

Baffle Diffraction Simulator

*An Excel-Based Interactive Tool,
Illustrated Introductory Operations Manual
& Multi-Topic Diffraction White Paper*

BDS - Beta Release 6.0

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I did not know anything about Baffle Diffraction last October (2000). I read a really excellent [White Paper](#) on the subject by Andy Unruh at David Ralph's [Web Site](#) and the rest is history. This project began as just a [distance graph](#) from vertically movable Speakers (by typing in values only) and seeing how far the Baffle Edge was and then only for Triangular Shaped Baffles with a sharp edge. The project has come along a great deal since then, and there are many who helped it get there that need to be repeatedly thanked and acknowledged for both their effort and for their Inspiration.

I would like to sincerely thank **Andy Unruh** for writing that paper, **Ken Perkins**, for providing a wonderful opening [Preface](#) and along with **David Ralph** and **Paul (Mr. Wizard)**, (the first two beta testers,) for many suggestions for improving the usefulness of the tool. I need to really thank **Ron Ennenga**, who with great patience spend much time and effort helping me understand and handle the technical complexity of the underlying mathematical models of sound propagation, exposing me to the wealth of knowledge available on the subject and for keeping me logically on track, and to both **Jeff Bagby** and **Jan Luszczek** for being a great sounding boards and for their inspired probing questions.

Separately I would like to thank again **Jeff Bagby**, **Jan Luszczek** and most especially **Kristian Ougaard** for helping me trouble shoot and work out the all of those bugs and problems in the program interface. Kristian's pre-existing [Excel Work](#) was both a guide and a goal throughout the design process for me. He also spend a great deal of his time with explanations, knowledge transfer and interface testing, during the early formative part of the project when nearly everyone else thought that what I was attempting was just a curiosity.

A very special thanks to three: again to **Ron Ennenga** (who also provided his troubleshooting, a great deal of insight and a detailed Pattern Lobbing Spreadsheet Example he authored based on the [Derivations of](#)) **Dr. Arthur Ludwig** for the mathematical basis of the Directional Models, and to **John Kreskovsky** who provided the underlying conceptual approach to solving Curved Edge Approximations. John specifically lead me through most of the unknown and rarely understood parts of diffraction, freeing me from earlier incorrect pre-conceptions, and focusing me toward the solving of the difficult solutions with easy to comprehend examples and clear methodology. John has always supported and fueled creative process in [Acoustic Design](#) with a precise approach atop an unconcealable enthusiasm to advance the deductive process, which makes an extremely inspiring teacher, indeed.

Lastly, I need to thank Madisound for allowing me to use their Audio Discussion Web Bulletin Board as the base of operations for this project, and the 125 Beta Testers from the Madisound Audio Discussion Group, whose bug reports, questions, projects, suggestions and ideas were essential in making this a viable tool. Of these testers, I would like to specifically mention David Ellis, David Dlugos, Ken Perkins, Steve Hammond, Sebastien Gaugé, Patrick Sun, Maynard Golf, John Coates, Sam Lim, Jay Hoppe, Andrew Manison, Andrew Rich, John Serbaniewicz, John Filicky, John Kreskovsky, Jeff Bagby, Martin King, Scott Larson, Johny Grenander, Paul Pickard, Kristian Ougaard and Byron Studer.

-- **Paul Verdone**

Beta Version Feature History

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6.0 New Features

[1600 x 1200](#)

[1200 x 1024](#)

[1024 x 768](#)

[800 x 600](#)

[640 x 480](#)

- 1) [Asymmetrical Edge](#) Sizes: An additional secondary Control for the edge chamfer or rounding size for the baffles sides other than the left and right.
- 2) Differential Gain Enhanced: Post-Edge Diffraction [Magnitude Variance](#) Compensation (For increased accuracy for off-Axis and for Wider Baffle Aspect Ratios)
- 3) Baffle Plane Tilt Back (0 to 30 degrees for Time Alignment Simulations)
- 4) Extended and Enhanced Ribbon Size/Shape/Model Controls
- 5) Asymmetrical Radiation: Ribbon Tweeter Radial Gain Correction for Angular Dispersion (Horizontal versus Vertical) on Diffraction Magnitude
- 6) Design Rules Checker for Recalculation Button Logic
- 7) Improved Observer Point Position Accuracy: H/V Triangulation Angular Interpolation
- 8) Enhanced Off-Axis Range (-45 to +45 Degrees for Distances Greater than 2 Feet)
- 9) Improved and Corrected Mutual Radiation Calculation and Graphing (On-Axis SPL and Off-Axis Power Response)
- 10) Increased Accuracy of Directional and Combined Radiation Source Models
- 11) Support for .FRD Outputting and Comparing of Axis and Power Response Sums
- 12) Support for IO of both existing and new extended DLP profile format
- 13) Massively Expanded Documentation Manual for the Inspired and Curious

5.8 New Features

- 1) Standard, Double and Quadruple [Angular Over-Sampling](#) Interpolation (36 @ 10 deg, 72 @ 5 deg, 144 @ 2.5 deg)
- 2) [Compare .FRD Function](#): (Subtract) Current Response from (previously saved) File and Display Difference (Magnify-able)

5.7 New Features

- 1) [Directional and Combined Mode Radiation](#) Sources Added
- 2) 5X Magnify Toggle on Response Chart, and Line Weight Control for all Graph

5.6 New Features

- 1) <Click UpDown> Drag <Click> Driver and Corner Reposition Interface Added For Excel 2000 Users Only
- 2) Chart(s) and Diagram(s) Scaled GIF Image file Outputting Added

5.5 New Features

- 1) 4 Line 1st - 3rd Order Approximation for Simple Rounded Edge & 8 Line 2nd - 7th Order Approximation for [Complex Rounded Edge](#) Added
- 2) On screen Roll Over Pop Doc for quick reference added
- 3) Full Error Trapping and logging to File added, with onscreen error indicator
- 4) Support for outputting not just response files for individual drivers but also for radiation gain and for sum response of groups added

5.1 New Features

- 1) Metric/Standard - - > Fully support all data entry, display and calculation space in both Inches and Centimeters
 - 2) Shape Enforcer - - > Baffle Shaper that limits and/or follows and corrects for baffle shapes that are impossible or nearly so.
-

5.0 New Features

- 1) Generalized Form : Quadrangles (Rectangles/Trapezoids), Pentangles, T-Pyramid, Triangles
 - 2) Differential Gain : Direct Wave versus Diffracted Wave (For close mike approximations)
 - 3) Load/Save Configurations with all Current Settings to Compact (1K) ASCII Text (Editable) Separate Files (With Library of a dozen configuration already available)
 - 4) Save and Update Trapping (Clean startup, Splash, Store Crash Lockout, Returns screen and excel parameters to normal)
 - 5) Trim-able (Base Gain Scaling) .FRD Frequency Response File Output for any Driver for later import to other programs
 - 6) High Speed Interrupt Driven Spinners - - > Numerical Entry with Up/Down Value Counting (and Boundary recovery)
 - 7) Edge Type, Enclosure Size, and Radiation Source Type/ Roller Toggle Operating Mode Control
 - 8) Display Improvements - - > Less zoom out required for smaller display, clearer text, Size color and Line weight improvements on Charting
-
-

4.0 New Features

- 1) wMTMw, wwMMT, 3 and 4 high Line Array Support (Summation & Radiation Gain)
- 2) Dome and Linear Ribbon Tweeter Support (Surface Multi-Sample)
- 3) Generalized Form: Triangles and Truncated Pyramids
- 4) +/- 30 Degree Horizontal Measured Axis Angle
- 5) Individual Speaker Horizontal Position Trim
- 6) 2 Size and 4 Position Frequency and Summation Chart Automation
- 7) Edge to Edge Screen Size Startup/Edit Automation
- 8) Reduced file size (Additional Macro Expansion/Compression)
- 9) Calculation Accuracy and Speed Enhancements
- 10) Numerical Entry with Up/Down Value Spinners
- 11) Improved Piston and Linear Surface Approximations
- 12) Chart Legend and field Updates, with Score-boarded Recalculation
- 13) Completed Percentage Indicators and Associative Color Coding
- 14) Baffle Shape, Array Type, and Chart Position/Size Roller Toggle Operating Mode Control

Beta 3.0

Beta2.0

Beta1.0

Notes and Warnings

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Requires **Excel 97** or **Excel 2000**. If **Excel 2000**, highly recommend **Service Release 1**. Known Macro Bugs with PowerMac, so **Excel 98 Mac** currently not supported.

It is highly recommended only running on machines with **at least 64 MB RAM**. In general, machines with less than 48 MB of RAM will find the calculation delay and module load times absolutely unbearable and may even crash.

You may also be required to "Turn On" some "**Add-Ins**", especially in Excel 97. Under Tools - - > Add-Ins : Enable "**Analysis Toolpack**" and "Analysis Toolpack VBA", otherwise Directional and Combined Mode Radiations Sources will not work at all. Please be aware that the Program will attempt to **enable the Analysis Toolpack automatically**. If the program either cannot determine conclusively or cannot upgrade and enable the Toolpack automatically, the program will prompt the user to manually enable it directly, through the Excel pulldown menu system: "Tools"--> "Addins". Until the Addin is installed, both the Directional and Combined Radiation Models will be greyed out and offline.

Please note that there are a few features that will only work in Excel 2000 or later. Accordingly, **Drag Mode** Operation Buttons will **not** appear to **Excel 97** Users.

There is a known bug in **Excel 97** and earlier releases of **Excel 2000** which prompts the user with Error messages about **Negative Values on Log Charts**. A "No Rad Display Button" has been added as a work around, see below.

Please also note that the overall performance of **Excel 2000** based configurations are much faster with increased realism of the selectable models. Long initial calculations indicate that table resources inside the spreadsheet are maxing out inside **Excel 97**. The Operating System further limits these resources, with **Windows 95** being the worst and **Windows NT/2000** having no limitations observed. Lastly, there are errors in all first release versions of **Excel** that are corrected in the later Service Releases. Many of these fixes are performance related and are at a minimum with **Service Release 2** for both **Excel 97** and **Excel 2000**. This program has not been tested with **Windows ME**.

The program was designed to work at any screen resolution from 1024 x 768 up. It is specifically programmed and edited at 24 Bit (16 million colors) at 1600 x 1200, but is tested at 24 Bit at 1200 x 1024 and at 1024 x 768.

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The largest problems solved are not Program Bugs, but user configuration Issues:

- 1) Not only is the Analysis ToolPak not enable, but in some cases, not even installed.
- 2) Without the latest Service Packs for Excel, Negative Values of Log Graphs cause errors.

Workaround Corrections:

Analysis Toolpak:

The process of dealing with the Analysis Toolpak has been, since version 5.7, to try and "enable it" if it was not already enabled. Since 5.75 on, there have been sporadic problems with this approach. First with the loading mechanism in Excel 97, but also because the excel installation process permits the user to not load in addin options. Since the introduction of Features in 5.82, failure to have this addin loaded would only break the Directional and Combined Radiation Model (I now know). With the introduction of Angle Interpolation extensions to Sample Interpolation in Version 6.0, several minor functions from the Analysis Toolpak were used outside of the radiation models and that broke the 2D to 3D distance conversion section on the Table page, causing no curves to show up at all, if the Analysis Toolpak was either not enabled or could not be enabled properly.

So to fix this limitation, we took the following steps

- 1) Wrote Native Functions that do not require the ToolPak for the non-radiation models. So the Program should work without the toolpak, except for Directional and Combined Sources
- 2) After detecting that the ToolPak is not loaded, attempting to load it, and failing, a pop up window informs the user of the problem and the actions that may be required to correct this, first by enabling manually and second by the user having to install those Excel options from CD... and...
- 3) Also by disabling and "graying out" the Directional and Combined Models until the Addin is both installed and enabled. The program checks for this until it is repaired.

Negative Values on Log Charts:

Excel 2000 Service Release 2 does not seem to care whether the values on LOG chart dimensions are positive or Negative. Other versions sometimes complain. Sometimes the complaints are annoying and sometimes disabling.

So to fix this limitation, we took the following steps:

- 1) All default Values for Charts are now zero. Previously, they were negative one, so as to be invisible when not disabled. The visual artifact of this change, is that previously turned off drivers, when enabled will land as a straight response at mid-chart near +6 db until recalculated.
-

2) When drivers are outside the boundary of the baffle, they now return rational but moderately incorrect answers as opposed to irrational answers. When a driver was beyond the baffle edge it would have a near infinite distance finding the closest baffle edge in the correct direction, yielding an extremely noisy frequency response (a message to the user, if you will) that sometime was set up wrong. Now, if the driver cannot locate any nearest edge in the proper direction, it just locates the nearest edge, period. The reason for this change is that this irrational geometry process generated Negative LOG Values when Cosine Integrated.

3) A button named "No Rad Display" is now on the lower Sum Frequency Chart. All response curves (except the Mutual Radiation one) are all now, by definition, positive LOG values. Since Mutual Radiation dithers below the zero line, this cannot be corrected easily. The "No Rad Display" button turns off this one curve (Rad Gain) , allowing the other two to be viewed. One of those two curves has the Mutual Radiation effects summed into it. If the user is pestered by error messages or sees curves on only one chart and not the sum chart, lighting this toggle button should fix this limitation.

