

## Part 4

### Working With System Screen

#### Chapter 12. System Response Module

##### Putting It All Together

So far, the designer using SoundEasy tools, has been focused on the performance of the individual components of the system under development. The following issues have been covered:

1. A library of fully edited drivers has been created on a mass storage media.
2. Individual drivers have been selected for the system.
3. Enclosures have been designed.
4. The input impedances of the drivers have been compensated.
5. The efficiency of the higher frequency drivers have been compensated (where necessary).
6. The frequency response of the drivers has been analysed and equalised (where necessary).
7. All other circuitry (eg. time delay) has been added.
8. The individual crossover filters have been designed.

##### Main “Front Panel” Screen

The “Front Panel Layout” screen enables you to place (in 3D) the microphone, and rotate loudspeaker measurement setup, while moving the microphone in 180deg half-sphere over the geometrical centre of the front baffle. An example of a two-way system, with the front baffle of width=50cm and height= 80cm , where the microphone was placed at 0deg horizontal and 0deg vertical location, is shown below. Vertical slider and horizontal slider allow you to rotate the viewing point of the set-up, so that the microphone does not obstruct the main view point. Please note, that the whole measurement set-up will be moved around as you adjust the vertical/horizontal sliders – this is NOT microphone location adjustment.

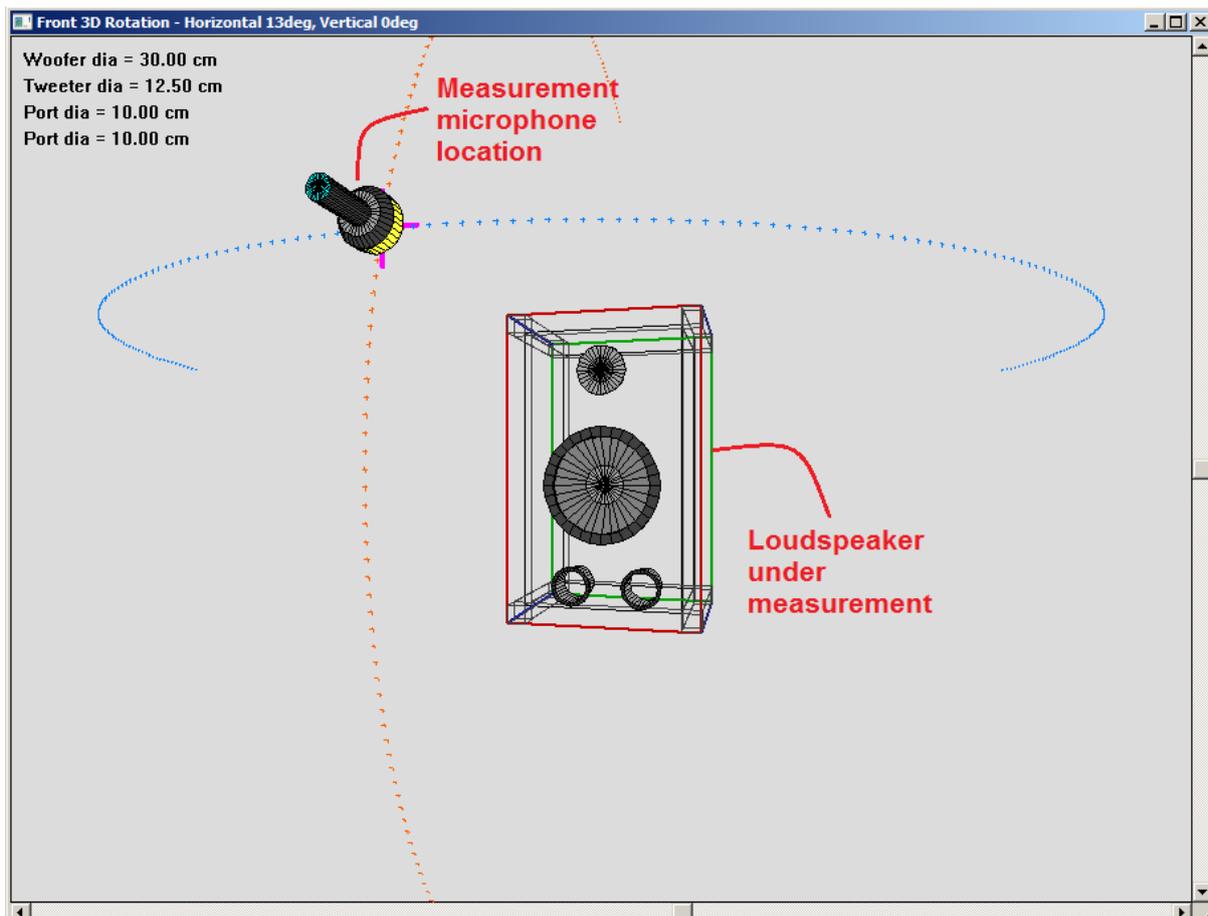


Fig. 12.1 3D Front Panel Layout system with vertical and horizontal slider.

The “Front Baffle Design” system and “Front Panel Layout” system share the same coordinates system for box dimensions.

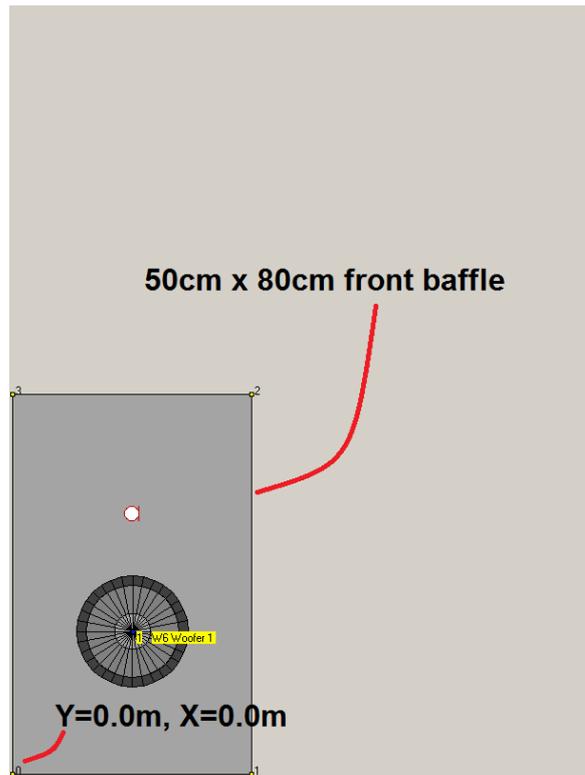


Fig 12.2 “Front Baffle Design” system and “Front Panel Layout” system share the same coordinates system.

Drivers tilt is shown in a separate window, accessible by pressing the “Show Tilt Window” on the “Front Panel” dialog – see below. You can rotate and tilt drivers from -60deg to +60deg.

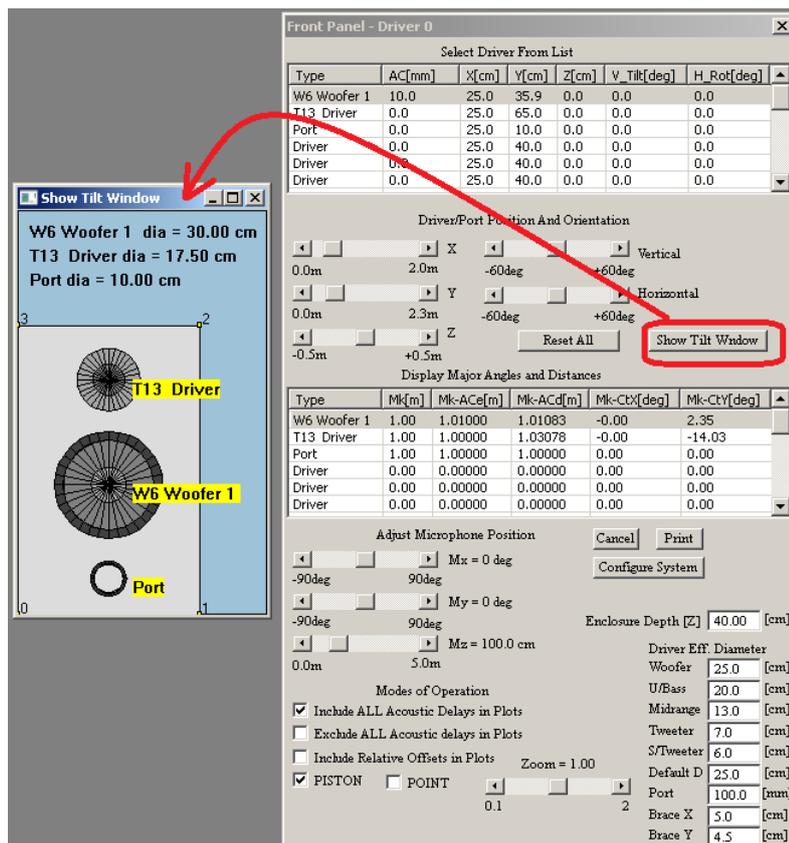


Fig 12.3 Separate window for showing driver’s tilt.

1. Coordinate system X=0, Y=0, starts at the bottom-left corner of the Baffle Design screen.
2. **Maximum size of the front baffle is X = 603cm, Y = 806cm** and its determined in Baffle Designer screen.
3. Test microphone moves within -90deg to +90deg along vertical and horizontal spherical lines. The centre (0 deg) of coordinates is the geometric centre of the front baffle.
4. Tilting drivers is visualized in a separate, 2D viewing screen.

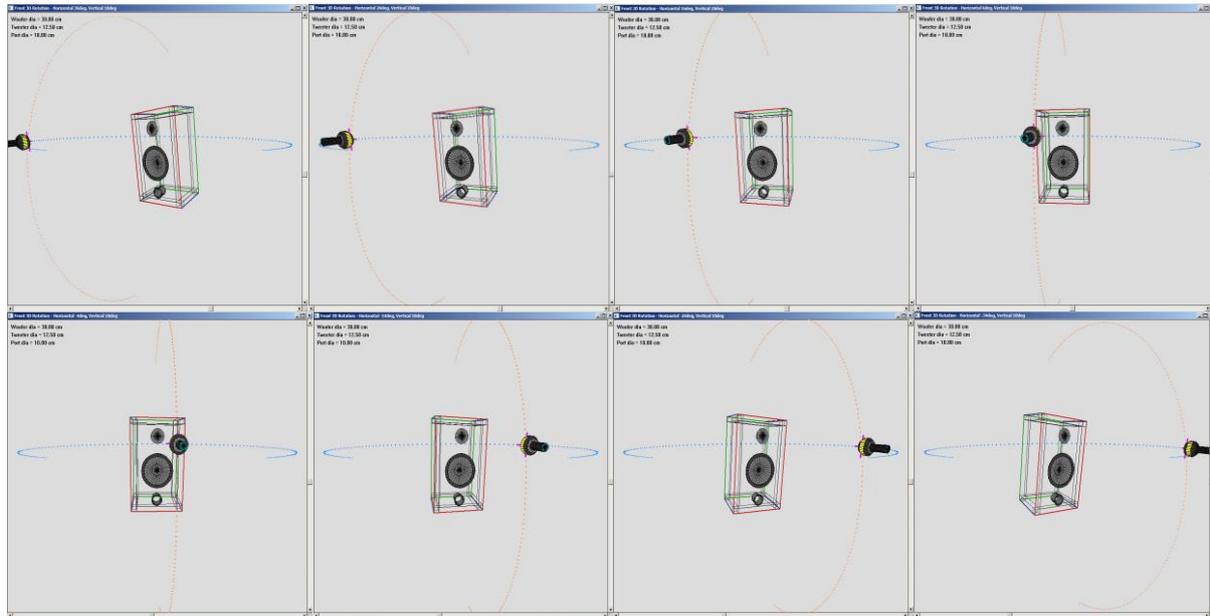


Fig. 12.4 Sliders allow you to rotate the whole measurement set-up.

