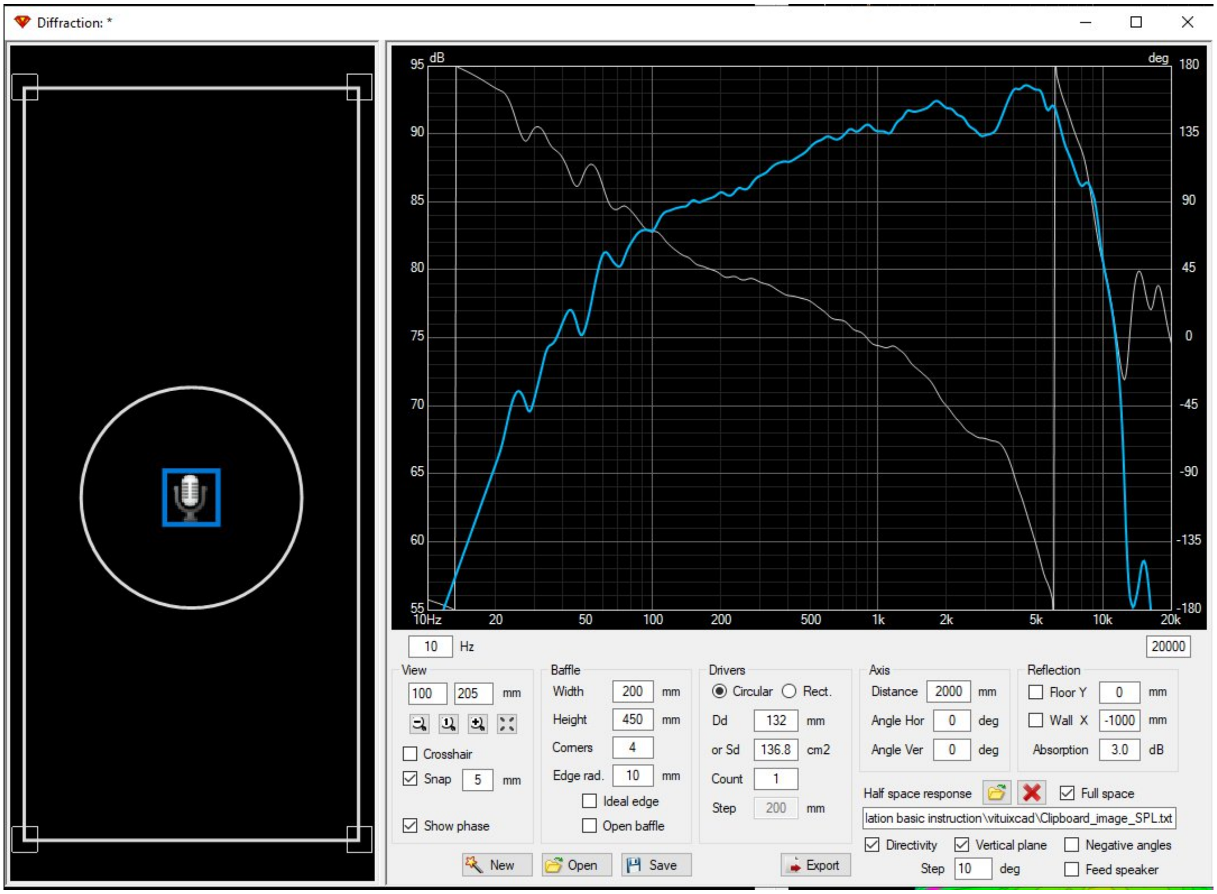

Figure 6 Half space measurement with diffraction applied

Step 5 - Combining it all together

Use the merger tool for this task. It combines low frequency data with high frequency data to generate a single set of frequency responses. In this case, the cabinet model is the low frequency component, and the Diffraction directivity data is the high frequency component.

Open the merger tool.

- Open the cabinet model response from step 2 as the low frequency part.
- Select “Diffraction response” and load the cabinet diffraction response that was exported in step 3.
- Last, open all the “full space” responses that were exported in step 4 as the high frequency part.