First a Preface

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I was asked to do a Preface for the Diffraction Simulation Spreadsheet to give it a "layman's" perspective. That's easy; Paul and the other beta testers did the hard work. The way I see it, there's a range of people who participate in this hobby we call speaker building. On the left, you have the folks who just want to put some drivers in a box, maybe to recycle a vintage setup or just have a set of party speakers. On the right you have those who want to take it down to the last mathematical model for proof of a design. I'm somewhat to the left of center here.

One thing we all have in common, however, is we need tools. We collect every possible copy of freeware and shareware, spreadsheets and online calculators we can find. Several months ago, Paul was discussing his spreadsheet on the Madisound Audio Discussion board and I told myself I had to get a copy and get in on this. I received it and opened it up and was immediately lost. I figured what harm can I do, I'll just not save it in case I mess up. I figured out how to define my baffle, plugged in the numbers to describe my drivers and loaded basic frequency support. Voila! I had a curve. It weirded me out so bad that I closed it and didn't go back to it for a couple of weeks until I was finishing a project and needed to figure out where to mount the drivers. One hour later, I had a half dozen scenarios for driver mounting. Two weeks later I was creating files for my speakers for DIY2001. All along, Paul would send me the next beta to test and I would ask questions. I suggested something I'd like to see and that was the tilt back feature, for those of us who like to tilt the cabinets back. It was a learning experience as much and finding solutions to a problem.

This is an excellent tool and a labor of love to our community. All you need is a basic understanding on the diffraction effects the baffle can cause and to understand the baffle step phenomena. Plug in the numbers to define your baffle, describe the drivers and start moving things around. When you get comfortable with it, start working with the advance frequency support. It takes a while, even on a fast machine. Once you see what you can do with this thing, it will become a part of your "suite" of tools you'll never stop using. Good luck and have fun. That's what this is really all about. And never stop enjoying the music!

--Ken Perkins

What is it?

"An ideal driver in free space radiates uniformly in all directions. When placed on an infinite baffle, the radiation is restricted to the forward hemisphere. But what happens when the baffle is finite? Sound waves propagate uniformly across the surface of the baffle in all radial directions. When the sound wave intersects the baffle edge, it is diffracted. To model the interaction of the sound wave with the baffle edge we follow the wave across the baffle surface to the baffle edge along a straight path, or ray, initiating from the driver's center (or source of the radiation) and back to the listener. Obviously, to account for every possible angular direction of wave travel across the baffle surface we would need to consider an infinite number of rays. However, a suitable approximation is obtainable by using a finite number of such rays."

**--"An Anonymous Computational Electron & Fluid Dynamics Expert
and Speaker Building Enthusiast"**

Baffle Diffraction: A Real Beginner's Introduction

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A baffle is a reflector. It divides the space in front of it from the space behind it. The larger its size, the longer it takes to get around it. In acoustics, longer distances, means longer time delays, which means lower frequencies. So, the larger the baffle, the lower the lowest frequency that it reflects (why this is so should become clearer a little further down). If the baffle were infinitely long, so would be the time delay traveling across it, and the lowest frequency reflected by the baffle would be near 0 Hertz. Smaller baffles only reflect higher frequencies. Larger baffles do that as well. As the baffle size is enlarged, so the cut-off frequency, where the baffle stops reflecting effectively, is reduced. This cut-off frequency is a key element of loudspeaker design and is known as the Baffle Step Frequency.

Over the frequency range that a baffle is reflecting, all of the sound is kept in front of the baffle, so the space that is filled by the sound is only half the "total space". The "total space" is usually described by an acoustic geometry term known as 4PI Space. The Area in front of the baffle is also usually described with the term 2PI space. This is a very straightforward once you get used to it. As long as the sound is only kept in 2PI Space by the baffle, its concentration or field strength is twice as great as when the sound is permitted to (go around the baffle and) fill the total 4PI space. This difference in strength or gain is another key element of loudspeaker design and is known as the Baffle Step Gain.

The Baffle Step Gain is not a fixed amount, but depends on the surrounding environment (your room), how far your speakers and baffle are away from the room boundaries, and how far you are away from the speakers and baffle. But in general, the Baffle Step Gain always tends to approach + 6db. The Baffle Step Frequency is not a fixed frequency either, but is really a frequency region or transition zone over which the change in gain happens, and can span several octaves.

What is interesting is that the effective size of the baffle and the frequencies that it reflects, from the perspective of the speaker, depends not on how large the baffle is, but rather how far away the edge of the baffle is from the speaker. Why? Because the frequencies reflected by the baffle are based on the distance that the sound must travel before bending around the edge of the baffle into 4π space: In acoustics, longer distances, means longer time delays, which means lower frequencies. So it is not the absolute size of the baffle that effects reflection and Baffle Step Frequency, but the distance the speaker is from the edge of the baffle.

Well, if the distance to the baffle edge is the determining factor to the reflected frequencies, then the placement of the speaker on the baffle is a major part of establishing that distance. If the speaker is closer to an edge, then more of the lower frequencies will wrap around the edge and not get reflected forward. If further away, then the distances traveled along the baffle are longer, so the time delays are longer so more of the lower frequencies are reflected.

The other thing to note is that, not only the placement of the speaker matters, but the shape of the baffle as well. If the shape of the baffle is circular and the speaker is centered then all the distances to the baffle edge are the same. If the baffle shape were square, and the speaker still centered, that there would be a series of different distances from the center of the speaker to the edge of the baffle. If the baffle were triangular shaped this would also be true, and the ratio of the shortest distance to the longest distance from the center of the speaker to the edge of the baffle edge would be greater. In other words, the variance in these distances is greater.

This variance of distance to a baffle edge is another key element of diffraction. But why? Well, diffraction as mentioned above, is about the distance that the baffle edge is away, and thus the time delay that the sound of the speaker experiences in its route along the baffle edge, trying to get around the baffle into 4π space. The reason that the delay is important is based not on what is happening along the path across the baffle, but on what happens when the sound reaches the edge. More specifically, as the sound wave tries to turn around the edge, the wave now finally sees a larger 4π space. Since the space is larger than the 2π space the sound wave was restricted to before reaching the edge, then sound wave has to expand. This expansion is a change of pressure of the sound as it makes the turn around the baffle edge. This change in pressure is an acoustic event and creates a reflection sent off in all directions visible from the edge where the change in direction around the baffle corner happens. The magnitude of the reflection is related to the pressure change, which is determined by the angle turned around the edge, or the angular space seen at the boundary.

This reflection is the basis of baffle diffraction. This reflection arrives at the listening position and affects the sound that got to the listening position directly (not by way of the

baffle). The two wave mix and affect each other. Since the baffle edge reflection took a longer path to get to the listening position, there is a time delay involved. In acoustics, time delays create reinforcement or cancellation depending on the frequency involved. This change in gain versus loss cycles up and down with rising frequency because the time delay has a different phase angle at each frequency. This cycling of the response up and down is sometimes referred to as a comb filtering response, because the periodicity of the peaks and nulls in the response are equally spaced and resemble a comb.

So for each path that the sound wave takes on its travels across the baffle, hitting the edge and wrapping around it, there is also a path that goes the other directions and arrives at the listening position. How far that distance across the baffle to the edge and back to the listener is the key delay that establishes the peaking and the nulling effect. Frequencies lower than this delay are unaffected. Frequencies above that delay warble up and down averaging twice as strong because of the reflection's contribution. This reflection's contribution is the energy or strength difference between 2PI and 4PI space and accounts for the Baffle Step Gain or what the baffle cumulatively reflects. The corner frequency is established by the time delay and is the basis of the Baffle Step Frequency.

But each path from the speaker to the edge to the listener may be different. If the speaker is not centered on the baffle, then some reflections will arrive at the listening position early and some even later. If the baffle shape is non-circular, then the paths taken are again different. If the listening position is further away then the path delays may be a little larger or smaller (triangulation with the direct wave). If the listening position is off to the side, or above then the paths from the baffle edge are again different.

The edge size and edge shape also affects these delays. Sharp edges provide a precise point where these reflections begin. Beveled edges provide more than one point, displaced in space a thus time. Rounded edges provide many points along the curvature. An extremely large curved surface, like a curved or spherical baffle represents one very large continuous edge or a near infinite set of reflective points. The size and shape of the speaker itself also affects these delays. Smaller drivers tend to start the journey of the sound waves aimed at the baffle from a near single central point. Larger diameter speakers actually launch many such waves each from a different point on the surface of the driver. So each of these points on the driver contribute a part that may get to that edge a little earlier or a little later.

It is the sum of millions of these individual paths that come together that collectively change the direct wave and create the sound of the baffle. If these delays are all very similar, then the reinforcements and cancellations will be as well and the response will look rather bumpy. If there are hundreds of minute differences in the delays then the overall effects in phase will tend to cancel and the response will look flatter. The transition zone, know as the Baffle Step Region will also be effected by these variances. If the variances are very small then there will be a rather large bump followed by a smaller dip, before the responses starts to even out a bit.

In addition to the time delay with each of the diffracted wave components, there are also magnitude differences. Longer paths mean weaker signals and less contribution. The size of the area of the driver radiating and the region used to describe it have an associated strength by virtue of its area. Speakers also have directivity, which means they tend to become

more directional with rising frequency, so the magnitude of the energy fired sideways at the baffle edge will tend to be smaller with rising frequency. Even the edge shape effects magnitude. All the reflections from a sharp edge happen or emanate from that single edge. A Beveled or Chamfered edge has two such event locations with different lesser strengths because the angle involved in each part of the turn is different. On a rounded edge the center on the activity is somewhere in the middle of the rounding, but has no precise spot. The individual contributions from the each piece of the rounded edge are very small, but collectively they total the same reflection as if the reflection were sharp. In this case, both the time delay and the magnitudes of each of these sub-reflections are different.

So Diffraction Simulation is about tracking all of these of these delays and magnitudes and summing them at the listening position to predict the effective frequency response contributed by the baffle. The baffle shape, driver size, driver position and edge treatment each effects this contribution. This contribution is the called the Baffle Signature. It is not a separate response. It is an affecter or change in response by the baffle, much like the change in the response from the crossover, the box model or the room itself. The Baffle signature can be viewed as something to optimize. It can also be viewed as something that requires compensation elsewhere. The Signature may be subtracted or removed from a measured response of a speaker in a test baffle to correct the measurements to reflect what the speaker really sounds like by itself. The signature can also be added to predict how that speaker would sound on a particular target baffle.

The prediction of Diffraction is just another tool for the designer to use. It may be a tool to explore a new design or to help troubleshoot a flaw in an existing or modified design. It may be used as a learning tool to come to better understand the tendencies and build a few rules of thumb or critical value thresholds or compare relative design techniques. The optimization of Diffraction is about trying to understand it and harness it, not necessarily trying to just avoid it, as its effects are inevitable.

This tool is not about a scientific study on the precise mechanisms of diffraction, but rather is a first attempt to fully explore closed box loudspeaker baffle diffraction in a highly interactive environment. Its intended audience is much more to the DIY'er than to the physicist or mathematician. It is supposed to be easy to understand. But there are many terms and buttons and values to consider so there is a learning curve involved. Its interactivity is an intentional trade off to exhaustive accuracy and precision and its approximations are of course upgradeable. Hopefully the control of the simulation complexity by the user will make it more practical and this documentation will make it more understandable, and most importantly, I hope it is perceived as extremely useful.

-- Paul Verdone

How do you use it?

Getting Started: What all the Buttons do.

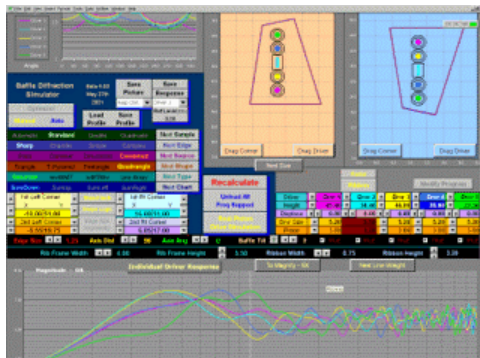
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When the Simulator first loads a message pops up and inquires whether or not to load Macros. Always select Yes.

A splash Screen sized window comes up next, which then enlarges to full screen, the worksheet tabs, editing tools and grid row and column markers disappear. The Button "To Modify Program", out by the right side screen edge, if pushed would return Excel with selection tools, tabs and grid markers if you want to change the zoom or out or go exploring on other pages. Otherwise the program is designed to be operated full screen as it first appears.

The general layout revolves around a left to right configuration bar across the middle of the screen. Below the bar are the frequency graphs. Above the bar to the right are the twin diagrams depicting the speaker layout: the blue and orange being vertical inversions on each other. Above and to the left at the very top is a distance delay graph from driver center via baffle edge to listener. Just below that are the IO features and below that are the main mode controls that select the modeled complexity of the simulation.