Diffraction effects are not modelled on this baffle, only driver's SPL curve, with the exception of off-axis simulations on piston model. Also, this screen allows you to position your test microphone. Finally, you may decide to select one of the two built-in models for the driver, or check the response without acoustic delays. Driver diameter is necessary for the models to work correctly and it needs to be entered from the "**Driver Effective Diameter**" groupbox. To get the driver displayed on this screen, you must turn it ON first, by selecting "**Configure System**" button. This will open the tabbed box with "Node" tab for turning ON/OFF any driver in the system.

There is a good chance, that you have developed the crossover first, and the drivers will be switched ON already. Perhaps the easiest way to work with this screen is to simply follow the controls from top-to-bottom. Please refer to Figure 12.3.

1. **Select Driver From List** – click on the driver listed in this box to gain access to its location parameters: X, Y, Z, position and Vertical Tilt and Horizontal Rotation.
2. **X slider** – position the driver horizontally (-90deg to +90deg).
3. **Y slider** – position the driver vertically ((-90deg to +90deg).
4. **Z slider** – position the driver baffle offset (-50cm to + 50cm).
5. **Vertical Tilt** – tilts the driver UP/DOWN
6. **Horiz Rotation** – rotates the driver around.
7. **Reset All** – resets all driver locations the default: X=0deg, Y=0deg, Z=0cm, Vertical Tilt=0.0deg and Horizontal Rotation = 0.0deg. Mike is reset to X=0deg, Y=0deg and Z = 100cm.

The next list box located just below the controls is for display purposes only. The columns show the following information:

1. Mic – the Z-distance from test microphone to the baffle in meters.
2. Mic ACe – Total distance from the test microphone to the baffle in meters.
3. Mic ACd – Distance from the test microphone Z-plane to the driver's acoustic centre Z-plane in meters.
4. Mic->CtX - Horizontal angle between the microphone and the driver in degrees.
5. Mic->CtY - Vertical angle between the microphone and the driver in degrees.

The "**Include ALL acoustic Delays**", "**Exclude ALL acoustic Delays**" and "**Include AC + Z-offsets in Plots**" check-boxes are really self explanatory.

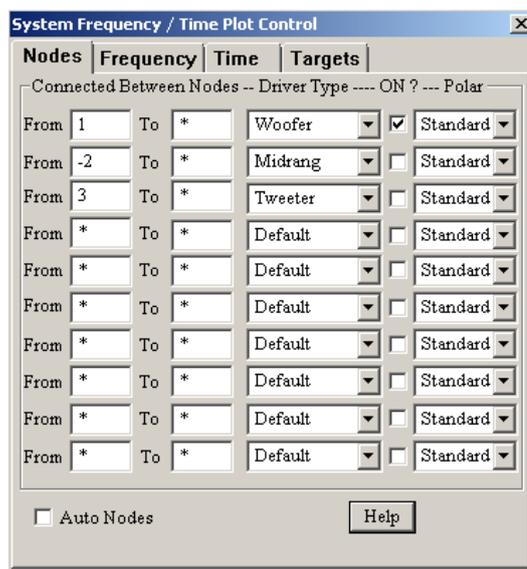


Figure 12.5 “Configure System” box

The “To” column of nodes would be used, if the driver was connected between two nodes AND none of them would be the “ground” node. For example, “series” crossovers have at least one driver connected to two floating nodes. Driver type will be displayed in the “Driver Type” column. Finally, you can switch ON/OFF any driver from the analysis by checking/un-checking the boxes in the “ON?” column – see Figure 12.2. You must enter one (for single ended loads, second Nx enter as “\*”) or both node numbers (for floating loads) and **numbers must be different from any ground node number**. “Auto Nodes” has been described in the CAD sections. “Help” button displays helpful information.

“Configure System” – button opens a control box allowing you to switch ON/OFF drivers in the system. SoundEasy software provides you with a high degree of flexibility in configuring the system. All 10 drivers can be switched ON or OFF the system. Also, when the driver is switched ON, it may be connected in-phase or out-of-phase with other drivers. The above process is accomplished via a dialogue box, invoked using the “Configure System” button. The phasing of the system is usually referenced to the woofer and it is preferred to leave the woofer in the “In-phase” state. You can then connect all other drivers ( their crossovers ) accordingly to your system configuration. The drivers switched ON must be loaded into the program data space. Do not attempt to switch ON a driver that was not loaded before. You may however switch OFF any driver from your system for the purpose of “what-if” analysis. The “Polar” column allows to select the measurement angle, at which the SPL was measured. The angles run in 5deg increments from -90deg to +90deg. “Standard” is the 0deg polar measurement. In order to use the off-axis SPL curves in modelling process, you must provide this data during the measurements for all angles.

### Correlating Display on Different System Screens

It is often beneficial to correlate what you see on different screens or dialogue boxes within the System Design process. For instance, rotating the microphone horizontally above the front baffle should have similar acoustic effect as rotating the drivers horizontally in the opposite direction, with the microphone fixed at 1m distance of the geometrical centre of the front baffle, as shown on Figure 12.6.

Two examples shown below explain the approach. Say, for instance, that we move the test microphone 34 degrees to the right and plot the frequency response. It is observable, that the resulting frequency response has developed a deep notch at 10kHz see Figure 12.7 below. We would then plot the vertical and horizontal polar responses for 10kHz test frequency. Given that Horizontal Polar Plot shows view from the bottom, the microphone moved to the right will appear on the bottom section of the polar plot as shown on Figure 12.8. It is observable, that the notch has indeed developed at 34deg – the same angle as the SPL plot.

Tilting or rotating drivers can be used to simulate enclosures with tilted or non-flat front baffles. Drivers mounted on “sloppy” baffles are really operating “off-axis” when tested with microphone suspended on the same height as the driver. Typically, the driver is facing slightly “upwards”.. Even though the microphone AND the driver are located at the same height (Y-distance) the resulting SPL has all the characteristics of “off-axis” measurement – notches and SPL reduction.

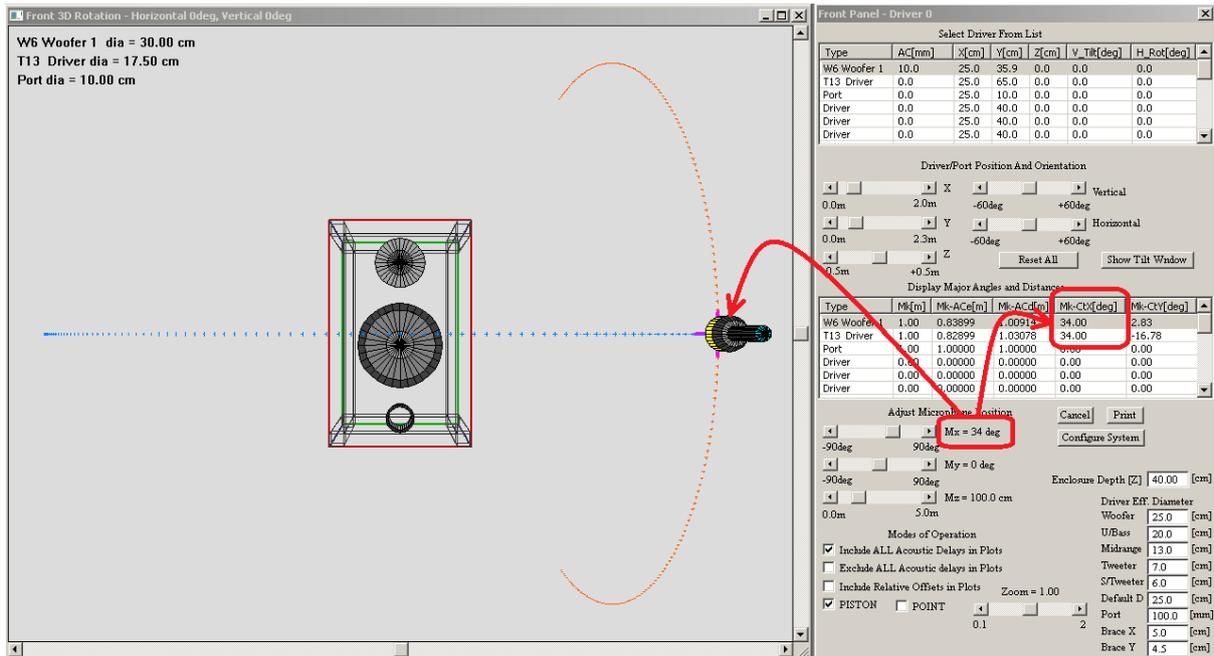


Figure 12.6 Microphone has been rotated to the right by 34 degrees.



Figure 12.7 Resulting SPL plot develops a notch at 10kHz.

Horizontal Polar Plot shows view from the bottom, so the microphone moved to the right will appear on the bottom section of the polar plot.

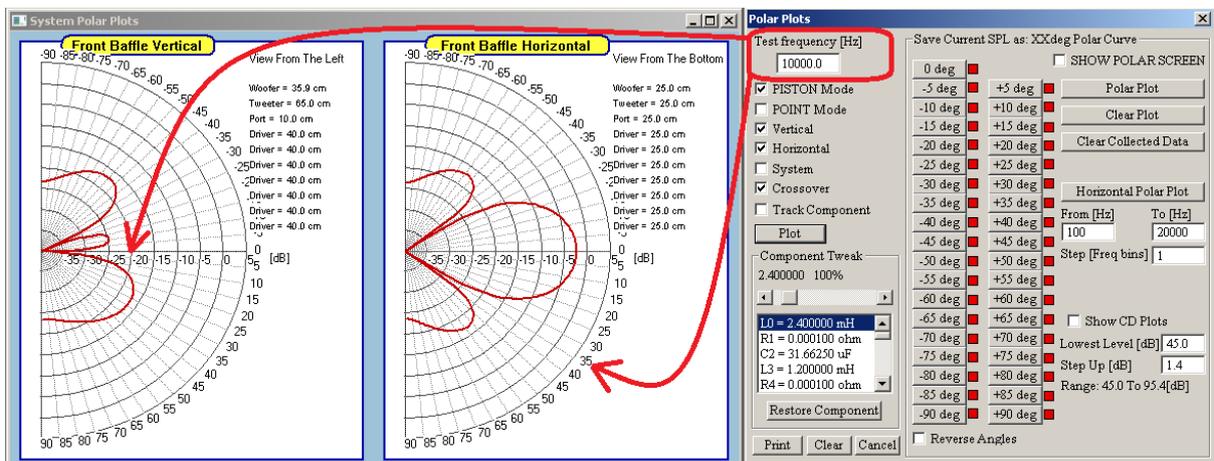


Figure 12.8 Horizontal and vertical polar plots.