Adjust the Scale so that the near field response overlaps the far field curve. You should see good agreement around 200-400Hz. Select the transition frequency at the lower end of where the frequency response overlaps. Save the merged resulting response set.

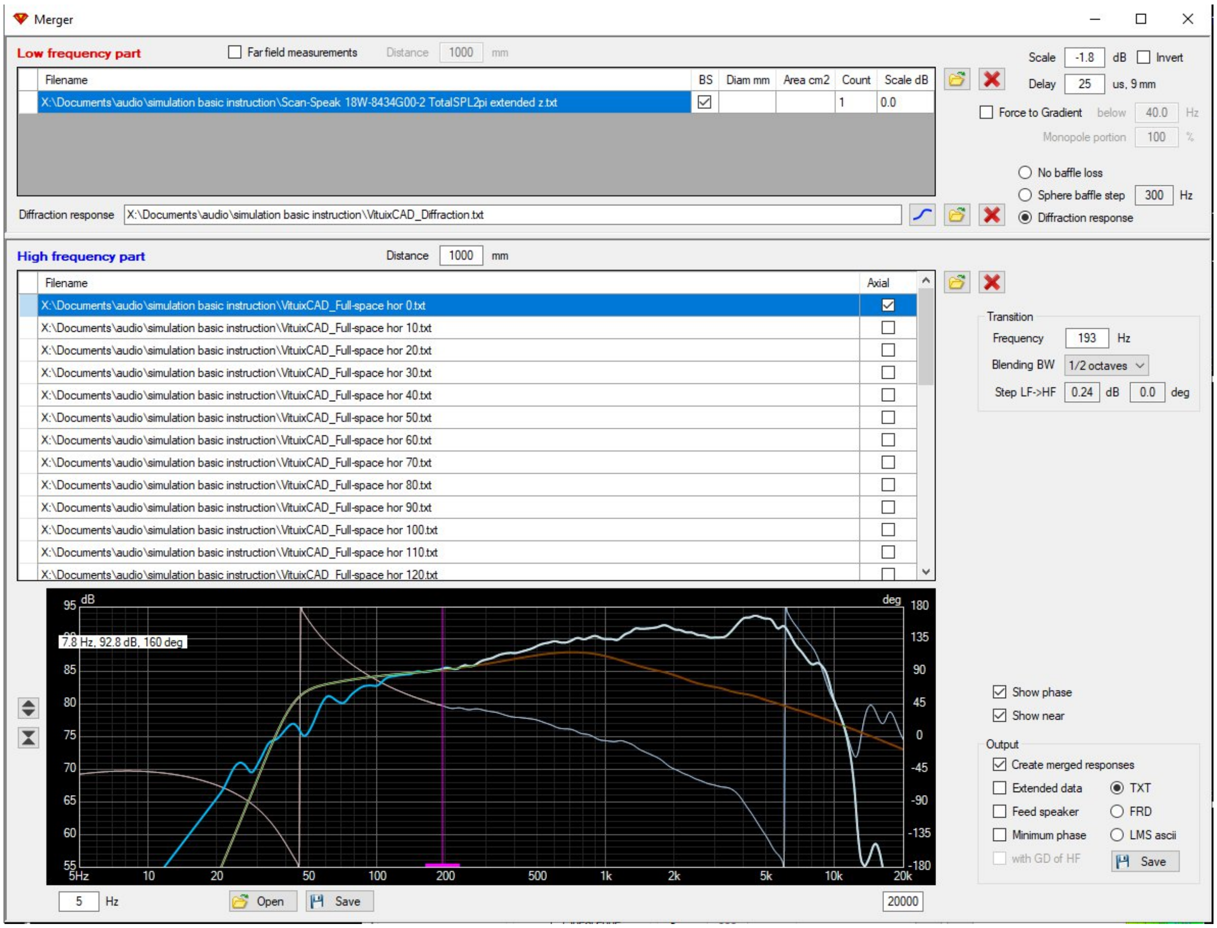

Figure 7 Merger Tool

Limitations of this process is that the traced response generates a “minimum phase” result. That is, when your speaker design includes more than one driver, as they often do, there is no timing delays present in these files that represents the difference in acoustic centres of the drivers. The best that can be accomplished with these results is to estimate the difference in acoustic distance by using the point where the speaker cone meets the voice coil as the reference point. Using this reference often gets close, but it is just a guess.