Click to Load
Large Picture in Browser
From Web

1600 x 1200
1200 x 1024
1024 x 768
800 x 600
640 x 480

The Central bar is divided into two sections by several large buttons at screen center. To screen left of these centered buttons are the baffle shape controls and to the right are the speaker placement controls. The first Centered Large Button is "Recalculate" and is probably the most used button, which is why it is screen center, with the largest font and in Red. Unless the program is left in Auto calculation mode (discussed below), every time you make positional or shape changes, requires hitting "Recalculate" to update the baffle measurement distances and both Frequency Charts.

Just Below "Recalculate" is the second centered large button: Load Basic Frequency Transforms. It's job, which when pressed is fairly quick, is to populate the spreadsheet with a formulas array (72,000 references) of the general distance frequency transform on the 5 cancellations pages. This formula is support for all point source driver sample simulations and is required for both single and dual reflection diffraction interleave frequency graphing. Until you push this button, all you can do is design the layout. Pushing this button increases RAM consumed from 23 MB to 30 MB.

Just below that is the third centered large button: Load Advanced Frequency Transforms. It's job, which when pressed is very very slow, is to populate the spreadsheet with a formulas array (360,000 references) of the piston driver distance frequency transform on the 5 cancellations pages. This formula is support for all non-point source driver sample simulations for both single and dual reflection diffraction interleave frequency graphing. Once loaded several toggles control Point Source versus Diameter Source and single versus dual reflection operation. Until you push this button, you can only simulate point source drivers. Pushing this button increases RAM consumed from 30 MB to 45 MB.

Loading and unloading Frequency Transforms lights up a completed percentage status indicator. This same indicator is used during long calculations when performing operations with either Rounded Edges or Over-Sampling or both. The longest calculation may take up to 2 minutes on 733 Mhz machines. Most calculations take between a half second and 8 seconds and do not require the indicator to inform you of progress or status. Just above the percentage status indicator is an Error warning. If the Error warning lights up, a file is created in your present working directory and for every error, it logs the error type, software module and time the error happened into a file called "differ.log". This error indicator can be cleared by toggling the Modify Program / Start Simulation Button twice.

If you have Advanced Freq Support fully loaded then you can also select Dome or Ribbon choices for the tweeter. Otherwise the tweeter is always a circulator piston like all the other drivers. The button at the top of the tweeter column is labeled Dome, and Toggles to Ribbon. Above that button is another button that shows and/or controls the radiation direction pattern for the tweeter, fixed for Domes with several selections for Ribbons. (if interested in Asymmetrical Radiation models that detailed information can be found in the [Ribbon Errors Section](#)) When Ribbon is selected an additional tool bar of controls appear under the central bar and above the Frequency Graphs, which controls the Ribbon's exact dimensions.

As mentioned previously, there are six roller toggles that control the Program Main operation. Those Toggles have a single button that lights up a selection rotates through as many as four selection levels each. These Main Categories are: Angular Over-Sampling, Edge Type, Driver Radiation Source, Baffle Shape, Multiple Driver Array Type, Frequency Chart(s) Size and Positioning. Details about what they represent are listed in detail below under "[Operating Rules](#)".

Above and to the very left are two mode control buttons, which help control recalculation. The simulator can be run in either Automatic or Manual Recalculation mode. Running in Manual Mode is best when radically changing driver quantity, size or position, radically changing enclosure dimensions or edge rounding. Manual Mode is also used with Simulations that are highly accurate and take long times to calculate. Automatic mode is for

comparing tiny changes. Automatic Mode tends to be used with just a single driver with the lowest model complexity to arrive at positional optima very rapidly (like finding the best place to offset the tweeter, left to right). All control buttons perform partial recalculation when in manual mode. Only the Frequency Graphs and Distance chart do not update in Manual Mode until "Recalculate" is pushed.

Next to the calculation control buttons are the Input/Output buttons. There are three types of IO operations. The first two are in the Upper row: those outputting image files of the graphs and charts, and those outputting or comparing ASCII text files of the .FRD responses of the graphs. On the second row are the Load and Save Buttons for IO of the operating parameters that setup the simulations and are called Profiles. The Images are saved as GIF files, the responses are saved as FRD files and the profiles are saved as DLP files. When an IO operation is selected, a Dialogue box that helps you choose the filename to load or store pops up. The Pop up will only show you only the file type applicable; DLP (Diffraction Layout Profile), GIF or .FRD files.

Contained in each of the DLP files is an ASCII text readable description of all the control settings in the program. When you load a profile, "all" buttons, values and selections take on the conditions that were in affect when the file was saved (with only a few specific and minor exceptions). The first exception is that loading a profile WILL NOT load, unload or change the level of Frequency Support. If you saved a configuration with a Ribbon Tweeter, when you reload that profile, if you do not have "Advanced Freq Support" loaded, all of the info about the Ribbon will be input, but a Dome will be displayed, until you manually load the Advanced Support and Re-Select Ribbon. The same is also true with Point and Diameter Radiation Source Selections as they also depend of Advance Frequency Support already being loaded as well. The second exception is that Over-Sampling status is never saved. So that when a new profile is loaded, the user does not have to wait up to two minutes to do anything with it. Over-Sampling is always reset to Standard during a profile reload.

For the button group that selects FRD type Frequency Response Files for Output, a Pull-down menu selects which Driver, or Sum Response is to be output. If any Frequency Support is loaded, and that particular Driver is currently turned "on" then a File Dialogue Window will pop up for Filename selection. Otherwise the Save Response button will flash a message why that IO operation cannot complete as selected. Whatever is actually shown on the Individual Response Graph (or Driver Sum Graph) for that Driver will be output to file. A Numerical entry "Level Adjust" is provided for Speaker Offset Level of the output. This is the baseline response above 0 db. The Top most button in the grouping can be toggled from "Save" to "Compare". The controls function identically in "Compare" mode as in The "Save" mode. The only difference is that the user selects which file (previously saved) to input and compare to the current simulation. The difference between the simulation under current control and the previous response are subtracted and displayed on the frequency graph. For best results the output reference level of the saved response and the current compare operation should total +6 db to center the response difference display on the graph. The Magnify button can be used then to inspect the response difference more closely, the picture of the graph of the difference also can then be saved, but not the difference response in .FRD format.

For the button group that selects the image output to GIF file format, also includes a selection pull-down to choose amongst the four graphs. The selection choices are the left and

right (orange and blue) Layout Diagrams and the Two Frequency Graphs (Individual Drivers and Group Sum Responses). The output images are scaled by screen zoom, so the image size output should be fairly similar regardless of the screen resolution on the simulation machine.

For the majority of the baffle and speaker dimensional controls on the central bar, all Numerical Values can be manually typed in, but will not update the diagrams until some other action is taken. All numerical values alternatively can be "spun" up and down with a value spinner. Clicking or Holding down the spinner buttons update the numerical values in real time and update the diagrams every one or two seconds based on your clicking behavior. A single click always performs a single update, while holding down the spinner accelerates the spin process rapidly, so it is very easy to over shoot your mark. The driver diameters, height away from the Apex (0,0 point) and displacement (left or right of the center line leading to the apex) and the outer driver size are for the speaker controls. The piston sizes are recalculated from the Driver Size. The X and Y coordinates of all corners (except the fixed Apex) are the controllable properties of the baffle. For greater detail in operation and definitions please look over the [Operational Rules](#) section below.

You can also select a "Drag" option (if using Excel 2000 only) to reposition speakers and corners. When selected, clicking the Left Mouse Button Down and Releasing "captures" the nearest driver or corner. Moving the Mouse around will carry that object until the Left Mouse Button is clicked again. Another Click Down and Releasing will re-capture the nearest item, etc. Clicking the Right Mouse Button, or left clicking elsewhere on the page Terminates the previous selected dragging Operational Mode.

Amongst the baffle shaping controls on the central bar at screen left are three gray buttons. The first is the metric to standard toggle. Pushing it converts all screen numerics to the other base. It also scales the screen coordinates and the positioning limits and display precision. Although not evident, all baffle size calculations and all frequency cancellation is actually performed with the alternate coefficients.

The second button is the Shape Enforcer. It can be toggled on or off. If left on, it will change the limits and correct for overlapping and near overlapping baffle shapes. If turned on after being left off, it will correct for the same on the current settings. It is highly affected by edge size. It does not currently have anything to do with speaker placement.

The third button is the Edge Size Asymmetry button. If pressed it reveals a second spinner for the size of the second edge. Which baffle edge the second edge spinner controls is dependent of which baffle shape is currently chosen and is described below in [Functional Description](#) section 2-f.

Along the bottom of the central bar are the main global parameters, of primary Edge Size, Axis Distance, left to right Observer Axis Angle and Baffle Tilt back. Each of these controls can be entered or spun as well. The Baffle Tilt needs to reference a specific diagram: Orange or Blue so as to designate what is the baffle top being angled away and a button with a "?" on it toggles that selection. The color of the text indicates which diagram is reference.

There are also Four modifier buttons that make viewing easier. The first is at the base of the Orange Diagram, is label "Next Size" and changes the zoom factor to view the layout. The

second is called "Magnify", is located on the upper frequency graph. It only affects that one graph (Individual Driver Responses) and increases the vertical Gain by five times, for close inspection. The third button is adjacent and is label "Next Line Weight". This button affects all five graphs and changes the graphed line thickness.

The Fourth button is on the lower frequency graph as is marked "No Rad Display". Some versions of Excel cannot tolerate Negative values on Log Charts. As only the Mutual Radiation Gain Values can be inherently negative, disabling the Radiation Gain curve will keep the other two sum graphs from disappearing.

Functional Description:

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1) Graphs a multi driver curve of relative distance to baffle edge from a user controlled arbitrary anchored planar triangular, arbitrary anchored planar truncated pyramidal, arbitrary anchored pentangular and arbitrary unanchored planar quadrilateral baffle shape.

2) Integrated Graph of a Multi Driver Diffraction Frequency reflective cancellation - augmentation achieved by triangulating differential propagation time and magnitude:

- a) Summated across all 36 Equal Angular Samples (10 degrees) for Standard Sample Resolution, 72 (5 degrees) for Double Over-Sampling Resolution or 144 (2.5 Degrees) for Quadruple Over-Sampling Resolution
- b) At 400 Discrete Logarithmic Frequency points from 100 to 10000 Hertz
- c) Sampled from either Driver Center or from 5 weighted (by region area) Multi-Point Samples (by four dividing chords perpendicular to Driver Center Emanated Source Ray) of actual Driver Piston Size (displaced at each dithered region vector center as a percentage of the driver Diameter) [User Toggle]
- d) For any combination of 1 to 5 Drivers [User Toggles], Driver Horizontal & Vertical Position and Driver Diameter [User Adjusted]
- e) To either a single Sharp Baffle Edge or using Both Reflections at the beginning and ending transition [User Toggles] on a Chamfer Edge [User Adjusted] or to a weighted time reflection and refraction corrected average (by mapping either 1st Order Reflections and up to 3th order subsequent Refractions) of 4 equidistant interpolated lines approximating a Simple Radius Round or (by mapping 1st or 2nd Order Reflections and up to 7th order subsequent Refractions) to 8 equidistant interpolated lines approximating a more Complex and more accurate Radius Round.
- f) Where the edge size is either selected for the entire baffle shape or where two edges sizes are separately controllable; for the Triangle the base being the second edge, for the T-

Pyramid and Quadrangle the top and bottom being the second edge, and for the Pentangle, the two upper sides being the second edge

- g) From any distance Axis [User Adjusted] from 2 inches to 20 feet
- h) From Perpendicular to Baffle Plane to plus or minus 45 Degrees Horizontally off axis, where the Baffle plane can be vertical and perpendicular to axis to as much as 30 tilted back, at the top, away from the Observer, with the diagram used to determine which is the top is User Selectable
- i) At a Magnitude level of the Cumulative Diffraction Signature set as a Differential Gain by the relative distance path from the average diffracted baffle edge total path distance compared to the Direct wave total path distance at the measurement point, and
- j) With an radial sample gain offset by the variance in path length from the average path length from baffle edge as compared to the individual sample distance
- k) With or without an individual driver diffraction gain further reduced [User Toggle] by the directional nature of a given diameter driver at that transmission frequency (calculated as the difference in magnitude between the User Selected Axis and parallel (90 Off Axis) to a Perpendicular Ray from the Baffle Plane.
- l) And, in the case of a ribbon tweeter, with either the vertical gain further attenuated by the orthogonal cross of the difference in dispersion for a driver of H and a driver of V diameter or by both a gain and an attenuation equal to the same total radiated energy [User Toggle]
- m) With all Values, Coefficients and Calculations performed internally and entirely in either Metric (Cm) or Standard (Inches) space. [User Toggle]

3) Integrated Graph of a driver groupings diffraction frequency reflective cancellation

- a) Graphs Radiation Gain from pairs, triples or quad collections
- b) Graphs Summation averages without Radiation gain adjusted As Axis SPL
- c) Graphs Summation averages with Radiation gain adjusted As Power Response
- d) This is toggle selectable for MTM and/or wMTMw groupings
- e) This is toggle selectable for MMT and/or wwMMT groupings
- f) This is toggle selectable for 3 high and/or 4 high line array groupings

Operating Rules:

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- 1) If Triangular: You can set the **x,y coordinates of the left corner and the right corner. The Apex remains fixed.** See below.