The notch is clearly visible for 10kHz, at +34 degrees.

## Comparing driver rotation with microphone rotations

First, we move the microphone up (in Y-directio), to be approximately aligned with the tweeter radiation axis.

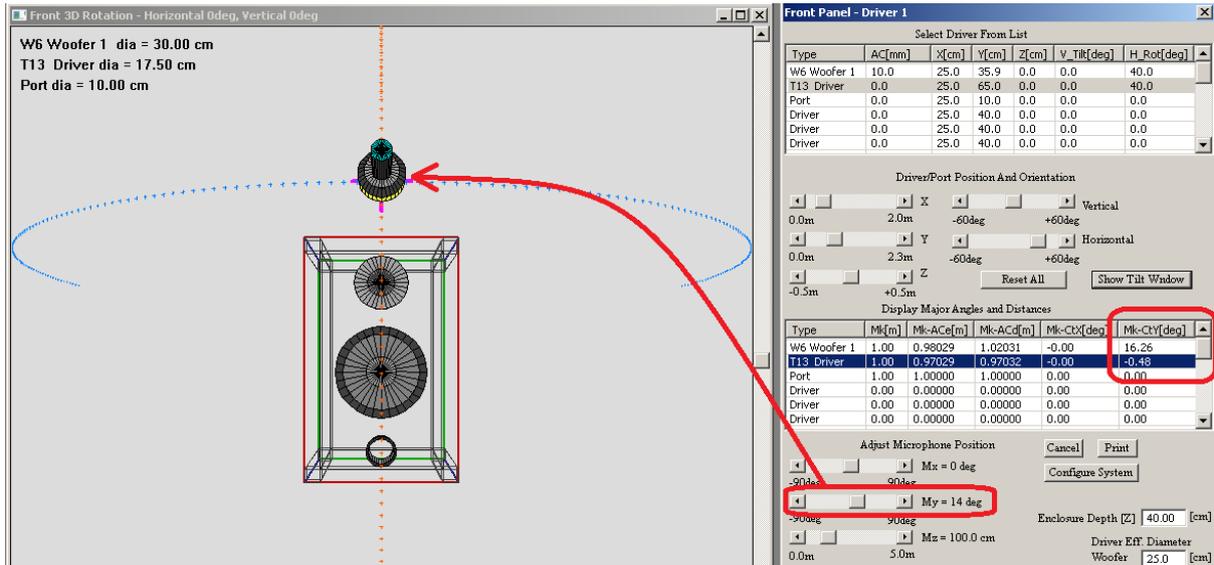


Figure 12.9 Moving the microphone up, to align it with tweeter vertical location.

In the next step, we rotate drivers horizontally 40degrees to the left, which results in 9kHz notch.



Figure 12.10 Rotating drivers to the left results in 9kHz notch.

And this is the same measurement configuration as keeping the drivers flat on the baffle and rotating the test microphone 40deg to the right – see PSL plot below. It's nearly identical to the SPL plot resulting from horizontal rotation of the 40 deg to the left.

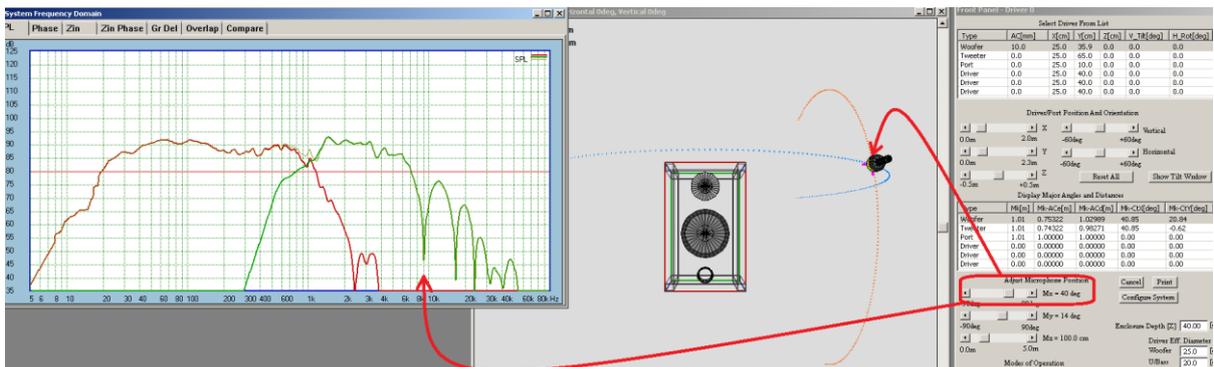


Figure 12.11 Drivers flat on the baffle and mike rotated 40deg to the right.

## Off-axis Response

The off-axis responses are better simulated in PISTON MODE. Remember, that point sources radiate in all directions, therefore, the “off-axis” response will be identical to the “on-axis” response for single driver. In the PISTON MODE, the program recognizes, that microphone is being moved off-center and is actually closer to one edge of the driver. If you can imagine dividing the piston area of the driver into many smaller radiating areas, you will realize, that moving the test microphone off-center, creates a difference in path lengths and thus the arrival times of pressures generated by each small radiating area. Vectoral summation (eg; taking into account individual phases) of all contributing pressures, creates peaks and nulls in the resulting frequency response. Peaks – when all contributions add constructively and nulls – when all contributions happen to cancel each other.

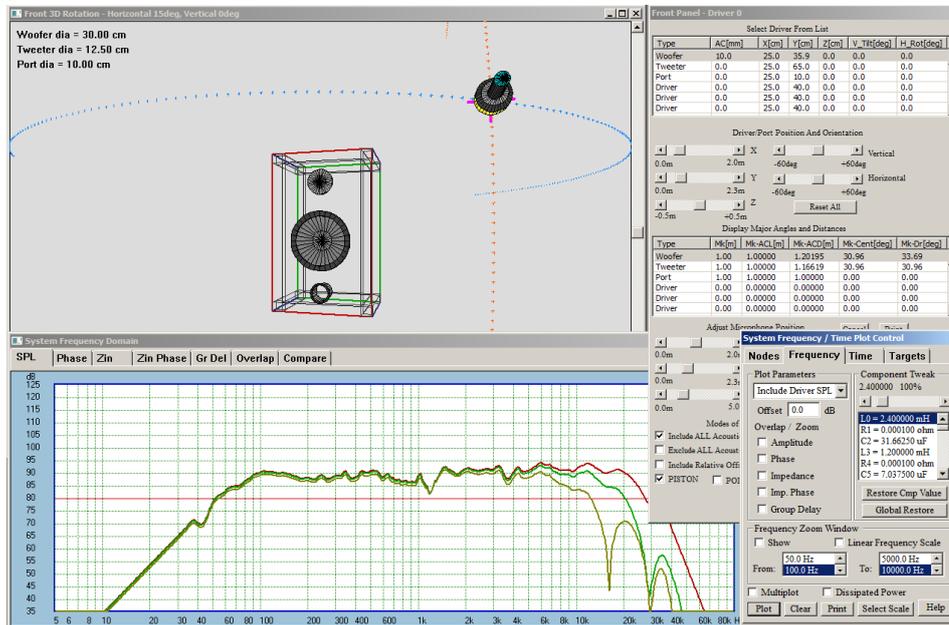


Figure 12.12 System SPL off-axis – green curves.

SoundEasy uses a model that divides the driver piston area into 81 smaller sections and then calculates contributions of each individual section. Model implemented in the program enables you to predict the “off-axis” response of a tilted driver as well. This will come very handy when simulating the “off-axis” response of a tilted front baffle system with 5 drivers.

Shown below are comparison screens for off-axis measurements and modelling. Measurements above 30kHz are highly unreliable. Sampling frequency was 96kHz, and the microphone was CLIO 1.

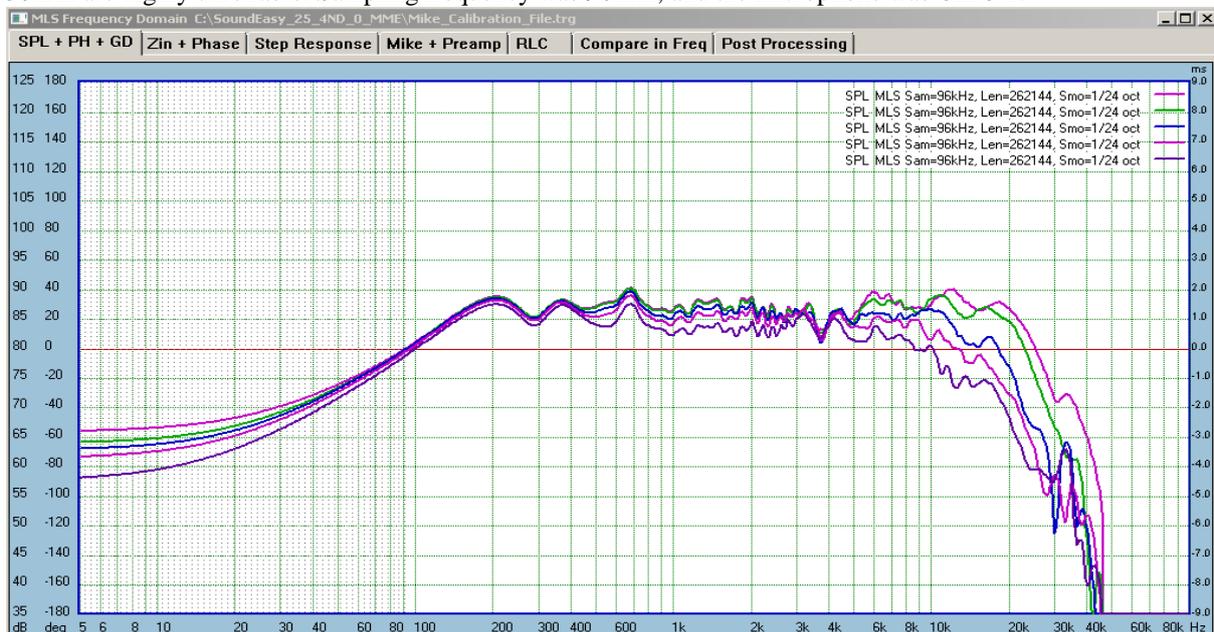


Figure 12.12a. Measured SPL of the RS28F tweeter for 0, 15, 30, 45 and 60 deg off-axis.