You can now load the merged result and traced impedance into the driver section of VituixCAD to view the result.

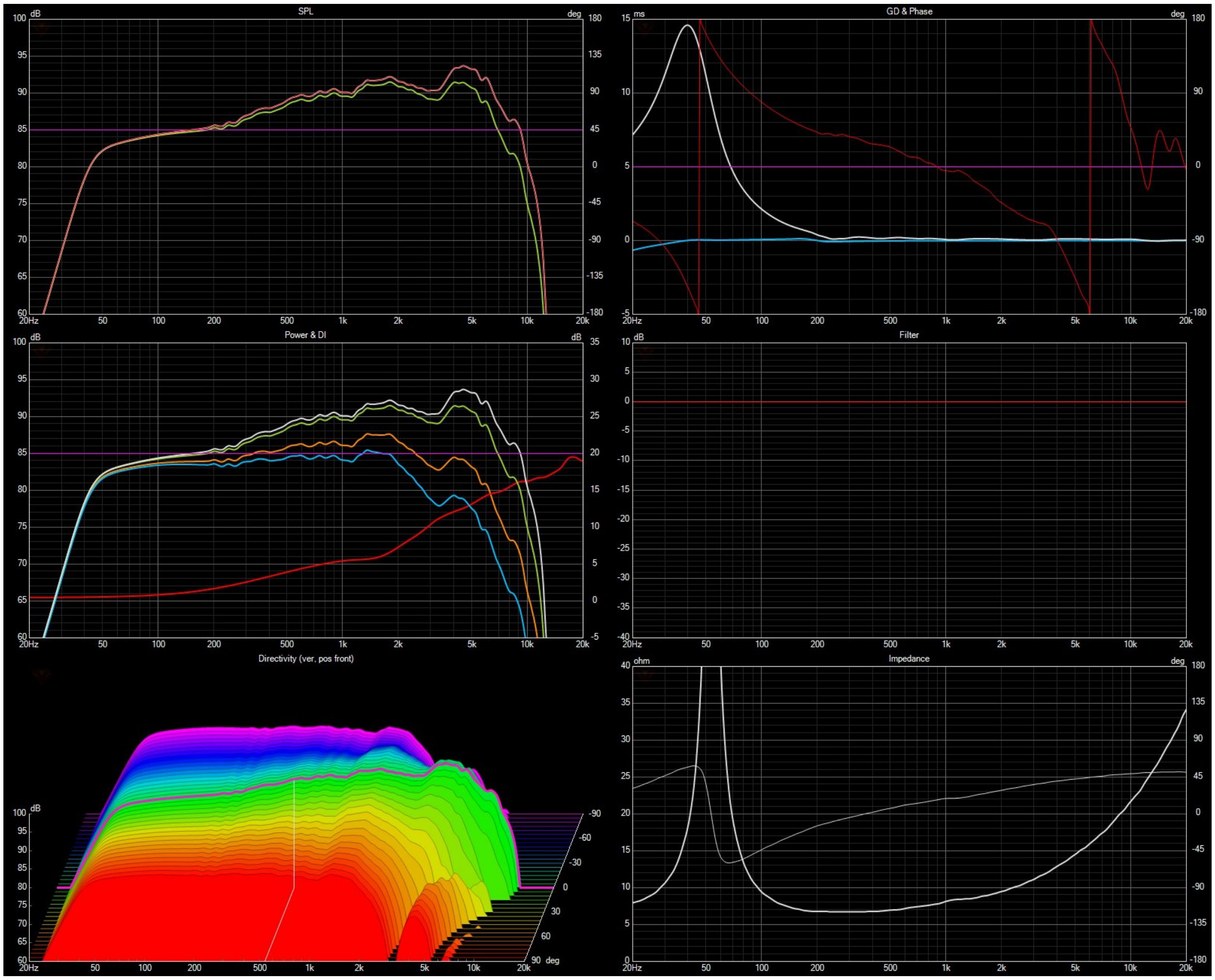

Figure 8 Complete Simulated response from traced data

This process replicates a similar process that would be followed with real world measurements. With a 2 channel measurement system, we would measure the driver at each off-axis angle, measure near field data, and apply a diffraction simulation to the near field data, then merge the result with the measured far field data. The benefit of course is that the real measurements will inherently include absolute accurate diffraction effects, cone breakup effects, changes in acoustic centre, and the acoustic delays between drivers can be easily captured, no guesswork is required.