- 2) You can set the **height above the apex for any driver**, all drivers are aligned vertically above the apex. The User can offset the distance from this vertical line with an individual speaker **horizontal displacement**.

- 3) The inverted speaker (Orange) is there for visualization only, **all references to position are with regard to the bottom apex (blue) diagram**. The diffraction signature is the same for either pictured diagram.

- 4) You can set the driver sizes. Except for the tweeter, the piston size is auto-calculated. The Tweeter is driver 2, and you set the piston and frame sizes separately for accurate visualization.

- 5) **The Tweeter has two type selections: Dome and Ribbon**. The Ribbon mode is only active when Diameter Source or Combined Source mode is on. The height and width of the linear ribbon and the height and width of the outside frame is user controlled by Spinning or numerical entry. The Ribbon width always defaults to .75 inches unless a profile containing another previous simulated Ribbon size is loaded. The same is true for the Ribbon frame Width and it defaults to 4 inches.

- 6) **A four-position roller toggle** selects baffle shape. [**Triangle, T-Pyramid, Pentangle, Quadrangle**]. The **Triangle, T-Pyramid** and **Pentangle** are anchored to the Apex. For the **Triangle** you only set the other two points. For the **T-Pyramid** you also set the individual height of the second two points. For the **Pentangle** and **Quadrangle** you freely set all four points. For the **Quadrangle**, the Apex Point is an arbitrary zero reference point that all corners and drivers are relative to.

- 7) **A four-position roller toggle** selects Driver Groupings. [**Separate, wwMMT, wMTMw, Line Array**]. The height fields for the individual drivers change color and the chart legends update to show which drivers are associated with which pairing, triple or quad: Red Group and white group respectively. In **MTM** mode drivers 1&5 are the first pair and 3&4 the second. In **MMT** mode drivers 1&3 are the first pair and 4&5 the second. If driver 1 is on, then the **Line Array** is for 4 drivers, otherwise just 3.

- 8) **A four-position roller toggle** selects Edge Type. [**Sharp, Chamfer, Simple, Complex**]. For a **Sharp** edge all measurements are a single distance function. For **Chamfer** there is two measured edge distances separated by the linear distance define by the edge size. For **Simple** Round there are two measured and two interpolated and weighted edge distances separated by and along the curved arc edge distance defined by the radius round edge size. For **Complex** Round there are two measured and six interpolated weighted edge distances separated by and along the curved edge distance.

- 9) **A four-position roller toggle** selects Driver Radiation Type. [**Point, Diameter, Directional, Combined**]. A **Point** source is always active and performs a measurement from driver center and radiates equally in all directions. A **Diameter** source is only available when advanced freq support is loaded and for a given driver diameter uses 5 weighted regions for measurement and radiates equally in all directions. A **Directional** source performs a measurement from driver center and radiates in a directional pattern determined by driver

diameter and by frequency. A Combined source performs a measurement for a given driver diameter using 5 weighted regions and radiates in a directional pattern determined by diameter and by frequency.

- 10) **A four-position roller toggle** selects Frequency Charts size and position. [**SumDown, SumUp, SumLeft, SumRight**]. In the first two modes, the graphs are full size with the driver group summation response either above or below. In the latter two modes the graphs are half scale horizontally and side by side.

- 11) **A four-position roller toggle** selects Over-Sampling Resolution. [**Automatic, Standard, Double, Quadruple**]. If the Operating Mode is set to Automatic Recalculation, the Sampling is set at **Standard**. If the Operating Mode is set to Manual Recalculation, the Sampling is set User Selectable. **Standard** Resolution is 36 Speaker Rays per driver surface sample per edge sub line. **Double** Resolution is 72 Speaker Rays per driver surface sample per edge sub line. **Quadruple** Resolution is 144 Speaker Rays per driver surface sample per edge sub line.

- 12) **A four position Single Button** selects Enclosure Diagram Size. These four selections change the scaling of the pictorial design diagram.

- 13) **A four position Single Button** selects Graph Line Weight. These four selections change the clarity of the pictures, which varies between systems with different Operating Systems, Version of Excel and Screen Resolutions.

In general there are a great many logic rules that the program follows that attempt to steer the user away from erroneous simulations and conclusions.

First, no off-axis angles are permitted when less than 2 feet axis distance.

Second, no baffle tilt is permitted when using Ribbon Tweeters.

Third, Ribbons can only be modeled in either Diameter or Combined Radiation Models and the program will correct to the proper Model that during recalculation.

Fourth, Radial Ribbon Models can only be used with the Combined Radiation Model.

Fifth, Hitting Recalculation ends automatic mode.

Sixth, Automatic Mode prevents Rounded Edges or Over-Sampling, and they do the same.

Seventh, Asymmetrical Edges cannot be used with Sharp Edge Mode.

Eighth, three of the four charting positions hide the "Magnify" and "Line Weight Controls".

Ninth, You cannot select Diameter and Combined Radiation Sources until Advanced Frequency Support is loaded.

Tenth, You cannot select Rounded Edge until Basic Frequency Support is loaded.

Eleventh, You cannot output or Compare Responses until Basic Frequency Support is loaded.

Twelfth, You cannot output or Compare Responses if the driver directly required (or for support of its group) are turned off.

Thirteenth, the graphs for Mutual Radiation, Axis SPL or Power Sum will not display until all the required drivers are turned on, and will not be correct until after a Recalculation.

Fourteenth, Changing the level of Frequency support always resets Recalculation to Manual, Over-Sampling to Standard, Radiation to Point and Edge to Sharp.

Fifteenth, all numerical values have both simple and complex value limits. To maintain these limits, values will either hit boundaries and/or be reset to that boundary or reset to the center of that control's range. Typing values outside the range will do this as well.

Historical Engineering and Unwritten Rules

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This project started out as a Triangular baffle simulator. Later it was expanded that to include Truncated Pyramids, and later still, Pentangles. Quadrangles were last, because they:

- 1) Were done by other programs already.
- 2) They are uninteresting or lesser so that non-rectangular shapes
- 3) They tended to violate the geometric basis of what had been used to derive all of this

To make a huge story shorter... All of these shapes started from a fixed Apex (real or implied), that sat at 0,0. So there was no logical reason that the left points ever needed to touch or cross the X zero line and the same with the right points. So X anything equals zero is invalid. In fact the Shape Enforcer will repel X values away from the zero line and repel points away from each other if they are close to zero and near each other.

The same applies to the Y Axis. Since the Apex was always at 0,0.... it never made much sense to have boundary corners very close to the Apex (for the Triangle and T-Pyramid at least). So the Shape Enforcer does not want to see the near corner closer to zero than $Y = 1$, and the Far corner closer to zero than $Y = 5$. In addition, there will be point repulsion between the top and bottom, as they get closer than a certain amount. This amount is different and governed by "rule sets" that are not the same for each shape, and further is enlarged by a multiple of the edge thickness. So as you crank up the edge size the corners will sometimes push further apart in an attempt to try and continue to make a rational (and buildable) baffle shape.

You should also note that putting the far corners above the near corners would be a geometric "no no", as that would force the program to extend the inner edge outside the outer edge. The Shape Enforcer handles that pretty well.

But the Shape Enforcer only runs when you click on the value spinners or terminate a drag operation. Typing in numeric values does not "run through" the "design rules" until you either spin, drag or recalculate (principally because it is a real pain to have the program monitor cells for activity as opposed to react to button pushes).

So in general, keep the left X values negative, the right X values positive, the Y values 5 units or more down (or up) from zero and keep the far corners further away from zero than the near corners and everything will make visual sense. BTW, I have no such test for driver

placement. You can put drivers on the outside of the baffle or straddling the edge. Nothing will correct for this. But your results will make absolutely no sense when frequency graphed.

Other Minor Details:

File is 500K in a self-extracting zipped exe format

File is 3.5M after extraction

In Memory image is 24, 33 & 45 MB respectively.

Near versus far reflection for Chamfer is set as angular expansion ratio squared or 56 percent for near and 44 percent for far reflection magnitude. Rounded approximation weighting is derived as a set of cumulative reflection energies linearly shared and multiplicatively applied to the weakened and decreasing wave-front around the edge according the angular dispersion define by Acoustic Reciprocity for the angle of edge department. This methodology is referred to as "Bounce Chasing" and the rounding derivation as "[Cumulatively Distributed Acoustic Reciprocity](#)"

All pages, macro VBA code, Global, Worksheet and Local Formulas are readable and nothing is hidden. The first two pages are protected with a password to prevent accidental disturbance of Chart parameters and Active X Controls, which readily lose macro references, formatting and placement, without protection. The page protect is absolutely required to use the dragging functions, otherwise, attempts to drag will not move the objects but instead the chart gridlines themselves. Macro VBA code activity, selectively and conditionally locks and unlocks the charting and other section parameters during execution, so a casual password unlocking is transitory without the proper simple change. All formulas and Macros are user changeable. If for some reason the user needs to modify anything on the first two pages, please contact me and I will send the procedure for toggling those interactive locks.

How does it work?

Theory of Operation

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In truth, this has to be the very first software development project that I have worked on in more than a decade where I had absolutely no clue where and what I was going to end up with when I started. I do not mean the results of the simulator only; I also unfortunately mean its features, layout and internal structure. Talk about Blue Sky-ing it.

I think that point is key. The simulator evolved in a very piecemeal fashion (because I did not move on to the next derivation until I felt closure with the present one) and with a vertical feature structure (read that as mutually exclusive objects).

What started out as a study in randomizing the distances from vertically movable speakers (by numerical typed value) on a triangular shaped, sharp edged baffle, evolved into a Triangle and T-Pyramid with H&V mobile drivers on a dual edged (beveled) baffle to show frequency cancellation and reinforcement. Later it generalized to polygon shaped baffles, with multiple piston surface path time smear (to the baffle edge only) and separately added mutual radiation for small driver groups amongst the direct-wave projections. After that, curved edges were added. After that, single driver On versus Off Axis Differential Gain based on a non-conical far field radiating driver for any given Diameter. Each of these approximations is mutually exclusive and separately developed, like buying each of the pieces needed to construction your house (bathtub from this supplier, roofing shingles from someone else). The thing you cannot assume is that all of pieces are there or that there ever was a master blue print.

So what have we developed?

Selective Reality. Interactivity (speed) is inversely proportional to Precision. The user chooses which physical domains are associated with what level of modeled complexity. With up to five samples per piston surface, up to eight Virtual edges per composite edge, up to 4X angular interpolation or 144 directional rays per instance at 400 frequency distance transforms..... that is 2.3 Mega Cosine Integration's per Driver. That is without the Directional Bessel Transforms, the Initial Slope Intercept Plotting, the Axis Triangulation or Mutual Radiation Calculations. With those included and all five drivers turned on, we are talking about 16 million Trig functions per plot, or 1 million at 16 passes through the Distance Frequency Engine. With a single point source Driver on a sharp edged baffle at standard sampling we are doing 1/800th as much computation, which is how you can drag and drop and/or spin in auto-calculation mode to find the sweet spot for a tweeter left to right in under 30 seconds.

The selective reality approach is very hard to manage, as all of those permutations are switches through the process. But if I just let coefficients fall to 1 or 0 or infinity, the calculation times would remove the tool from useful status. As it stands currently, I can get screen updates for simple operations of a 733 Mhz processor in well under a second. I seem to get five "Diameter drivers" with a beveled edge and Standard Sampling to calculate in about 7.5 seconds. Five, Complex Rounded, Combined Source Radiators, with Quadruple sampling takes just about two minutes. The user selects this. If you want to simulate an offset tweeter, the fastest method to find the best baffle location is probably not turning everything on and running a dozen simulations, that would take a half hour. The best way is to turn off all the drivers except the tweeter. Using Automatic Recalculation for a Point source driver on a sharp baffle edge, center the driver and hold down the driver Horizontal displacement spin button. Once a second the graph updates. You will see the response start to smooth. When the response starts to ripple more, back up two clicks. Turn on Complex, Quadruple, Combined and the rest of the drivers. Select the edge rounding size that you intend to use. Push all baffle four corners outward away from the tweeter one half that edge size amount (to re-center the driver to median edge distance). Hit recalculate. Two minutes later, you have your projected Diffraction response; Ten times faster than doing it brute force.

This methodology is not precise. It is informative. I hope it is useful. But it is not always perfectly accurate. It is an enormous list of approximations. Some of the approximations are really superlative. Some of them are just sufficient. Many of them really suck. Cumulatively, I believe they tell you effect the baffle should have on your drivers.

Let's walk through the various part of the simulator to become better acquainted with the both the process, technique and the terminology.

Driver Radiation Models

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Unlike what you might expect, when you choose a "Point Source", you do not get a very small diameter, you get, that's right, a single point source. The distance from the point source to baffle edge to the user selectable axis point is found for each of 36 speaker rays fired from the center of the driver. The path of the direct wave to the listener position is also found and subtracted from the baffle path, yielding a distance delay. This delay for each frequency is converted to a frequency response via a straight Time/Frequency to Phase Cosine process.