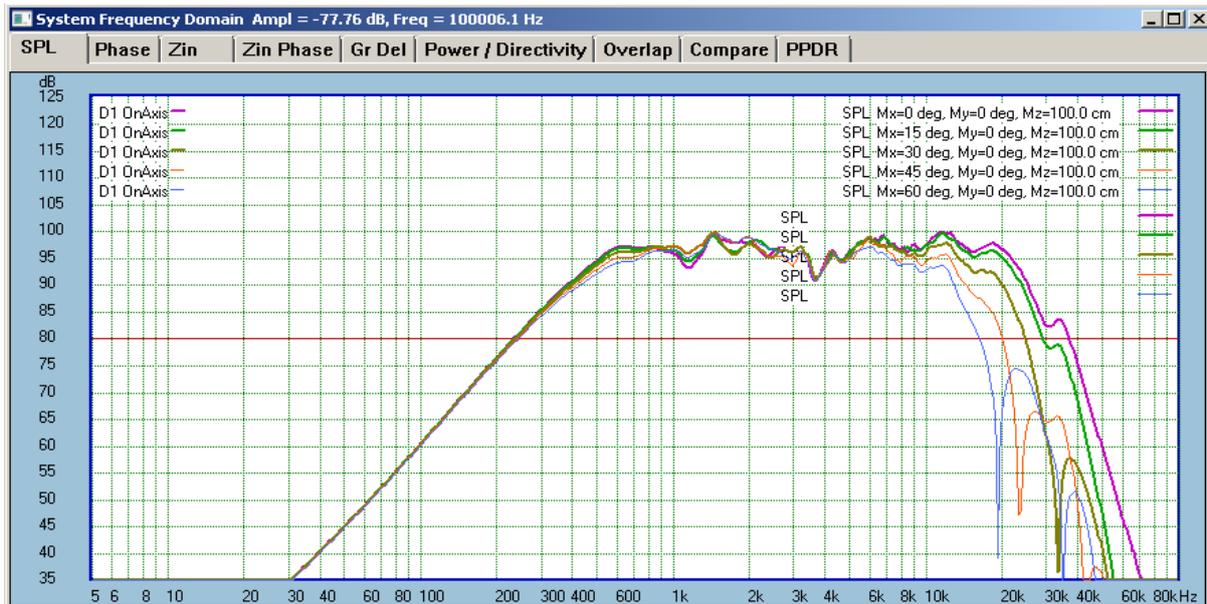


Figure 12.12b. Modelled SPL of the RS28F tweeter for 0, 15, 30, 45 and 60 deg off-axis.

Mathematical modelling will always show sharp dips, but measurements typically do not show them at such a high frequencies. So, if you disregard the dips in the modelled response, the SPL calculated curves represent the measurements quite well. The curves above 6kHz are dropping in a very similar way to the measured curves.

### System Vertical and Horizontal Response Plots

Polar plots (vertical or horizontal) modeled on your computer are quite easy to obtain. Assuming correctly implemented software algorithms, typically, a few clicks of the mouse is all that you require. However, practical verification measurements are nothing short of a problem. Ideally, you would set-up your test jig in an anechoic chamber and use computer-controlled, sophisticated turntables and microphone movement equipment to obtain the required degree of accuracy. This is because typical polar plots require transducer movement in TWO dimensions – on the X-Y plane. In your “home laboratory”, it would be unlikely, that you would go to these lengths to verify the theoretical predictions of the polar plots of your design. Still, you may need to MODEL and MEASURE your system responses as close to the standard spherical lines set up as possible. Moving the test mike along one spherical line is not a simple process, as you will really need to control both: x and y-coordinates on microphone location. Then, you can easily obtain excellent “off-axis” responses, and this is exactly what the polar plots are representing. Now, if your software is also capable of modelling microphone movements along spherical lines, you can easily correlate and verify model predictions with the actual polar measurements.

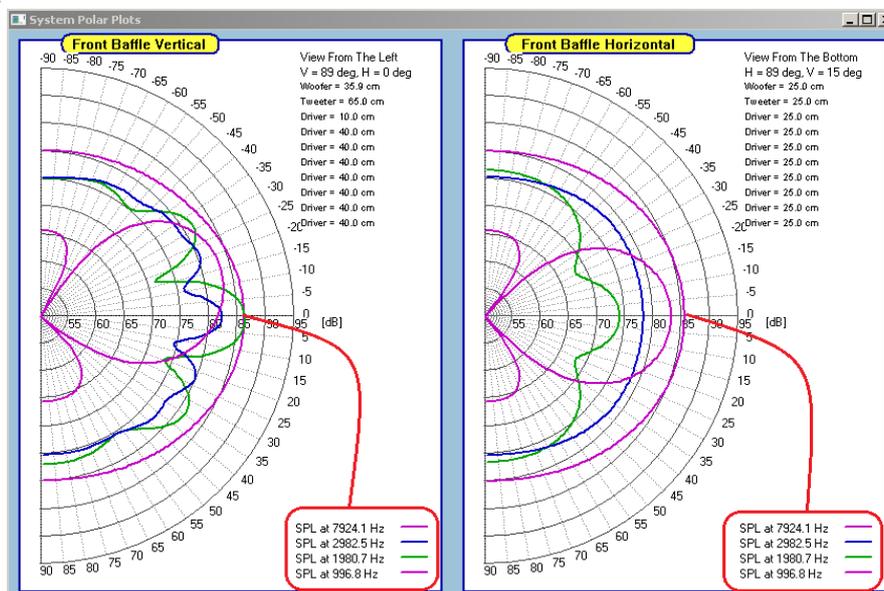


Figure 12.13. System Vertical and Horizontal Polar Plots box.

In your “home laboratory”, it would be unlikely, that you would go to these lengths to verify the theoretical predictions of the polar plots of your design. Still, you may need to MODEL and MEASURE your system responses as close to the standard spherical lines set up as possible. Moving the test mike along one spherical line is not a simple process, as you will really need to control both: x and y-coordinates on microphone location. Then, you can easily obtain excellent “off-axis” responses, and this is exactly what the polar plots are representing. Now, if your software is also capable of modelling microphone movements along spherical lines, you can easily correlate and verify model predictions with the actual polar measurements. System vertical and horizontal polar response can be evaluated using “**Polar Plots**” dialog box. The box opens when you select “System Polar Plots” item from the main menu. The associated plotting screen will actually generate two plots – if you select both, vertical and horizontal check boxes. A good hint to remember is, that frequency response plots are generated for a “stationary” microphone setup over the whole range of frequencies. Polar plots are generated for “stationary” frequency over the whole range of microphone positions. All these plots **must** correlate with each other. For example, if you see a notch in the frequency response at some frequency and particular microphone location, the same notch must be present in polar plot performed at this frequency. This was explained above.

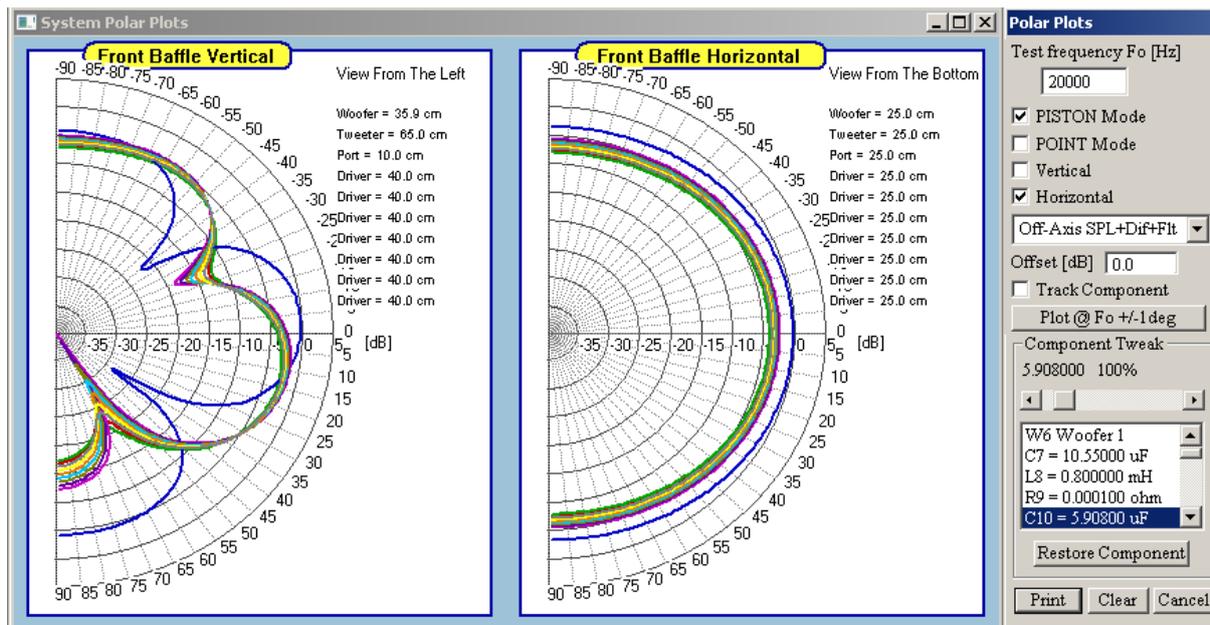


Figure 12.14. Example of “Polar Plots”.

The dialogue box is rather self-explanatory and contains the following controls:

1. “**Test frequency**” – this is an editable data field for you to enter the frequency of interest in Hertz.
2. “**Plot**” - use this button to generate vertical/horizontal polar plots of the crossover.
3. “**Vertical**” – use this check box to select Vertical plots.
4. “**Horizontal**” - use this check box to select Horizontal plots.
5. “**List Box**” – DoubleClick on any component to select it for slider adjustments.
6. “**Restore**” – button to RESTORE component value to the 100% prior adjustment.
7. “**Clear**” - button to clear the plotting area and re-prints the scale.
8. “**Print**” button – simply prints the screen.
9. “**Cancel**” button – closes the box.
10. “**PISTON Mode**” – check box to select PISTON mode.
11. “**POINT Mode**” – check box to select POINT mode.
12. “**Slider**” – adjust component values 1%-1000%
13. “**Track Component**” – select this check box if you have System frequency domain screen opened and you want the SPL plots to be updated automatically.

Is often desirable to visualize changes Frequency Response while checking Polar Response. The Polar Plots dialogue box has built-in functionality allowing you to change a selected component and then adjust it with the slider within 1-1000% of the original value. All changes are automatically reflected in Polar Plots curves. However, you can also observe SPL/Phase changes at the same time. Please make sure, that **the System Frequency Domain plotting screen OR CAD Frequency Domain plotting screen are opened** and the “Track Component” check box is “checked” on the “Polar Plots” dialogue box.

## Horizontal Dispersion Plots

In typical loudspeaker systems, as the frequency of the test signal applied to the loudspeaker system increases, the radiation pattern from the system changes as well. Capturing this phenomenon provides you with more thorough characterization of your loudspeaker, and may lead to design changes to improve off-axis performance. Capturing Horizontal Dispersion is accomplished by measuring loudspeaker's SPL for a wide range of angles. The program provides you with storage capacity for plots ranging from -90 degrees to +90 degrees with 5 degrees increments in loudspeaker orientation angles. This will give you 37 plots, if you include 0degree reference (on-axis) SPL plot.

The polar plots displayed in the plotting window are shown for "Current Buffer File" option selected from the list box at the bottom the Polar Plots dialogue. When you collect SPL measurements for all 37 angles, please save the file as for corresponding driver type (woofer, midrange, tweeter....). The polar plots stored in those driver files, will be used later in your Projects, so that you load a project and review all off-axis plots for all drivers included in your Project. The driver selected for off-axis display will be chosen from the same list box, after the project (and all driver files) has been loaded. Measurement process is rather simple:

1. Set-up your measurement jig with the ability to make angular measurements with your microphone.
2. Use MLS system to capture 0degree reference SPL plot. Please note, that you must plot the resulting SPL in the MLS system.
3. Go directly to "Polar Plots" main menu option.
4. Check "Show Polar Screen" box on the "Polar Plots" dialogue box. This will open SPL plotting screen arranged for "waterfall-like" display of all captured plots.
5. Select "Current Buffer File" from the "Show Polar Data From" list box - see below.
6. Press "0 deg" button to store the reference (on-axis) captured SPL plot.
7. Go to step 2, and repeat the process for all other angles.