Appendix A - My measurement data isn't half space infinite baffle measurements, what can I do?

If the measurement data you have isn't half space data, you will need to know the baffle dimensions of the measurement baffle, as well as the driver location on the baffle. With this information, simply enter it into the diffraction tool. If you know the mic distance as well, you may enter it in the diffraction simulation as well. Place the mic in front of the speaker and export the result.

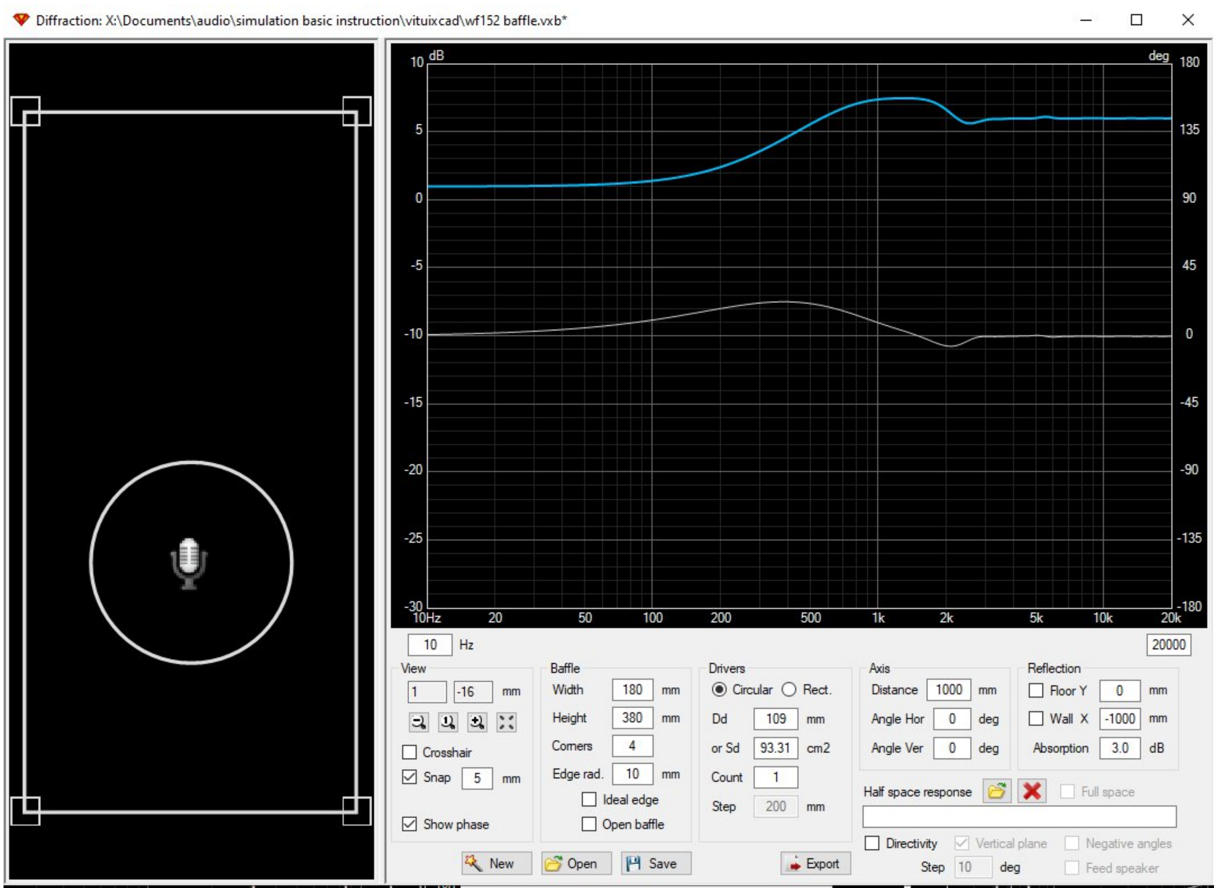

Figure 9 Diffraction simulation of known baffle