If you instead choose a "Diameter Source", then that same Point Source delay distance is used. In addition we divide each piston with four parallel chords to create five regions, with the driver center, centered in the middle most region. We calculate the vector center for each of the five regions and the area associated with each region. As these five vector centers lie along a diameter perpendicular to the four chords, these five points reduce to a scalar displacement (from driver center) and a scalar relative magnitude (area influence). As we fire rays from driver center these four chords always remain tangent (perpendicular) to the fired

ray. We subtract or add the displacement from the point source differential to user distance (as each rays just starts its journey along the same path a little earlier or a little later). The five weighted samples are summed separately for each ray angle and after each frequency cosine integration. We also do some dithering by moving two of the chord lines relative to the center, to remove the symmetrical displacement and the associated harmonic relationship between the five surface samples (Leave the center and end points alone and move the in-between points different amounts in opposite directions actually).

Now, if we use a "Directional Source" Model, than again we are only using a Point Source for the baffle diffracted components. But we are doing an "Infinite Set Summation" to determine directivity of the piston. The actual transform is over my head, but I have confirmed that I am using the formulas correctly. It is a real/imaginary number Multiplication of a Bessel Function for the cosine fall-off, a good bit more exact than five weighted surface samples, I would think. It is for a round piston of a given diameter, so the H to V aspect is fixed at one. As I said, the math proof behind it is over my head, but I do understand that physical displacement of the radiation points that create peaks and nulls by phase addition.

We are using the Directional integration as only a gain function. We do this integration for each driver at its uniform diameter at each frequency. We perform this at the User Selected Axis (angle) and at the baffle wave angle (90 degrees off of perpendicular to the baffle), dividing one over the other to get a differential gain. Now that would be all we would need to do if we always remained on-axis. This Ratio that we just created by comparing the magnitude of the user selected axis to the baffle traveling wave is always greater than 1, if we remain on axis (perpendicular), because no side lobe is ever greater that the on-axis magnitude for any single given frequency. But this is not so, as our user selected axis is displaced from perpendicular. Now the User selected axis may be at a null point for some frequency because of the off axis lobbing, which would potentially create situations where the baffle traveling lobe would appear to be stronger then the user selected axis and the magnitude of the ratio would drop below 1. So to compensate, we next filter (rather we limit this) to a minimum gain of unity and a maximum gain of 200 so that on "user selected axis" a small null does not become a wildly inaccurate diffraction gain. This response is a magnitude multiplier (actually a divisor) for the diffraction component set.

The "Combined Source" model (or [Real Model](#)) of course uses both the above approaches together in a limited vector sum: small set average time smear of the baffle component and differential gain of the direct to diffraction component by the infinite set integration.

For the Math inspired here is the Basic Cancellation Math basis and the Directional Model (all others might just want to **SKIP AHEAD** :^)

The basic formula for a single (N) edge reflection was derived from Andy Unruh's White Paper, starts out simply with:

*=Cosine [([(Sample Frequency * Delay Distance) – Reflection Phase Offset] / Speed_of_Sound) * 2 * PI]*

Each of the N edge sources would have a strength of $-1/(2N)$ for a flat baffle.

For the Directional Model we perform an infinite set summation on the piston surface to develop gain coefficients for each compared angle:

The excel math looks like this:

```
=IMABS(IMPRODUCT(COMPLEX(0, Kval*PisRad^2*0.00012*Speed_of_Sound),  
IMPRODUCT(IMDIV(IMEXP(COMPLEX(0, Kval)),COMPLEX(1,0)),  
COMPLEX(BESSELJ(Kval *PisRad*SIN(Angle), 1)/(Kval *PisRad*SIN(Angle)),0))))
```

Where Angle is either 90 or

= (ASIN(SQRT(SIN(RADIANS(AxisAngle))^2+SIN(RADIANS(TiltAngle))^2)))

$Kval=2*PI*Freq/Speed_of_Sound$

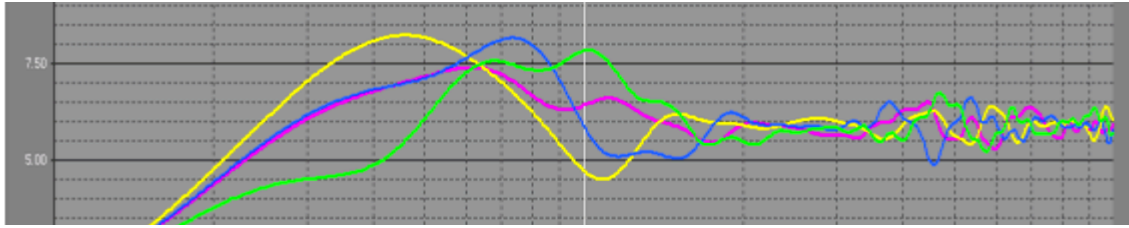
Edge Approximations

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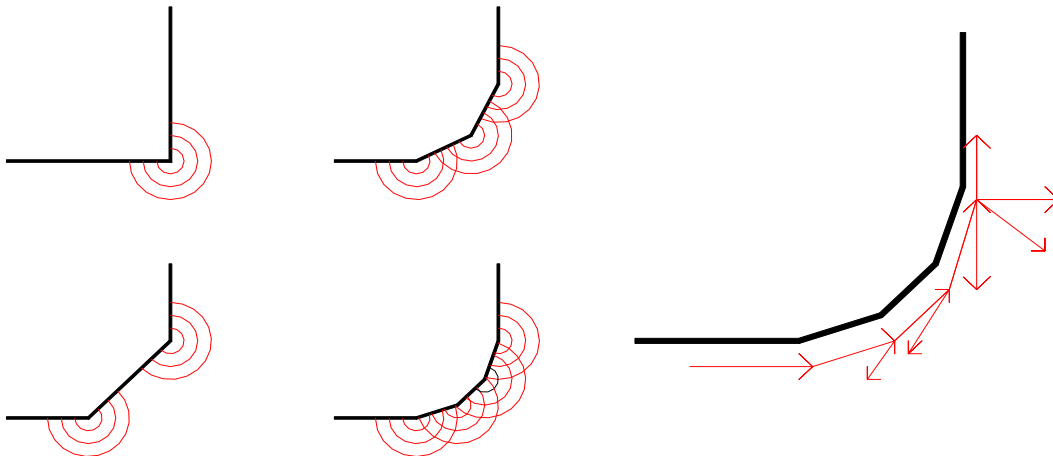
If you sharply turn a baffle corner, there is a pressure change that sends a reflection back at the listener, which arrives late and causes a comb filter frequency effect. If you turn that same corner, and instead of finding a single 90 degree sharp turn you pass over two 45 degree sharp edges forming a bevel, you create two such filters. The distance to the median point between those two edges is the center of a notch-filtering band. The distance between those edges is a width of notch effect. The item filtered by that notch filter is the cancellation of the comb filter like warbling. In all actuality, it is a beat frequency pattern, not a notch at all. The first nodal destruction is a half wavelength sum and the periodicity is every harmonic thereafter. But it still resembles a notch-filtered band, and as that is the way it appears when you view its effects in the frequency domain, so I improperly refer to it as a notch filter.

So. If you sharply turn a baffle corner there is a reflection that comb filters. If you turn that same corner with a two sharp edges forming a bevel you create two filters. The distance to those two edges is the center of a notch-filtering band. The item filtered by that notch filter is the cancellation warbling. For that narrow region there is significant cancellation of the comb filtering effect because there is a destructive phase alignment of the two reflecting filters. Above that frequency and below that frequency you see increased evidence of the combing effect. Below that region the phase difference is not significant (they remain correlated) so the two reflections sum more or less. Above that region the phase difference is again changing with frequency and so appear to be uncorrelated, so they sum and difference at the harmonics of the notch but for only tiny frequency windows and with only a modest amplitude effect in total. In the graph below, notice the Region around 2800 Hertz. Neat picture huh?



Now add a third edge in between and along an imaginary curved edge; a very crude approximation of one, anyway. The notching remains mostly unchanged, but an octave higher another notch appears because the distance between the middle edge and the outside edges is now half. Since there is one delay between the two outside edges and two delays between the inner edge and the outer edges the cumulative effect is nearly twice as great at the higher frequency.

Add and redistribute a fourth edge line. Now the fundamental node and the second and third sub harmonic of the destructive alignment of the edge time delay are present. The frequency notch band moves wider and higher. See the trend?

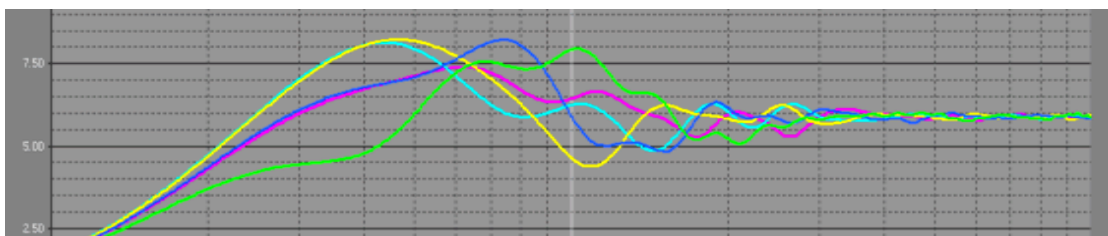


Now factor in the next item: If these edges were not separate but part of a combined rounded transition then the total amount of reflected energy across all inner and outer edges remain constant. So not only is the physical separation of these sub edges introducing phase differences that partially nullify each other at higher and higher frequencies, but (for rounded surfaces) the individual magnitude contributions for each of these sub edges are getting smaller as well. This is to preserve the law (rules) of "Acoustic Reciprocity". Simply put, the total reflection magnitude is only related to the angle turned, because the reflection is loading (re-radiated) into a certain sized space determined by that angle. So call this multiple sub edge addition, where the sum of all interpolated edges always adds to the same value: "Distributed Acoustic Reciprocity".

Now for the last piece: As the wave-front encounters an edge, its reflected energies rob the initial wave-front of strength (phase cancellation), generating a new reflection and

weakening the initial wave as it travels to find the next edge. Each of these reflections may also encounter other edges after being reflected which in turn would be re-reflected again. Each time this happens the initial waves and early reflections weaken and new smaller reflections form. These reflections sum in time steps. The delay in these time steps is always nearly equal to the distances between the edges. (geometric grain of salt please... I assume that the reflection can be described well enough in the time domain by dividing them into two discrete sets; those moving away and incurring additional time delay and those moving back toward the listener and incurring no additional time delay relative to the direct wave. So I am avoiding the complexity of triangulation of those differential delay times along the edge's curvature.)

I refer to this reflection magnitude tracking process as "Bounce Chasing". All we really do is create the summation of relative magnitudes for each time location along the edge. In the simulator, a simple approximation of the edge would be four lines, two real and two interpolated, and a more complex approximation eight lines, again two real and six interpolated. With this table of magnitudes, we run each of these delayed edge pairs through the reflection frequency cosine process and weight accordingly. So, call this complete operation, that of subdividing the wave-front's total energy and then tracking the re-apportionment of the subsequent recombination of the reflections and refractions at these discrete time steps: "Cumulatively Distributed Acoustic Reciprocity".



In the end, you have a notch filter with increasing gain at higher frequencies with a bandwidth that exceeds the pass-band, which I believe is damn close to a low pass filter :^) It actually resembles a shelf function like baffle step, and un-loading if you will, because both end asymptote to a fixed value or gain. Below the knee of that filter are those frequencies whose mutual or self-interference yield only reinforcement in all directions and the strength of the reinforcement is virtually nil because of the tiny phase variance.

Notice that the roll-off begins at a higher frequency, with the rounding approximation when compared to the chamfer or bevel. The reason for this is that the average distance between lines is smaller for the rounded section; something approaching approximately half. So the frequency effects tend to start between a half and a full octave higher. This is in spite of the fact that the edge rounding, as physically measured is actually a little bigger (the Chamfer is measured in linear separation (displacement) along the edge and the rounding as the 90 degree arc distance for that radius). Also notice that the transition region is also between a half and a full octave, depending both how you measure it, but also on the number of interpolation lines used. More accurate results with higher line densities show less attenuation below the knee, more above the knee and a slightly more rapid transition.

This is just a suggestive thought process behind explaining Diffraction Based, Baffle Step Gain fall-off, with little to no measurable edge reflection that you would normally observe on a heavy rounded baffle edge or near spherical baffle shape. So the impedance, as you might describe it, is another way of saying the phase summation across the surface has a constant null behind the baffle at frequencies higher than the filter cutoff and no null anywhere below the cut-off established by the edge wavelength.

When we calculate a "Sharp Edge" baffle, there is only one distance from each of the surface samples to be concerned with. With a "Chamfer Edge", there are two. When doing those [Rounded edge approximations](#) we just recursive line pairs that are equal distances apart between the inner and outer edges. We actually loop, weight and sum, twice for "Simple", and four times for "Complex". The derivations for the weighting are the real brainteaser part of the job (If really interested see below). For the "Simple" coefficients we are performing 1st Order reflections with up to 3th order secondary refraction's. For "Complex", the coefficients are based on either 1st or 2nd Order reflections with up to 7th order secondary refraction's. Each iteration is another instance through the cosine engine calculations previously described, with each pass carrying both an inner and outer edge weighting factor and each pass having its own relative weighting for that pair's overall influence as well. As this iteration is only dealing with the diffracted elements, the direct wave continues to remain a constant. Again this is only an approximation of a rounded edge and the process of choosing the methodology is atomic and separate from the Source Radiator.