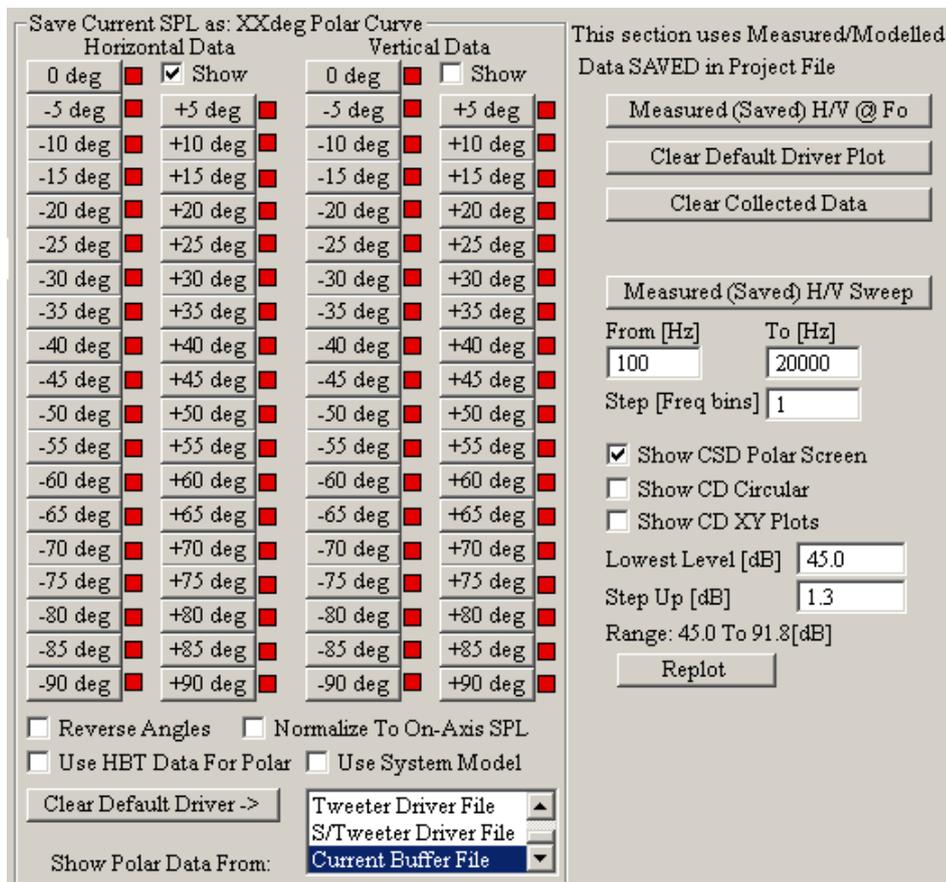


Figure 12.15. Dispersion Plots controls.

When finished, you should end up with a picture similar to the one on Figure 12.15. Please note, that you would follow the same testing process when measuring system dispersion. Use "Current Buffer File" option, but save Project File (rather than Driver File). Consequently, the system dispersion plots will be saved into project file.

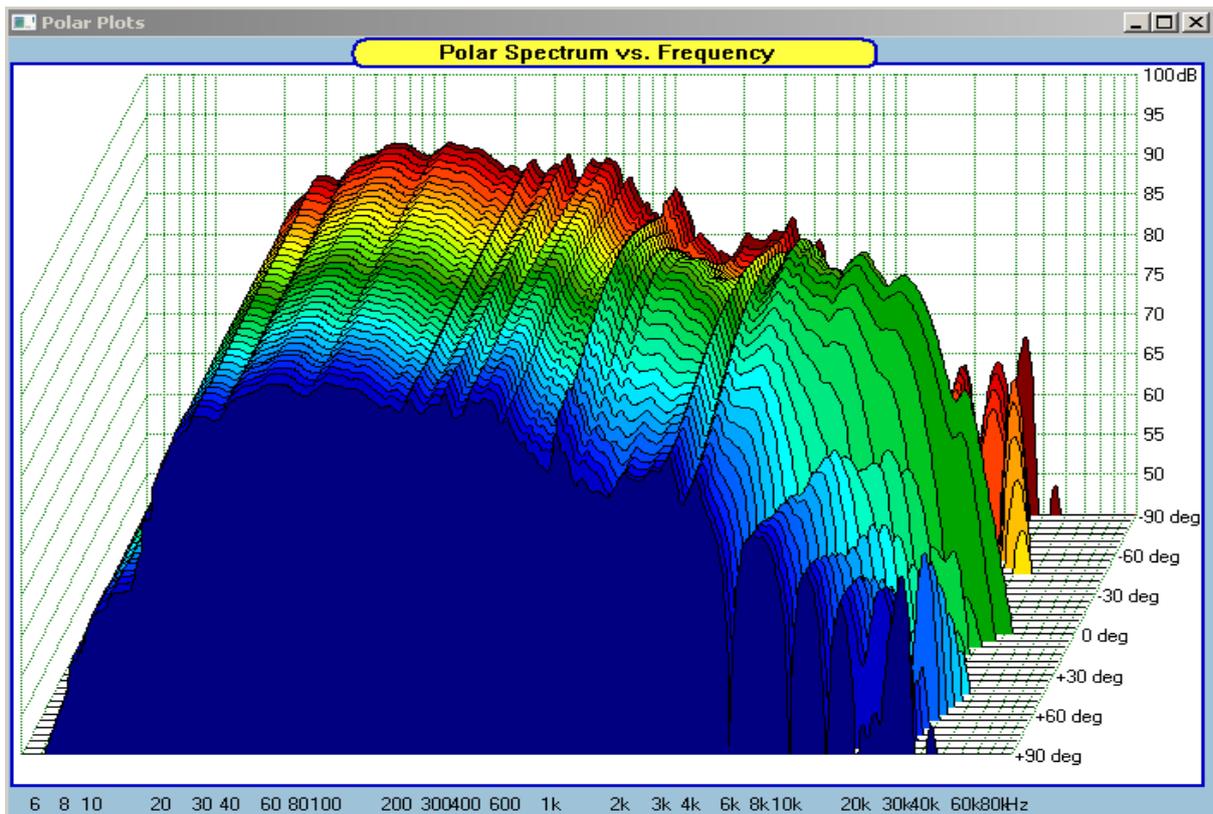


Figure 12.16. Horizontal Dispersion Plots – “waterfall-like” arrangement.

Captured measurements can be presented as, for example, “waterfall-like” plots. Since the loudspeaker can be horizontally asymmetrical, the control box includes a check box to reverse viewing angles of the waterfall plots – “**Reverse Angles**” check box. There are two other options to view collected SPL information:

1. Polar Plot for single frequency.  
The chosen frequency can be entered into “**Test frequency**” data field of the “**Polar Plots**” control box. Then press “**Measured (Saved) H/V @ Fo**” button to have the SPL curve displayed for all 37 angles. This curve will be displayed in the “Front Baffle Horizontal” section of the display. Since the resolution of the SPL scale can be scaled ( 3dB, 5dB, 10dB...per division), this option provides you with the ability to zoom on SPL curve for individual frequencies.
2. Polar Plots for a range of frequencies.  
Selected frequency range can be entered into “From[Hz]” data field and “To[Hz]” data field. Please note, that the frequency scale is logarithmic. Therefore, you can also select log bin step, by entering a number from **1...100** into “**Step[bins]**” data field.  
Plotting process is activated by pressing “**Measured (Saved) H/V Sweep**” button.

In addition:

“**Clear Plot**” - button clears the displays.

“**Clear Buffer**” - button **erases all collected data**. So please be careful when using it.

“**Show CSD Polar Screen**” - checkbox enables the display of Polar Spectrum vs. Frequency screen.

“**Show CD Circular**” - checkbox enables the display of Polar Spectrum vs. Frequency in circular fashion.  
(as originated by Erin’s Audio Corner).

“**Show CD XY Plots**” - checkbox enables the display of Polar Spectrum vs. Frequency in rectangular fashion.

“**Use HBT Data For Polar**” – If you generate HBT curves during Postprocessing in measurement system, OR using Driver Editor HBT TAB, you can use the HBT data for polar plots. **When you check this checkbox, the HBT data will replace raw measurement off-axis data in the driver’s file. Clearly, you can have HBT-derived SPL or raw-measured SPL mutually exclusive for off-axis plots.**

Please note, that the coloured boxes next to the degrees buttons change state to red when the curve corresponding to this particular angle is placed in the buffer. State of empty buffer is signalled in green. So for instance, when you press “Clear Buffer” button – all boxes should change their state to green.

## Off-axis SPL for all drivers in the Project File

The off-axis polar performance of all drivers loaded via Project File can be viewed by selecting the desired driver from the “**Show Polar Data From:**” dialogue box. Two examples shown below depict Polar plots for woofer driver and tweeter driver – both drivers were loaded via Load Project mechanism.

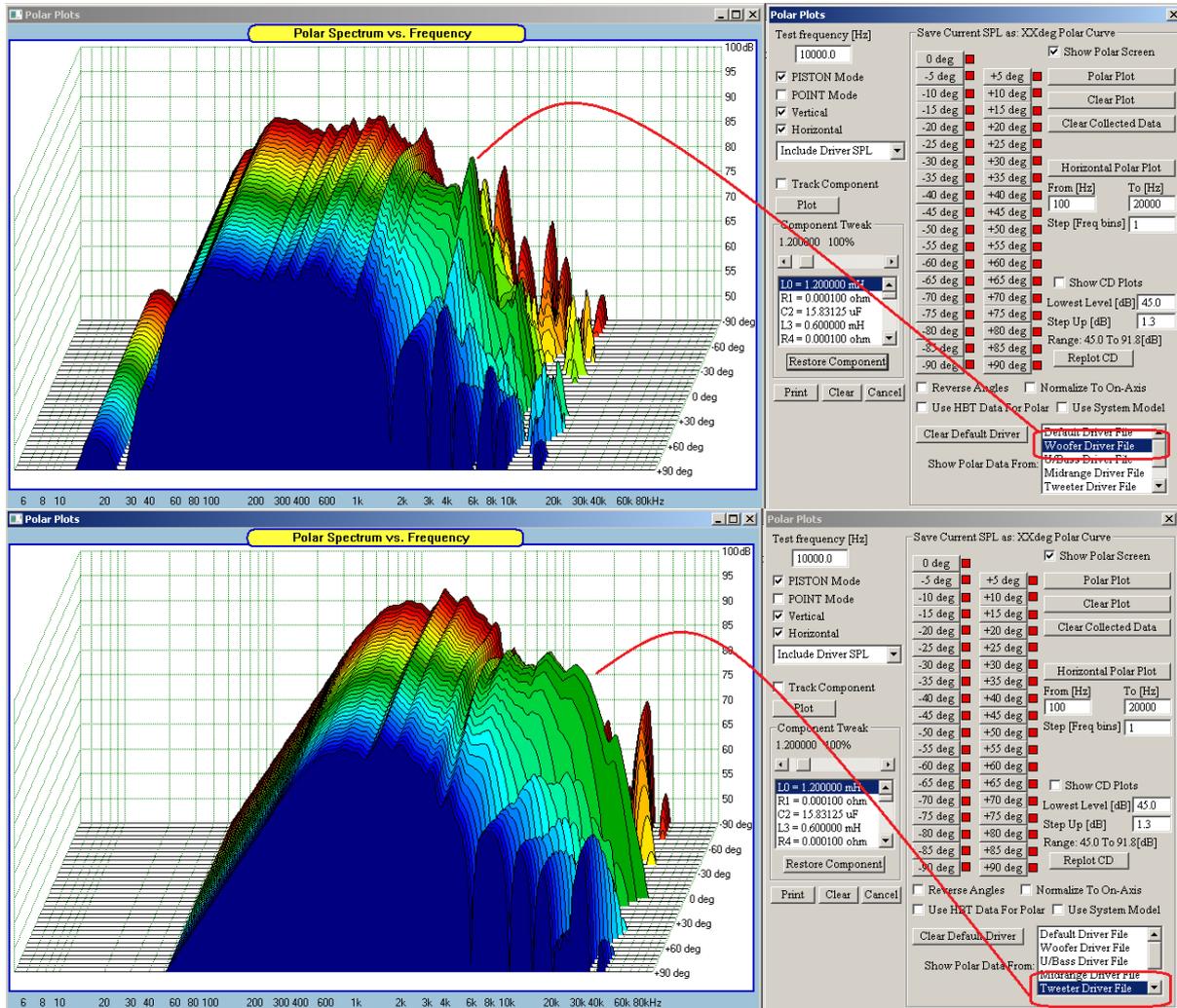


Figure 12.17. Polar plots of drivers loaded via Project File.