We will use the calculator tool to remove the diffraction from the traced measurement. Open the traced measurement as the "A response". Open the diffraction response as the B response. Select the "Divide A / B" function. In order to retain the measurement amplitude, the diffraction model must be scaled by -6dB. This function will effectively remove the diffraction from the measured data, converting the full space measurement to half space infinite baffle data. Like all other simulated / calculated processes, the accuracy is limited to the accuracy of the simulation and input data. You may use this calculated result and continue the above process from step 2.

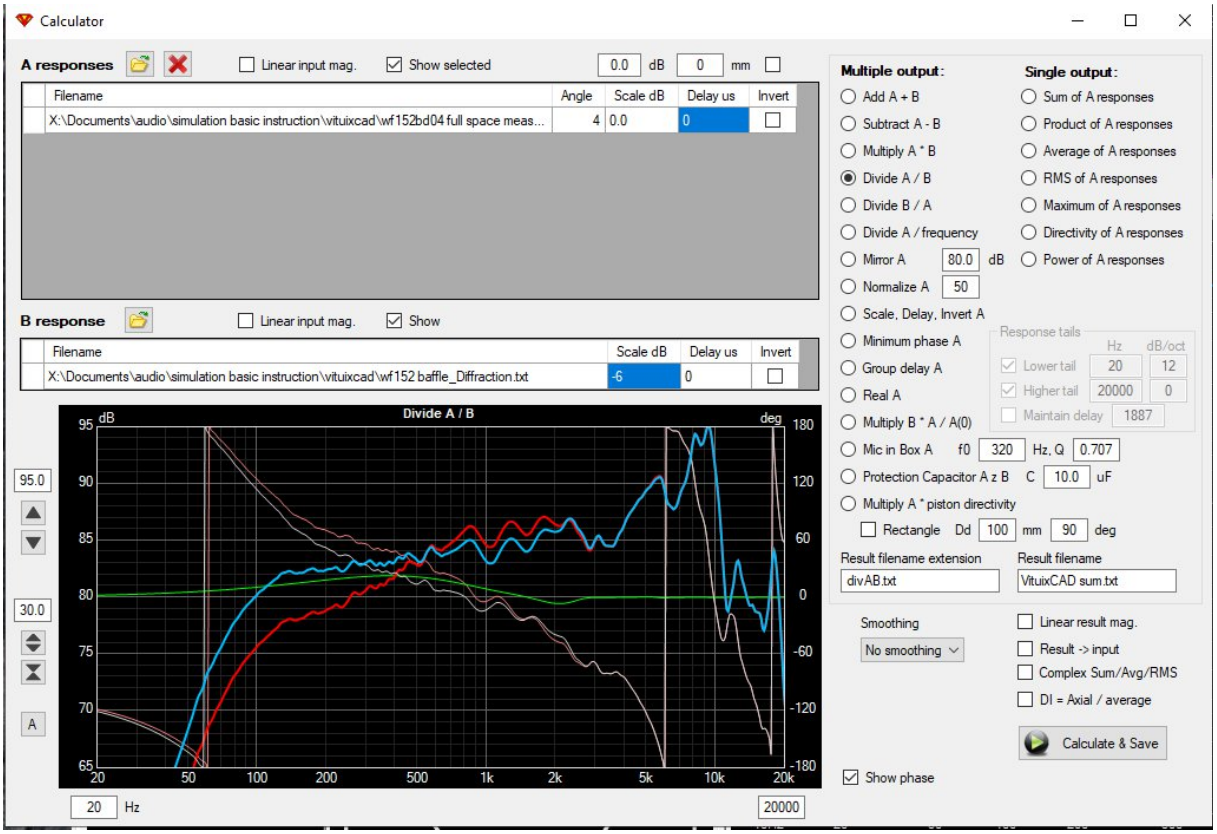

Figure 10 Calculator tool