For the Math inspired here is the base derivation for Cumulatively Distributed Acoustic Reciprocity, (all others might just want to **SKIP AHEAD** :^)

*If a 90 degree edge transition reflects: $-(4*PI()/(4*PI()-RADIANS(Angle))-2)/2$ approximately 0.4286 of the initial wavefront (for the moment lets temporarily substitute the value that all diffraction software and formulas use: 0.50*

Then each of the angular subsamples would each contribute the same relative (multiplicative) reflective component that in total would yield the same final resultant wavefront:

For one edge: $1 - .5 = .5$ or $1 - x = .5$

For two edges:

*$(1 - x) - [(1 - x) + (1 - x)(1 - x)]$ or $(1 - x) * (1 - x) = .5$ or $1 - x = \text{sqrt}(.5)$ or $x = 1 - \text{sqrt}(.5)$*

thus $\text{sqrt}(.5) = .707$ $x = .2929$

First post - reflection strength : Next reflection : Final Strength

*$1 - .2929 = .707$: $.707 * .2929 = .207$: $.707 - .207 = .5$: $1 - .2929 - .207 = .5$
so generalized: $x = 1 - (.5^{(1/N)})$ where N is the number of samples*

For three edges; $x = .5^{(1/3)}$ So...

$$1 - .206 = .794: \quad .794 * .206 = .164: \quad .794 - .164 = .63: \quad .63 * .206 = .13: \quad .63 - .13 = .5$$

$$1 - .206 - .164 - .13 = .5$$

Substituting Acoustic Reciprocity back in:

$$\text{Individual Reflection Magnitude at each sub-sampled inner edge} =$$

$$1 - [(-4 * \text{PI}() / (4 * \text{PI}() - \text{RADIANS}(\text{Angle})) - 2) / 2] ^ (1 / N)$$

Plugging this into the bounce chaser:

For Three Edges:

Time Delay Inner strength= Reflect1

Time Delay Middle strength= Reflect2 + Remaining1(Reflect2)

Time Delay Outer strength=

$$\text{Reflect3} + \text{Remaining2}(\text{Reflect3}) + \text{Remaining1}(\text{Remaining2}(\text{Reflect3}))$$

A more detailed approach breaking that down into a uniform radiation element:

For Three edge Time Domains:

$$\text{TDS1} = \text{RefTrans}(\text{Ang})$$

TDS2=

$$(1 - \text{RefTrans}(\text{Ang})) * (\text{RefTrans}(\text{Ang})) +$$

$$(1 - \text{RefTrans}(\text{Ang})) * (\text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang}))$$

TDS3=

$$(1 - \text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang})) * (\text{RefTrans}(\text{Ang})) +$$

$$(1 - \text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang})) * (\text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang})) +$$

$$(1 - \text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang})) * (\text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang})) * (1 - \text{RefTrans}(\text{Ang}))$$

So, generalized:

First edge is First Reflection

Second Edge is Reflection * (Post Reflection + Post Reflection squared)

Third Edge is Reflection * (Post reflection Squared + Post Reflection Cubed + Post Reflection to the Fourth)

And so on.....

So for N Samples, That would be the magnitude list from

Time1 = Inner Real Edge to Time1 + (N * Delta Time)

where Delta Time = (Outer Edge Time - Inner Edge Time) / N

Which for an eight line approximation in Excel Math is a series that looks like this:

The edge reflection magnitude is edge8flect:

$$\text{edge8flect} = 1 - [(4 * \text{PI}() / (4 * \text{PI}() - \text{RADIANS}(\text{TotalAngle})) - 2) ^ (1 / \text{Number_of_lines})]$$

..... the remaining field strength of the continuing wave is $edge8cont$:
 $edge8cont = 1 - edge8flect$

1st edge time magnitude = $edge8flect$

2nd edge time magnitude = $edge8flect * (edge8cont + edge8cont^2)$

3rd edge time magnitude = $edge8flect * (edge8cont^2 + edge8cont^3 + edge8cont^4)$

4th edge time magnitude =

$edge8flect * (edge8cont^3 + edge8cont^4 + edge8cont^5 + edge8cont^6)$

5th edge time magnitude =

$edge8flect * (edge8cont^4 + edge8cont^5 + edge8cont^6 + edge8cont^7 + edge8cont^8)$

6th edge time magnitude =

$edge8flect * (edge8cont^5 + edge8cont^6 + edge8cont^7 + edge8cont^8 + edge8cont^9 + edge8cont^{10})$

7th edge time magnitude =

$edge8flect * (edge8cont^6 + edge8cont^7 + edge8cont^8 + edge8cont^9 + edge8cont^{10} + edge8cont^{11} + edge8cont^{12})$

8th edge time magnitude =

$edge8flect * (edge8cont^7 + edge8cont^8 + edge8cont^9 + edge8cont^{10} + edge8cont^{11} + edge8cont^{12} + edge8cont^{13} + edge8cont^{14})$

Slope Intercept

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For each Driver we fire rays from driver center every 10 degrees and see where in space that ray intersects with each of the 3, 4 or 5 sides of the baffle. A boundary test for "X" values and one for "Y" values determines if the ray is firing into the proper quadrant and thus whether the measured distance is valid for that direction on that edge. Those tests are defined as named equations "Xt" and "Yt". (Believe me it was easier doing it this way than determining if the slope of the line was inside or outside the current side's corner :^). Since the driver can be moved vertically and displaced horizontally, each sample requires X-Intercepts recalculated for each fired ray. The X-Rise and Y-Rise are derived from the Sampled angle.

On each Driver page there are in two table blocks. The first is to measure the distance to the Outer edge of the baffle, and the second to the Inner edge. These are also subdivided into five calculation regions each for up to the five possible baffle edge sides. Depending on the operating mode there are four types of baffle shapes that we need to track the distances for:

An arbitrary Anchored Planar Triangle is a Three Sided Baffle with a Fixed Apex and two Movable Corners. All Screen numbers are relative to that Apex.

An arbitrary Anchored Planar Truncated Pyramid is a Four Sided Baffle with an Implied Apex, two Movable Corners and two Height Adjustable Corners. All Screen numbers are relative to the Implied Apex.

An arbitrary Anchored Pentangle is a Five Sided Baffle with a Fixed Apex and four Movable Corners. All Screen numbers are relative to the Apex.

An arbitrary Unanchored Planar Quadrilateral is a Four Sided Baffle with an Arbitrary zero point and four Movable Corners. All Screen numbers are relative to the Arbitrary zero point.

For the Math inspired here is the Slope Intercept Calculation (all others might just want to **SKIP AHEAD** :^)

The basis of the distance measurement, is that there exists three, four or five lines with an $Nx + My = z$ function. First, determine the $X=$ zero crossing. As the Apex is anchored at 0, 0, for a triangle the apex accounts for two of the sides $X=$ zero crossings (by definition), and the opposite side bar the crossing is computed by a slope intercept. For a T-Pyramid the left and right edges lead to the implied Apex and are treated the same way as the triangle. The base and top are both slope intercepted in the same manner as the triangle. For the Pentangle the top left and right edges adjoining the Apex are treated like the sides of the triangle. The remaining three sides are slope intercepted. The two lower sides away from the apex are prevented from ever achieving vertical (infinite) slope by a tiny (1×10^{-16}) offset. For the Quadrangle, all four sides are totally independent with the same offset prevent infinite slope as well. Once the X crossing is known, that value is used as Z constant in the above formula. Do a simultaneous equation for the $[X, Y]$ for each corner of a line and that establishes the X and Y coefficients. This is solved with a simple matrix.

$X1, Y1, \text{intercept}, \text{MMULT}(\text{MINVERSE}(B7:C8), D7:D8) = x \text{ cof}$
 $X2, Y2, \text{intercept}, \text{MMULT}(\text{MINVERSE}(B7:C8), D7:D8) = y \text{ cof}$

With the X and Y coefficients determined and the Z value (intercept) already known, then we can solve for X and Y and find for the crossing point of any ray as it hits any line in space. The solution in the spreadsheet is (in excel lingo) the MMULT of an MINVERSE for any two variables and one constant statement using a two by two matrix; the first line being the speaker ray and the second line being the baffle edge.

All the driver pages use the 36 angular samples by setting the distant terminus point of each speaker ray at some very large distance away from its origin and using simple tangent function values for every 10 degrees and flipping and inverting and subtracting as required. Each of these are generated using the same MMULT/MINVERSE function to convert the start and end points to X intercept, X and Y coefficients. Then the ray and lines are crossed, with the simultaneous Linear Equations again.

*Xbafcof, Ybafcof, edge intercept, $MMULT(MINVERSE(B7:C8),D7:D8) = x \text{ bafpnt}$
Xraycof, Yraycof, ray intercept, $MMULT(MINVERSE(B7:C8),D7:D8) = y \text{ bafpnt}$*

If the ray is heading off in the wrong direction, an arbitrarily high distance value (9999) is substituted (this is done with a quick boundary value test, Xt, Yt). The smallest ray length to each of the three sides of the triangle is chosen as the real one and its distance value entered into the angle table.

If the smallest value is the substituted 9999 maximum, then that implies the center of the driver is outside the boundary of the Inner or Outer Baffle edge or beyond the cabinet. Though this is clearly an error, the way to best represent it and to cause the least disturbance to the response is to perform the same smallest value test to each baffle side, this time ignoring the Xt, Yt quadrant boundary test (since we are now on the wrong side of the baffle edge, so the quadrant will be wrong in half of the angle cases). This yields the diffraction distances that hits the nearest outside edge of the baffle and is both logically, operationally and close to being acoustically correct.

In addition, we also “tag” each radial sample with a Boolean value that indicates whether that measurement is from an edge that is part of the set of edges controlled by the primary or secondary edge size. If the user chooses to use “Asymmetrical Edges”, this changes the distance triangulation calculation downstream.

Angular Over-Sampling

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With only 36 Equal Angular Samples I decided to run some simple tests. I compared the response of three or four same-sized square baffles each with a centered single point source radiator. The only difference between the tests was the rotation of the square baffle. I have a feature in the simulator that does a "Compare" function that lets the user recall a previously stored .FRD file and subtract it from the current simulation and see the difference between them. When I ran two of these rotated squares through this process, I [saw a difference](#). This difference resembled a sine wave with growing amplitude with increasing frequency. This difference was radial sampling error from the 36 samples. We needed a way of controllably increasing the number of radial samples depending on the baffle shape and size we are

simulating and the design stage we are in. For most things the 36 samples are sufficient, but when a higher resolution is required we require a way to Over-Sample.

The Over-Sampler is just an inter-sample interpolator based on Bisecting the angles. It does a clockwise and a counterclockwise extrapolation to determine if we have hit or missed a corner. If both directional projections both do not match the slope-intercept measured value by a certain percentage, we do a half angle extrapolation (in each direction) instead of an inter-sample interpolation. The lesser of the two directional extrapolations is the one that lands on the line half way between the two missed corner wraps. Using this method, I generate either double or quadruple the number of angular samples (72 samples at 5 degrees or 144 samples at 2.5 degrees). Using the same method as above, I run these same sets through the cosine frequency engine either twice or four times. The sample gain coefficients are all the same, unity, unlike the edge stuff. The summations, like the edge are done by VBA software automation by a copy and iterate process. The accumulation occurs on the "Cancellation pages" for the Sample multiplying and the accumulation is on the "Radiation page" of the weighted Edge multiplying. Again this is only a simple sample multiplier and only applies to the diffracted component and not the direct wave components.

Another important observation that I have made since adding over-sampling is related to what I thought I was trying to prove with the simulator early on when it was just dealing with triangles. It seems that until you increase the angular sampling rate, you fail to see a good deal of the benefit from sloped sided baffle shapes. The improvement with rectangles is small with the increase sampling accuracy. But the differences between rectangles and T-pyramids are a somewhat more evident with double and even quadruple over-sampling. It is nice to note that there was at least something logical about my initial premises.

The combination of the edge iteration with double weighted (inner and outer) summations and the unity gain sample iteration is either 1, 2, 4, 8, or 16 passes through the dual edge cosine integrator (using either 1 at unity, or 5 weighted samples, with a triangulated average sample gain) (with or without a Directivity Gain weighting). All of these elements are separately compartmentalized and separately introducible.

Triangulation Delay & Average Gain

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The process of converting driver center to baffle distances to differential baffle wave distances is the process of mapping delay. Another way of looking at this is to convert the 2D distances along the baffle to the 3D distances to the listening position. The process starts by setting up a Law of Cosines triangle in the horizontal plane to deal with the Axis distance and a second Law of Cosines triangle in the vertical plane to deal with Baffle Tilt. This is such a triangulation for both the inner edge and one for the outer edge. The outer edge also needs to

add in the difference between radius and arch length along the baffle edge and need to track which edge size is involved to do so.

Part of the Triangulation is to then subtract the edge rounding and direct wave distance for the total. So the final distance is not the distance from driver center to baffle edge and then to the listener, but that figure minus the direct path to the listener, so these figures are really the additional time required to reach the listener or the delay. It is this delay that has the impact of the phase cancellation at the listening position.