If you used HBT for deriving SPL and phase plots during the measurements, you can use the polar HBT stored plots. The difference in SPL is shown below.

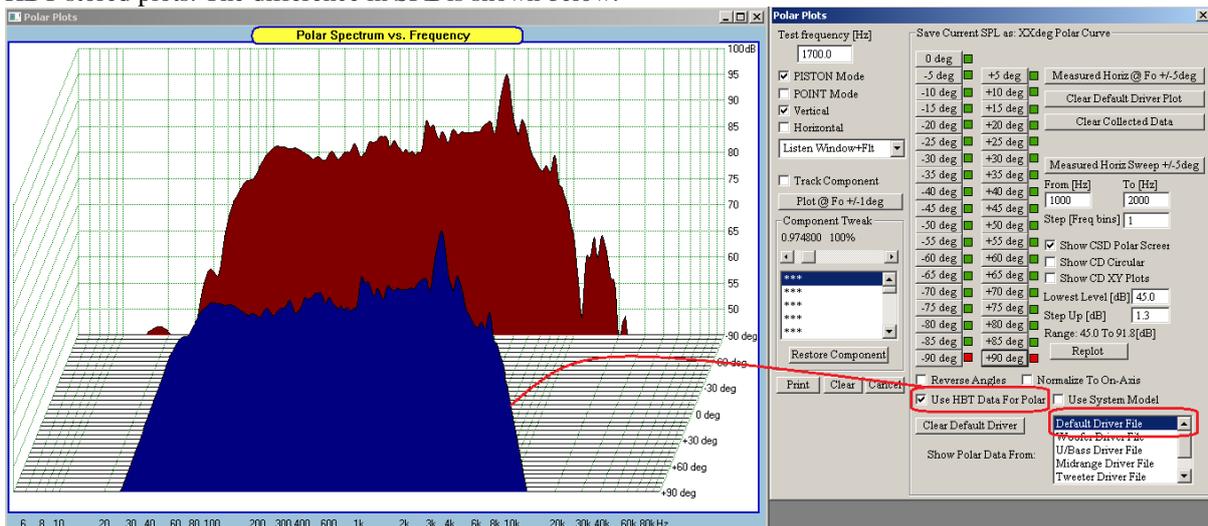


Figure 12.18. Using HBT polar plots.

## Normalizing Off-Axis Display

The off-axis curves can be displayed as they were measured, or they can be normalized to the on-axis curve.

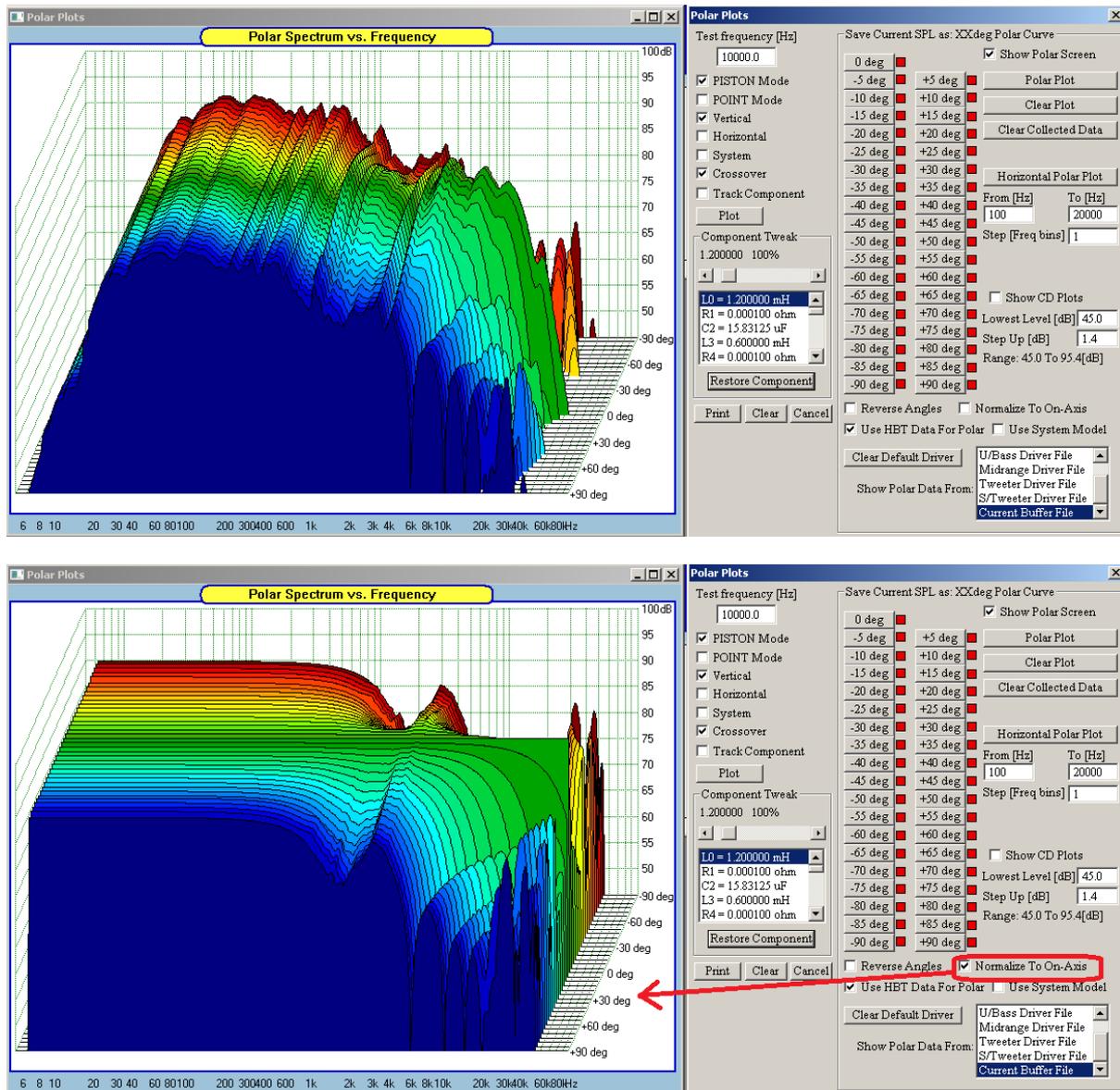


Figure 12.19. Using Normalization option

## Using Off-Axis Modelled Responses

Off-axis responses can be modelled in System Module, by simply moving the test microphone around and plotting the resulting off-axis SPL curves. These curves can be used in Polar Plot System.

In order to facilitate this mechanism, please select “System Polar Plots” from the main menu and when the dialog box is opened, check the “Use System Model” checkbox. This flag will ensure that SPL curves plotted in the System Module, will be acquired by the Polar Plot dialog box.

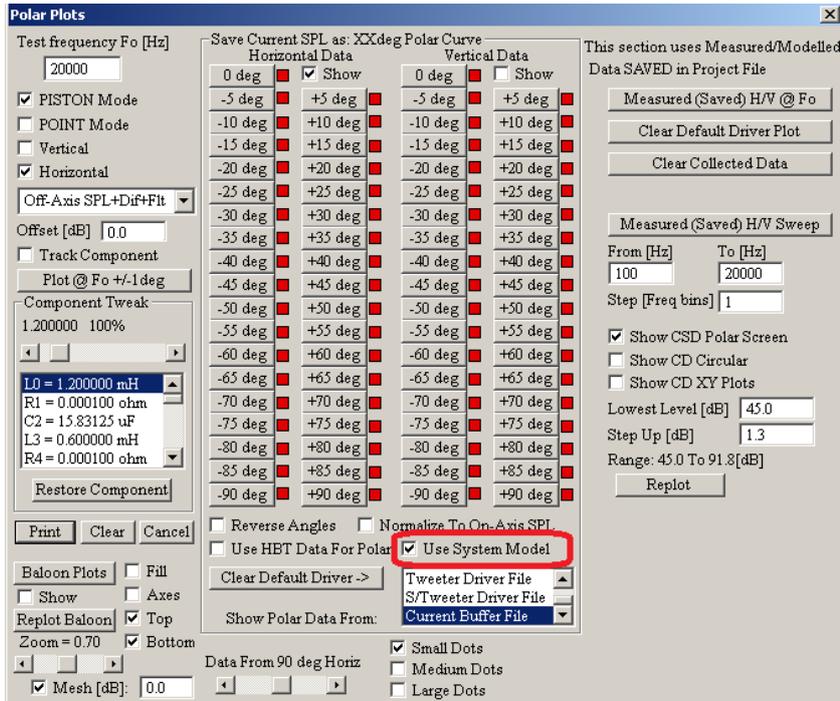


Figure 12.20. Enabling collection of SPL modelled in the System Module.

Next, proceed to the System Module to plot system response for “0deg” angle – by adjusting the location of the microphone.