The excel math looks like this:

$$= (\text{SQRT}((\text{AxisDist}^2) + ((\text{Bdist} + (\text{IF}(\text{SecondEdge}, \text{ERadOff2}, \text{ERadOff})))^2) * ((2 * \text{AxisDist} * \text{Bdist}) * ((\text{SIN}(\text{RADIANS}(\text{SampleAngle}))) * \text{CAxisOff}) + ((\text{COS}(\text{RADIANS}(\text{SampleAngle}))) * \text{STiltOff})))) + \text{Bdist} + (\text{IF}(\text{SecondEdge}, \text{ERad2}, \text{ERad}))) - \text{AxisDist}$$

Part of the process is also to setup a ratio of the average diffraction distance as compared to the direct wave to arrive at a magnitude of the diffraction contribution. This ratio forms the basis of a square laws fall-off to compensate for the proximity of the listener to the baffle. It also provides a platform to handle variance to that distance for each paths elongation.

Ribbons, Close Measurements, Off-Axis and other Sources of Error, Reasonable Approximations, Guesses and Novel Corrections

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The three largest errors in the diffraction simulator are all related to a single design decision made at the very beginning. The reason for these limitations is rather simple. We are using equal angular radial sampling. We fire a ray every N degrees and see what we hit, measure the distance, triangulate to the listener position and determine an absolute time delay.

The first error is the limited number of angular samples, which we have attempted to correct with the Over-Sampling Interpolator, described above. Please note that the original applied correction (Beta 5.8), even though we were accurately interpolating and extrapolating the inter-sample edge distances, we were still manipulating the measurement axis triangulation based on the original 36 directions. So although the two times or four times the number of samples reduced the edge dx size, the law of cosines used to find the target distance was still constrained to a 10 degree radial increment accuracy. That has recently been extended to the full Over-Sampling Angular precision (10 degrees for Standard, 5 for Double and 2.5 for Quadruple Sampling).

The second error type is that either long aspect ratio baffle shapes and/or off-axis measurements will not have an accurate magnitude component (frequency and delay are always accurate) when the axis distance is close, like less than 3 feet.

The third type of significant error is that of non-uniform pistons, like short line sources that have a different H and V size will not be accurately handled in their directional angle/gain versus frequency.

Again these errors are based on using equal angular radial sampling. We fire a ray every N degrees and see what we hit, measure the distance, triangulate to the listener position and determine an absolute time delay. Since all of the diffraction sources represent equal angles then they each carry the same unit energy until diffracted at the baffle edge. So since we use equal angular sampling there is no ray specific magnitude component. As long as the ray is traveling along the baffle surface it is rarifying in a uniform manner as all the other samples. When it reaches baffle edge the longer traveled rays hit a larger target, but the energy stays collectively uniform. Once diffracted, all magnitude bets are off.

In the simulator, the Gain between the diffracted set and the direct wave is arrived at by comparing the average total path distance for all point source diffracted waves versus the direct wave distance and applying a square law fall off. The only significant difference in their magnitude is the differential path length along the hypotenuse to the user position for each diffracted component. So if the differential path back to the listener is a very small amount longer or shorter than the other samples and the unity applied magnitude cannot be 100 percent correct for all the samples. The phase (time-distance) component is always accurate, since we precisely track distance of all paths from source radiator to edge to listener by triangulation using the law of cosines, but the magnitude is only uniform till the baffle edge is reached. The reason we use a collective average of all the samples compared to the direct wave and do a square law fall-off to predict what the average absolute diffraction component is, so as you get closer to the baffle, the diffraction component gets relatively softer.

The good news is that the triangulation path back to the listener is a trivially small percentage of the total differential path back to listener (when compared to the direct wave). So as long as the baffle is fair symmetrical, in H versus V or we are far away or we remain on axis, the magnitude component error per sample is very small. As long as the axis measurement point is at least three plus feet away and the measure is on or near perpendicular to baffle plane axis and the baffle aspect ratio is less than three to one, this magnitude difference is much less than one percent amongst the baffle samples. But for a narrow tower at 30 degrees off axis at a 1 foot axis distance, the gain components are way off (which is why the tool tries to prevent the user from doing off axis calculation under 2 feet). The aspect ratio problem by itself is less significant. If one tries and makes a 6" measurement on a tower system, the results may not be uniform, but then again the diffraction component is so far down (attenuated) that the baffle contribution is less than 1 db anyway, so the error is not relevant.

So, to correct for the above error, we added a very simple approximation for Post-Edge Diffraction, Triangulated Path Distance, [Magnitude Variance](#). This correction was the direct result of having to answer a Beta tester's request for an additional angular axis change, that of Tilting the Baffle top backward away from the user. The combined affect of the horizontal axis angle and the baffle tilt could place the listening position as much as 60 degrees off of baffle

perpendicular. Under these conditions, differential path delays would be much too large for the simulation to be accurate. Adding another full phasor sum into the array to make this minor correction was not an option. But since we already had a direct wave to average diffraction wave square law fall off represented downstream, it became clear that we could build a fairly easy and low computation scalar array of coefficients for each radial angle. Each coefficient would be the departure or "Variance" to the average and we could add this into the inner and outer edge gain as a secondary correction. Not perfect, but a great deal closer of an approximation.

The other (third) mentioned problem (source of error) is obviously short ribbons and multiple driver groups suffer problems because even with the H sampling bias on the linear sampled source, we are still over estimating the amount of energy that is hitting the top and bottom of the baffle. Notice that nowhere are we directly attempting to model discrete points on the piston surface arriving directly at the listening position and that the radiation source is always H to V symmetrical. This model prevents long aspect ratio devices, such as ribbons or multiple drivers from being calculated properly. When we model ribbons, in the Diameter Model, five surface samples arranged and fixed vertically are used. We actually slope intercept 3 of the 5 points (Near Top, Middle, Near Bottom). We then create (interpolate) and dither the two in-between points (total of five) to reduce Harmonic relationship effects. Next we further use another smaller dither component modulating radially (like for the pistons) but only scaled to the Ribbon's width. Since there are five times the number of coincident samples laterally (as opposed to vertically) there is the beginning of a radiational angle cancellation in the vertical plane. But this is only a tendency and is not an accurate magnitude depiction of the H versus V dispersion differences for non-symmetrical radiators. It a reasonable approximation, but that it all it is. In the Diameter Model, it is a somewhat optimistic diffraction projection when the ribbon is used with a long parallel edge baffle shapes traditionally associated with Ribbon use, but it does demonstrate the increased degrading effect of elongated rectangular baffles on near line sources when compared to the round pistons. Overall, ribbons on long parallel edged baffles suck (with no sloping or edge treatment). The tool in the Diameter Model shows that. But is probably shows it just a touch more optimistically than it should be.

To be perfectly honest, as an aside, I still do not have a complete understanding of the spectral effect overlap between the Infinite Set Magnitude calculations, used in the Direction Mode, and the physical based time smear, used in the Diameter Model, respectively. It is quite obvious that they serve somewhat different purposes and are best when both included in the simulation, as in the Combined Model. The errors in each domain are completely different in nature and effect and tend to cancel each other out. Their effects are only similar on-axis. But it is also clear that the linear sum of both approaches tend to "double up" a bit on the overall low pass effects, so some scaling is necessary when both are used together. The best I have been able to do is estimate that effective overlap and reduce accordingly. A clear math derivation to predict the overlap between these two techniques would help greatly to improve upon my empirical approach. Currently, when in Combined Model I reduce the gain of the Infinite Set Ratios by half.

Anyway, back to Asymmetrical Radiation sources. The same problem with Ribbons also applies to multiple driver groupings. The time-phase summations along the baffle edge are always very accurate. Within differential path tolerances those magnitudes differences on the diffracted components are trivially tiny, so are not really that much of an error. The Single

Driver Magnitude ratio of direct wave to diffracted wave is also close to perfect, but please remember that there is no real combined axis for multiple drivers for the direct wave. The two or more drivers share an imaginary perpendicular ray, which of course is not correct except in the extreme far field. There is no group triangulated measurement point. But the key here is that the diffracted component is reasonably correct.

I do not have an available correction for multiple driver groups, but again, I found a reasonably and straightforward correction for simple asymmetrical radiation sources, such as the Ribbon tweeter. As I stated above, for regular diameter drivers we use the ratio of the gain from the "user selected axis" divided by the gain at 90 degrees off of perpendicular to the baffle and get an attenuation index. We filter (limit) this index at unity gain and 200 times gain to remove the lobbing effects from generating wild diffraction predictions if the design axis happens to land on a null.

Well, for the ribbon tweeter only, and only when using both Diameter and Directional models (The Combined Model), we now also do a second Bessel Infinite set approximation. The first one is based on the Ribbon's Width, the second on it's length. We do the same "user selected" to off axis ratio with gain limits separately to both. Then we ratio the two resultants and limit their gain in the same manner. What we end up with is a coefficient list with rising frequency that is the difference between the general horizontal and vertical dispersion. We apply these coefficients at each of the 36 radial angles using a Cosine Squared plus Sine Squared of the radial sample angle, so that the vertical response tracks the greater attenuation index. This is basically an orthogonal cross of the two radiation patterns.

What I do not understand is how these two fields may be secondarily related. Accordingly, after some observation, I have given the user three slightly different ways of conceptualizing the potential interaction to the vertical and horizontal lobbing fields and their cross modulation influences. In the First Model, I assumed that the reduction in vertical dispersion had no effect on the horizontal dispersion. Putting that another way, the effect in the horizontal plane at zero degrees vertical has equal effects to the gain of the direct wave and the horizontal traveling baffle diffraction wave. Whatever the forward-firing gain from the cancellation in the vertical plane, there is an even distribution to the horizontal Radial Pattern. This would be a sum zero horizontally and a vector sum loss spherically in total diffraction available radiated energy. This is the default Model.

The second way of looking at this is that the vertical cancellation is maximal at zero degrees horizontal. Since the Orthogonal Cross favors the diagonal sums, it would not be a very surprising conclusion that the folding down of vertical energy may have a greater effect at horizontal angles further off axis than the direct wave. Putting that another way, the effect in the horizontal plane at zero degrees vertical has lesser effects to the gain of the direct wave than the horizontal traveling baffle diffraction wave. Whatever the forward firing gain from the cancellation in the vertical plane is an uneven distribution to the horizontal BiRadial Pattern. This would maintain a sum zero spherically in total available diffraction radiated energy. I find this Model most intriguing.

The third way of looking at this is that the vertical cancellation has maximal energy loss at zero degrees horizontal. So the folding down of vertical energy may have a greater effect on the center of the radiation pattern than at horizontal angles further off axis. Putting that

another way, the effect in the horizontal plane at zero degrees vertical has greater effects to the gain of the direct wave than the horizontal traveling baffle diffraction wave. Whatever the forward firing gain from the cancellation in the vertical plane is an uneven distribution to the horizontal SubRadial Pattern. This would create an additional horizontal cancellation by virtue of an increased forward firing gain, and thus total spherical energy "may not" remain sum zero, and a significant loss to all off-axis directions in ratio related to the dispersion difference. In essence diffractive available energy is the lowest of the three models. I find this model the least plausible, as it makes ribbon sources the least diffraction affected, something that I have not seen in anecdotal literature at all.

So depending on how we define the output to be "zero sum", we would need to apply most of the effect as a reduction of vertical diffraction magnitude and potentially a much smaller amount as the complimentary gain or additional complimentary loss on the horizontal set. So, we directly compared a dome tweeter and its ribbon counterpart on a very large, perfectly square sharp edged baffle with quadruple over-sampling in combined radiation mode and arrived at empirical values that seems to work properly for each of these three potential interpretations. The value is based on exactly $\sin(60)$ degrees or 0.86603. When we take the vertical to horizontal attenuation ratio and raise it to that value and invert it, it becomes a vertical lose factor, and take 1 minus that value (0.86603) or .13397 as the exponent and do not invert it that becomes the horizontal gain factor, we have created spherical zero sum diffraction energy. If the horizontal exponent is negative, we have zero sum total spherical energy, but with an increase of the forward firing gain of the direct wave and thus an effective diffraction loss. And if we only apply the full magnitude as a vertical loss with no change in the horizontal, we have zero sum radial energy and a small spherical diffraction loss.

So we have everything set up so that a single numerical change from .86603 to 1.000 makes the complete operation a subtractive affair, even though the diffraction signature is then .707 the amplitude in the ribbon versus dome simulations. Since I can produce arguments of equal apparent validity justifying all these approaches, I instead give the user a choice of which model they prefer to trust, as opposed to arbitrarily applying a fudge factor. The "Radial" Section is the default for Ribbon Operation. The "Radial" Selection assumes that the reduced vertical dispersion is only a vertical attenuation, creating no differential effects in the horizontal plane. Thus the Radial Model tends to show ribbons with less diffracted energy than piston drivers. The "BiRadial" Selection assumes a conservation of diffracted energy by re-apportioning a very small amount back in the horizontal plane. The "BiRadial" Model tends to show near identical diffraction energy level signatures for ribbons when compared to piston sources. The "SubRadial" Selection assumes a conservation of energy and a loss of total diffracted energy by re-apportioning a very small amount back in the horizontal plane as a further cancellation (or actually a lesser gain than to the direct wave). The "SubRadial" Model tends to show further reduced diffraction energy level signatures for ribbons when compared to piston sources. The "Spherical" Model is for piston drivers (and not for Ribbons) and assumes symmetry in H to V. All Selection choices are only available when using the Combined Radiation Source Model. Overall, the total effects of these three ribbon models are very small.

So, within bounds of reasons we have reduced three of the four errors major sources of Error: Angular sampling error, post-edge diffraction differential magnitude tracking error and ribbon based source asymmetry radiation error.

Mutual Radiation and Driver Groupings

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Which brings me to mutual radiation. I have never had a good way of approximating its effect. Since I do not have differential magnitude or point driven H versus V multiple driver radiator groups, I do not even have a starting place. The truth is those Mutual Radiation curves tell the user a great deal, that I believe would be very helpful to them even if there are some limits on what I can graph and what the user may conclude from that.

The goal of the simulator should be to give the user as much reasonable information possible. As you add drivers in multiple groupings the whole approach to Baffle Step Compensation and Subwoofer Integration changes. Whether or not you can see that effect on axis or not is maybe just a bit moot. To represent Mutual Radiation Frequency dependent effects on axis is inaccurate. To leave it out is somewhat misleading. From corresponding with the beta testers, I can tell you first hand, that half of them are planning MMT, MTM or Line array type projects. Mutual Radiation frequency response is very significant to this group.

What I have is just the superimposition two slightly different colored graph traces. The sum graph that has the Mutual Radiation effects and is named to "Off-Axis Power Response". The new graph overlaid in a slightly different color is called "On-Axis SPL Level" and is the same multiple driver summation without the Mutual Radiation effects. The difference in the two traces would be just the low frequency extension (and the interference warbling).

What I have not figured out is how to reconcile these two graphs as we move off the directly perpendicular to slightly off-axis. You would think that by 25 or 30 degrees the self-correlation would make them virtually identical. For what its worth, I have a big problem with a technically accurate representation of something that tends to leave out vital information, or worse, gives the wrong impression of what is actually happening. In this case, if I were to move maybe 5 degrees of axis, I would start to measure the frequency correlation cancellation effects. If I were just to listen to the in-room response while sitting on axis, I would hear that same low frequency response change in the reflection. See the conundrum?

I believe that when people ask about SPL at Madisound, they usually do so for a couple of reasons. Either they are trying to guess at the tweeter padding that would be required in the crossover, they want to know how much amplifier power they might need for their size room, or they are trying to estimate excursion and distortion in their Midbass when selecting their Sub Woofer crossover frequency and crossover acoustic and electrical order. In two of those three cases the power response (assuming no dipoles) would be more helpful, I think.

For the math inclined, the Mutual Radiation is calculation goes like this: (all others may want to **SKIP AHEAD**)

*The Gain is $10 * \text{Log Of } (1 + \text{complex frequency } (N-1))$, where N is the number of drivers in the array. The basis of N's frequency dependent gain formula is a*

$(\sin(KDF))/(KDF)$, where D is distance, and K is $2\pi/\text{Speed_of_sound}$.

For four drivers, for example, you would need to introduce all the inter-driver distances:

$D1-D2, D1-D3, D1-D4, D2-D3, D2-D4, D3-D4$

As four driver have a gain of four, each of these 6 distances have a weight of $(N-1)/(N-1)!$ or $1/2$.

So it looks something like this:

For $K = 2\pi/\text{Speed_of_sound}$ and

For $N = \text{Number of Drivers}$ and

For $D12, D13, D14$ as a $N-1!$ series of interdriver distances....

$\text{Gain} = 10 + \log \text{ of } [1 + ((N-1)/(N-1)) *$

$[(\sin(KF*D12)/\sin(\sin(KF*D12))] +$
 $[(\sin(KF*D13)/\sin(\sin(KF*D13))] +$
 $[(\sin(KF*D14)/\sin(\sin(KF*D14))] +$
 $[(\sin(KF*D23)/\sin(\sin(KF*D23))] + \dots$

Where do I find it?

Road Map to the Program

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Recently, I have found that maybe three out of four people interested in this diffraction tool just want to hit the buttons and nod or shake their head at the results. There is nothing at all wrong with that. And strangely enough, that "fourth" individual wants to know exactly what everything is, observe each individual effect and understand "why" in greatest intricacy. There does not seem to be a middle ground for that mildly curious and somewhat conscientious experimenter. Either the simulator approaches a totally trusted and nearly mindless tool, or it is a Classroom Instruction Manual, to be reviewed and then debated. Go figure. I am sure you have noticed this effect amongst the DIY crowd. Either "tell me what works, what I should do".... or "tell me why it works that way and leave me alone to figure it all out for myself". The world is bipolar, I guess. :^)

The introduction and the first section of this Manual is for the former crowd. The section you have just read through and this one is for the latter. Actually, this section is for the explorer who wants to dissect the work and see, not what it is trying to do, but rather, how exactly it does it.

There are two very separate parts of the program, the Spreadsheet itself, which performs the diffraction calculations, and the Visual Basic software that automates and controls it. The Software is written in vertical subject object modules dealing with a particular control domain:

BaffleShape EdgeType GroupType OverSample RadSource Units Drivers

AppIOClass ChartClass DragMoving FchartPos PictSize Spinners SpinLogic

Globals Swapper IO Freq Mode

The first row are the modules responsible for establishing state for each of the diffraction parameters they represent. The second row of modules specifically control button and extended display logic. The third row controls the overall program structure. "Freq", for example, does the spreadsheet repopulate function, coping and pasting almost over a half a million formulas into cells so that the program can be stored in a "striped" state. All the input and output of pictures, responses and profiles, and even the error logging are in the "IO"

module. The "Swapper" is the mechanism used to iterate through the spreadsheet when Rounded Edges or Over-Sampling are used, to keep memory requirements from growing exponentially.

The first row of modules is probably the simplest code, basically just changing button values, displayed messages and checking and resetting the operational state. The Second row is the most complex. With the exception of the "Swapper" (which is a bit complicated), most of these modules are entire extensions of the spreadsheet mouse, active-x and charting controls are designed from the ground up to supply a completely custom function to the user interface. The second largest class after IO is SpinLogic, which (fed by Spinners) controls all of those value spinners and the shape logic. The ChartClass and the DragMoving module together provide the drag and drop diagram design interface, and so on.

But the software, with the exception of the "Swapper" and "IO" are basically User Interface enhancements that come between the Buttons the users hit and the values and state of the spreadsheet. In general, the spreadsheet maintains the entire process, including state.

The Spreadsheet is not divided by vertical category but rather by horizontal flow. With a few minor exceptions, everything in the spreadsheet flows from the "Values" Page (the main page) through all the other pages in a huge loop and back to the "Values" Page. The Software is between the interactive charting and the numerical values and the buttons that control them, all on the "Value" Page. But the main function of the software is to observe and change the operational state of the "Score" page. The "Score" page (short for Scoreboard) maintains the state of the entire program including the VBA code. Basically the state on the "Score" page and the values on the "Values" Page ripple the entire calculation set of all the other pages.

The Basic flow through the spreadsheet is as follows:

Everything on all pages flows by the control values set on the "Score" page (so I will not repeatedly mention that "Score" is a precursor to all page flow conditional controls, so just assume it). You will get a great sense of what is really going on by scanning through "Score". Everything is grouped in control blocks as they were invented, so there is no top to bottom, left to right flow that you will find on the majority (actually the remainder) of the other pages.

Two Special purpose pages are "Spkr" with calculates the displayed speaker elements and on the twin diagrams, and "Bounce" page, which is the only page that is output only. The "Bounce" page generates static coefficients needed for the Rounded edge approximations. These coefficients are round robin referenced by the "Score" page and feed the Cancellation pages during the swapping operations.

So the main flow starts with the Values (from the "Values" page) that feed the "Baffle" Page. The "Baffle" page generates the Slope intercept values required for distance target calculation on all seven of the Driver pages ("Drv1" through "Drv5" for the individual drivers, and "Drv2T" and "Drv2B" for the top and bottom sampling of the ribbon drivers). The "Baffle" page also supplies the "Values" Page with the Charting end points for display of the baffle edge elements on the twin diagrams. The start of the long journey is the values and the baffle geometry. The next stop is the mentioned Driver pages that do slope intercept to the baffle edges (inner and outer) to find the cross baffle distances at each ray-fired angle.

The center of the spreadsheet is the "Table" page. It is where all of the distances from the Driver pages are fed and where all the data is then dispatched to the five Cancellation Pages ("can1" through "can5"). The "Table" page changes baffle distances into triangulated path distances to the listening position, so, in affect, the "Table" page converts absolute 2D distances to differential 3D distances or delays. The "Table" page also calculates average distances and variances to those average distances to help create relative magnitudes downstream. The "Table" page is also the master to the Interpolation page ("Int") where the Over-Sampling in-between distances are derived. The "Table" page feeds and swaps-in the interpolated values and also interpolates the triangulation angles as well. The "Table" page also derives the spatial sub-samples needed for the in-between lines on rounded edge approximations. Basically every time a rounded edge is calculated, line pairs called the inner and the outer lines are sent through the Cancellation pages. The inner derived lines pairs are created in the "Table" Page. As I said, it is the center of the entire spreadsheet flow.

The Cancellation pages are where differential 3D distances are changes into frequency field strengths and scaled and summed. Much of the swapping goes on here and some of the accumulation. The Directional Bessel Infinite Sets are derived and both those and the piston area scaling are applied here as well. All five Calculation pages feed the Radiation Page ("Rad") where all of the values come together. The "Rad" page calculates Mutual Radiation Gain, sums the driver Groups and applies them together or not. The "Rad" page also provides the final storage for the accumulation and iteration of the rounded edge sub samples, and also for the Compare function. The "Rad" page is the source of the frequency graph data on the "Value" page, so the "Rad" page completes the circular journey.

Values Score

Baffle Spkr

Drv1 Drv2 Drv3 Drv4 Drv5 Drv2T Drv2B

Table Int Bounce

can1 can2 can3 can4 can5

Rad Values

Everything before the "Table" Page (Baffle, Spkr, and the seven Driver pages) is about 2D Geometry. The "Bounce", "Table", Interpolator ("Int") is about conversion to 3D geometry and derivation of magnitude. Every thing after the "Table" Page (Radiation and the Five Cancellation pages) is about Frequency response. All of this is fed and feeds the "Values" page under the control of the "Score" page. So ends the journey of the explanation and perhaps your journey in followings the process. I hope that helps. Good Hunting.

And What is Next?

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The Diffraction tool is step two of four logical steps of discovery. The first step is always to observe and document behavior of an unexplainable event. The second step is to model the observed phenomenon to predict this behavior. That is what the simulator does. The last two steps are to break down the model into atomic parts, and the fourth is to prove out all of those parts. The result is a unified explanation that does not have any exceptions or suppositions or guesses.

In the very first explanation at the beginning of this document when trying to explain what baffle diffraction is from a beginner's perspective, I easily and quietly proposed that baffle diffraction is solely based on the events that occur at the edge or boundary of the baffle. If is a very plausible explanation (not mine) and matches well with observable events, but it is not a real justification for diffraction, it is just a rationalization. Even if you define any change in curvature of the baffle that enlarges or reduces the size of the space that is radiated into, as an edge or boundary that generates a pressure change, and thus a reflection, that sums at a listener position, it is still, at best, a rather contrived and limited model.

It has always bothered me that the explanation works so well. I mean, should not the entire baffle be contributing something (reflecting something) and not just its termination, the edge? We take for granted that an infinite planar baffle prevents all radiation from going around it, because that does make sense. But then we use the edge reflection model to explain it. So we call that infinite baffle a 2 PI environment, and we assume the gain is uniformly + 6 db and there is not a baffle step transition frequency response. But there also is no edge for the sound to diffract off of, so where is the reflection? Where is the reflection that we depend on to build the diffraction model upon and account for the Gain? Where do we get that doubling of forward energy if not from the reflective edge?

The fact there is no edge on an infinite baffle might mean that there is no diffraction signature in the frequency domain, but that does not stop the baffle reflector from performing its reflection duties down to 0 Hertz, so the gain does exist without the edge. Maybe the entire baffle is indeed reflecting. Perhaps the only observation we can make is the cessation of that reflective operation, and that ending of the reflecting process, at the baffle edge, is the observable behavior. So maybe we are modeling this entire thing backward; using a negative model. Perhaps the forward reflection we define at the pressure change boundary of the baffle edge is really the end of a continuous forward reflection available everywhere along the baffle except the edge.

The good thing about models is that they permit us to predict future results. That prediction does not imply a complete understanding of the actual underlying process. That would require a more detailed and methodical approach, breaking down the model and its

premises and exceptions until everything is both logical and provable. That is what would come next.

There are many places to look on the web to find relevant additional information; both better observed behavior, alternative conclusions, applicable math and the results of other experiments, tests and simulations. Thank you Andy and David for starting me off on this journey. No telling where it will end.

There is no end