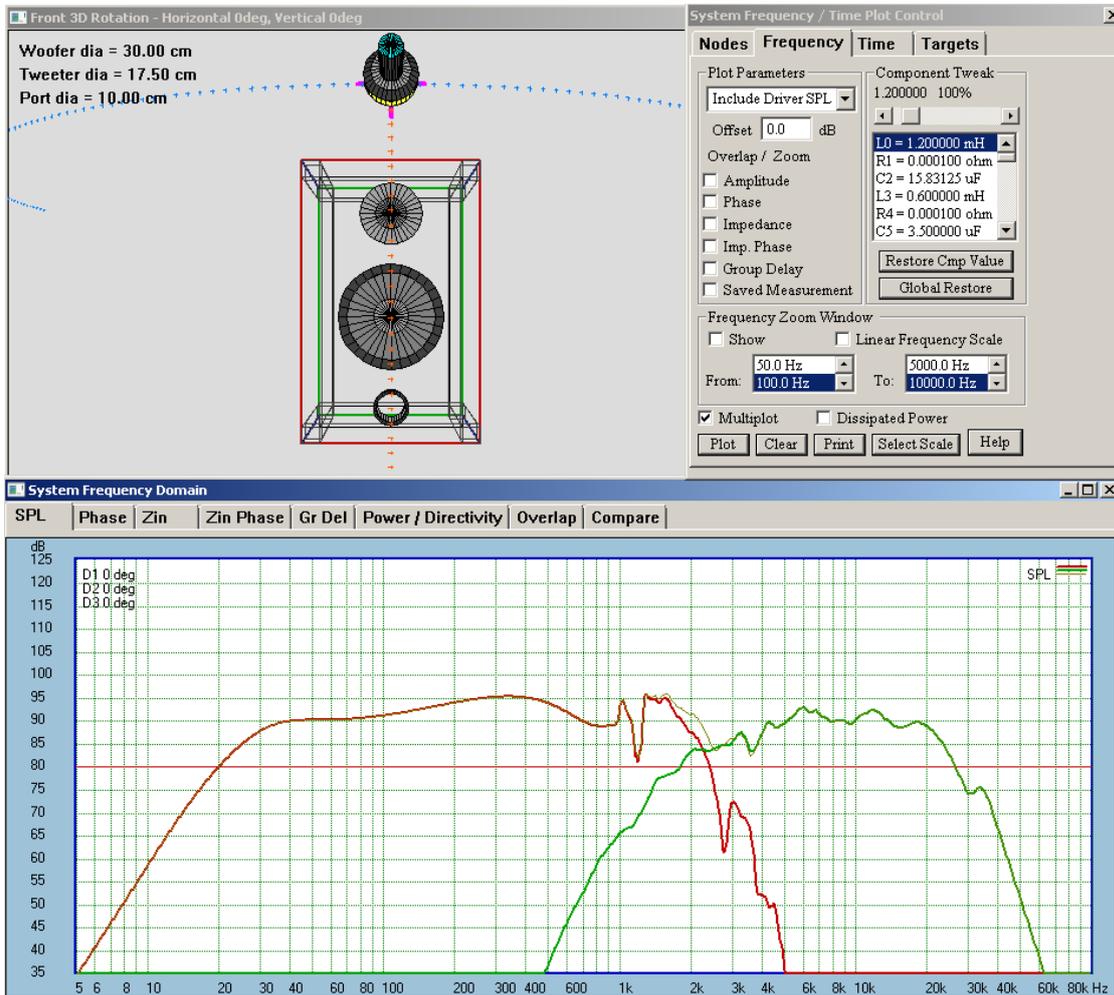


Figure 12.21. Plotting the “0deg” SPL in System Module.

Finally, return to the Polar Plot dialogue box and press “0 deg” button.

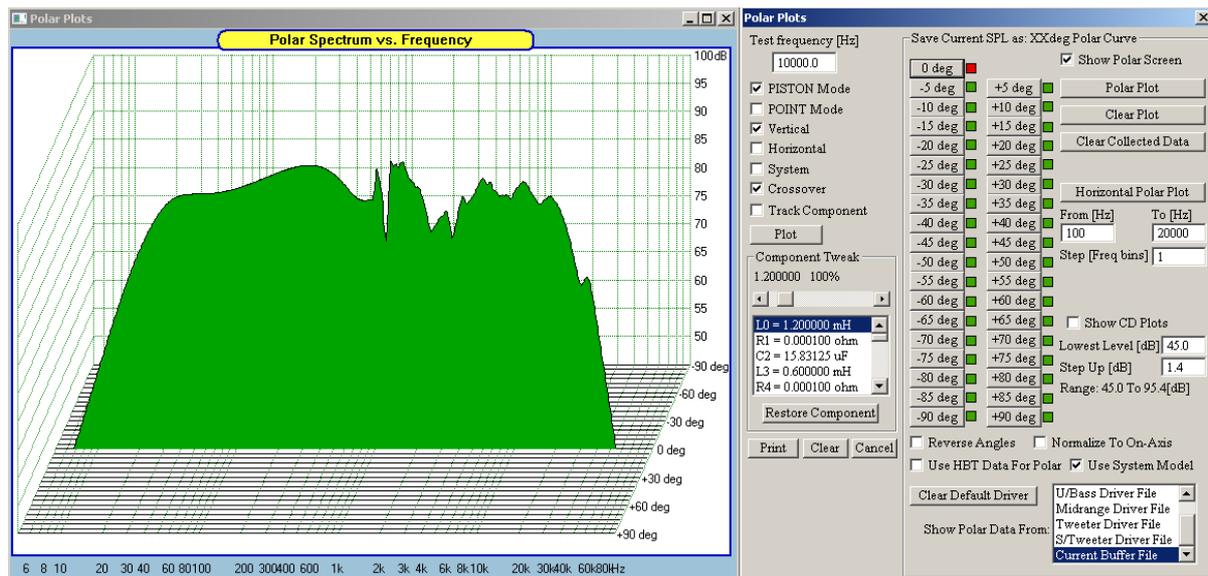


Figure 12.22. Plotting the “0deg” SPL in Polar Plots Module.

As observable, the SPL modelled in the System Module is now acquired as “0deg” plot in the Polar Plot system.

### Working With Project Files

The Project File is designed to hold the following:

1. Five paths and file names for the selected driver files.
2. XYZ mounting/tilting/rotating coordinates of each driver.
3. CAD schematic of the complete crossover.
4. System optimisation parameters and more.....

The file names are then used to automatically load the drivers' data files. The names of the drivers' data files can be entered into the project using the "New Project" option from the window menu. In summary, you would follow the steps below:

#### To create and save Project file:

1. Open SoundEasy.
2. Go to Preferences screen and set the “System Frequency Range”.
3. Create Woofer Driver File and save it to HD.
4. Create all other driver files and save them to HD one by one.
5. Select “New Project” from main “File” menu. A dialogue box with 5 editable fields will be opened.
6. Browse to all driver files and select them into the allocated dialogue box spaces.
7. Load the drivers – there should be no error messages.
8. Save the Project file to HD using "Save Project" option.

If adhere to the above, Driver Files will have the same frequency range data as the newly created Project File. Still, it remains User’s responsibility to associate Drivers File with Project File with compatible frequency range. When a Project File with different frequency range is loaded into SoundEasy, the program will display warning message about mismatch in frequency ranges and will give the user an option to Abort. **If Aborted**, no further action is taken. **If continued**, the program will automatically re-set the frequency range in Preferences screen to the one loaded in the Project File. Since Driver Files are compatible with the Project frequency range, there will be no further warning messages. For more information, please refer to Help File.

#### To load Project file:

1. Activate "Open Project" option.
2. Select and load required project.
3. You will be given an option to review the individual drivers' filenames.
4. Press "Load" button to load ALL the files into the program data space. The program will also re-open the default screen and will display all loaded drivers on the front baffle.

## Phantom Project Files.

SoundEasy does a lot of background work checking presence and validity of data. when performing the design tasks with fully edited driver files, using methods described in this manual, the subsequent module checks consistency of data provided by the previous module and, usually issues no warnings. Processing of the data follows broadly the steps described below:

1. 'Box' module provides:

- \* driver's complex transfer function, driver's type and
- \* electro-mechanical parameters – **remember to include driver's diameter for Piston Model**
- \* enclosure type and enclosure parameters, calculates driver's impedance vs. frequency.

2. 'Crossover' module provides:

- \* provides complex transfer function of the compensation circuit.
- \* provides total impedance vs. frequency function of the driver mounted in the box, with the impedance compensating components attached.
- \* includes compensation complex transfer function in the final crossover transfer function.

3. 'System' module adds vectorally all individual transfer functions in XYZ space.

It is clear, that subsequent functions relies heavily on the data provided by the previous module. Phantom files are an attempt to "fool" the program. They provide a short-cut and force the algorithm into using default values to much greater extend. Phantom files are useful when performing crossover or compensation circuit study. These files do not contain drivers' transfer functions or electro-mechanical parameters. However, there are still some data, that must be entered in order to run the program.

## Working With Several Projects

SoundEasy allows you to open up to **3 projects at the same time** and store them in RAM memory. This approach requires you to have somewhat more advanced design skills, however, it offers you an excellent way of making quick comparison between projects, **cutting-and-pasting from one project to another** and so on. Projects are controlled from the main menu and Digital Filter and Digital Equalizer dialogue boxes.

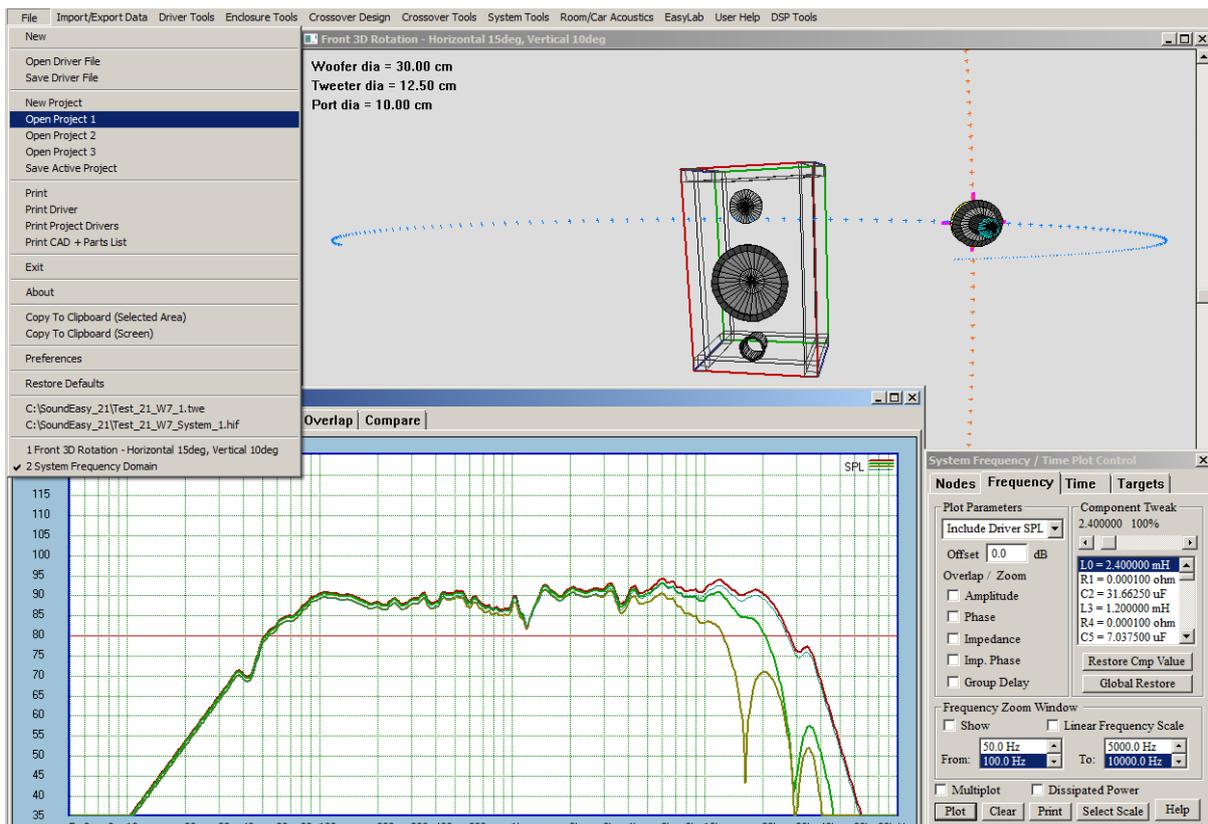


Figure 12.23. Loading all 3 projects into the program data space.

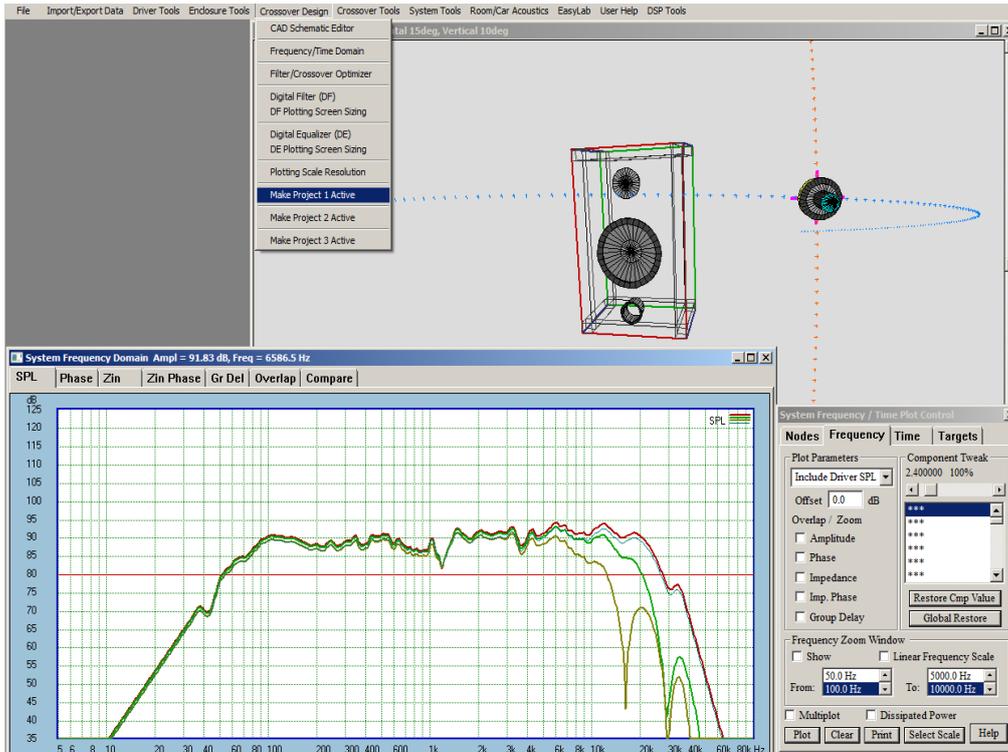


Figure 12.24. Activating Projects from “Crossover Design” menu.

### System Relative AC offsets

When all drivers in a multi-way speaker system are placed on the front baffle, their “acoustic center – to – microphone” distances,  $D_i$ , will be affected by the distance between the microphone and the baffle itself. By subtracting this distance from the total distance  $D_i$ , we can view the “relative acoustic distances” (or offsets) between the drivers. The relative offsets, primarily determine interaction between the drivers at the crossover points.

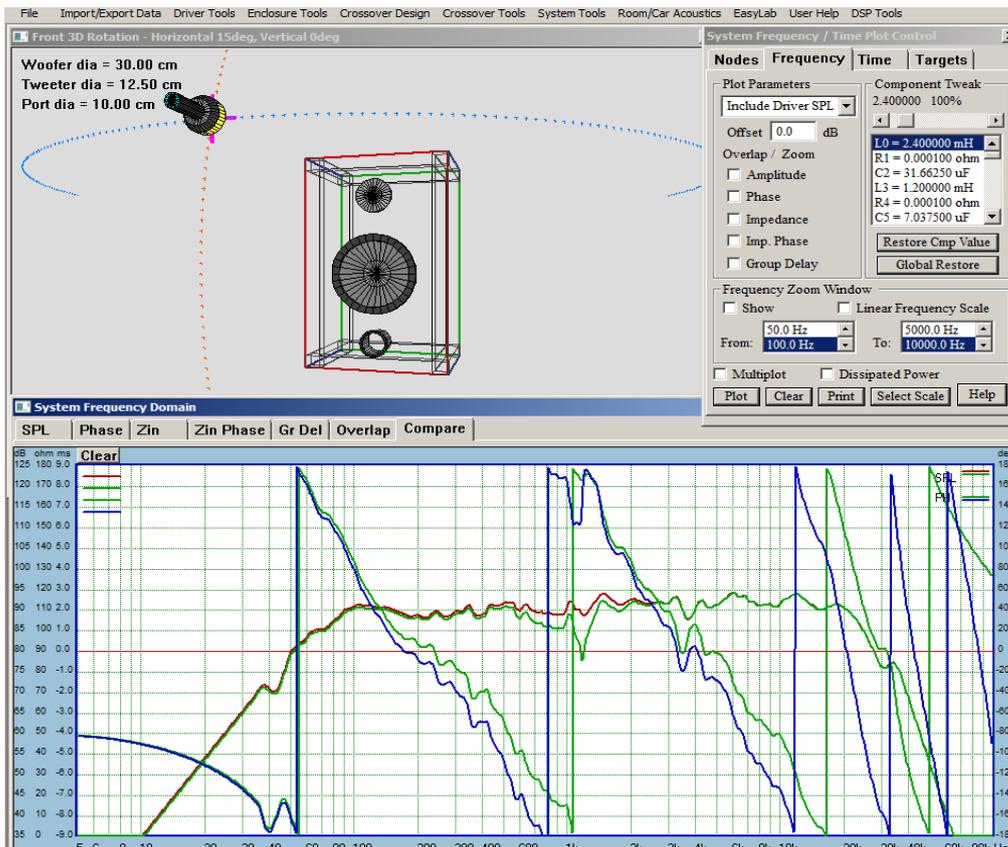


Figure 12.25. Relative acoustic distances (red) phase response.

### 3D Zoom-in Feature

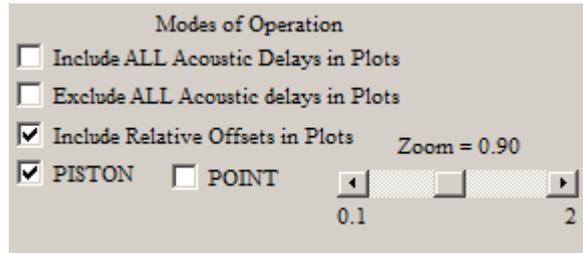


Figure 12.26. Zoom-in slider.

At the bottom of the dialogue box you will find a set of controls that allow you to change viewing aspects of the front baffle. The zoom-in function allows you to control the viewing distance between the front baffle and the observation point.

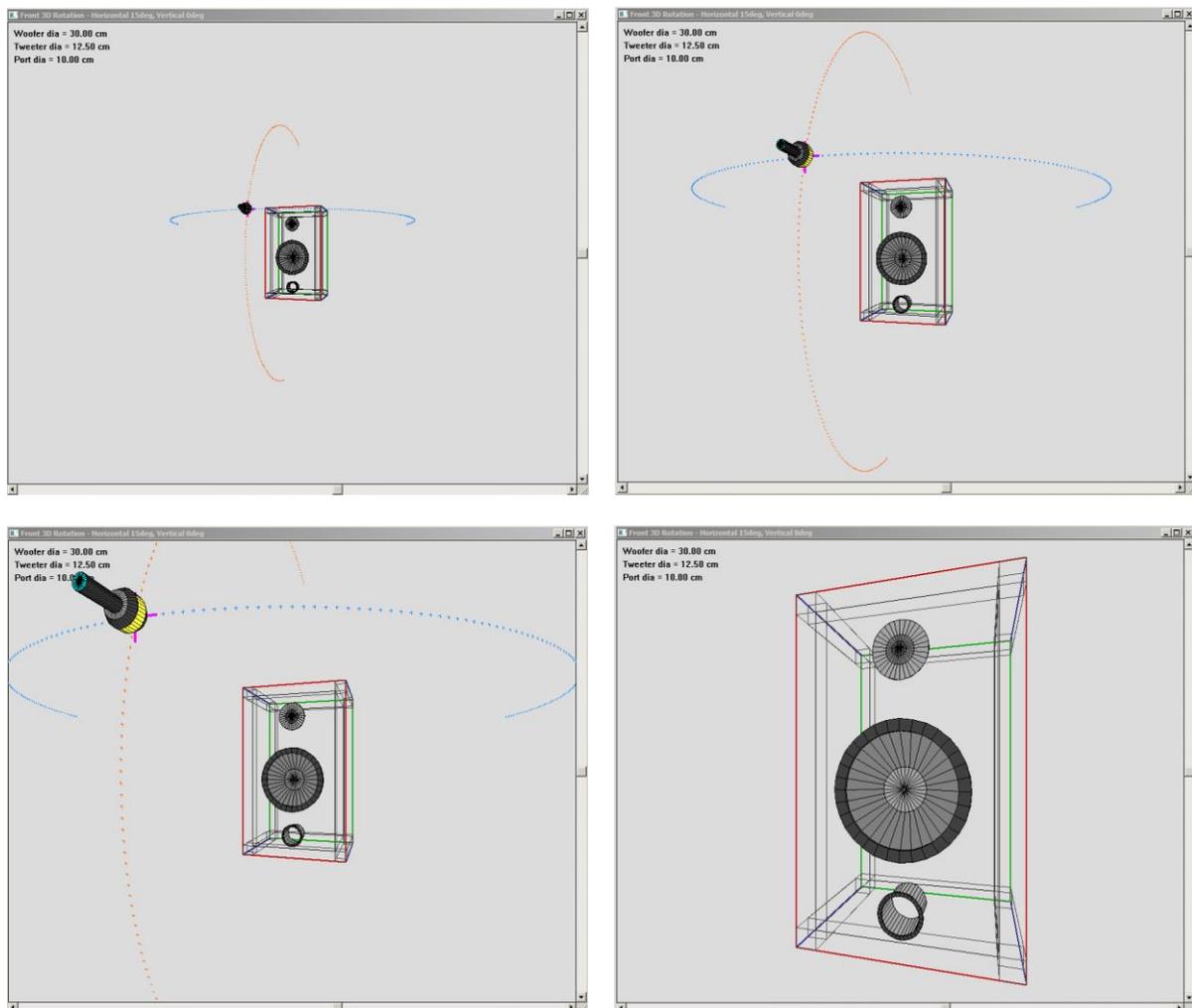


Figure 12.27 Zoom-in examples of 3D front baffle.

Enclosure dimensions can be entered into the dialogue box, using the data fields provided within “**Front Baffle Size**” group of editable fields. Typically, you would enter the same dimensions as for the **Diffraction Baffle**, and also for the **Rectangular Enclosure Calculator**. This would keep the consistency across all data within the program.

### 3D Rotation Feature

At some point, you may take advantage of the 3D viewer of your design, and have a look at some aesthetical aspects and proportions of your design. The 3D Rotation feature allows you to rotate the whole measurement (enclosure + microphone) setup horizontally and vertically. This accomplished by using vertical and horizontal sliders at the edges of the screen.

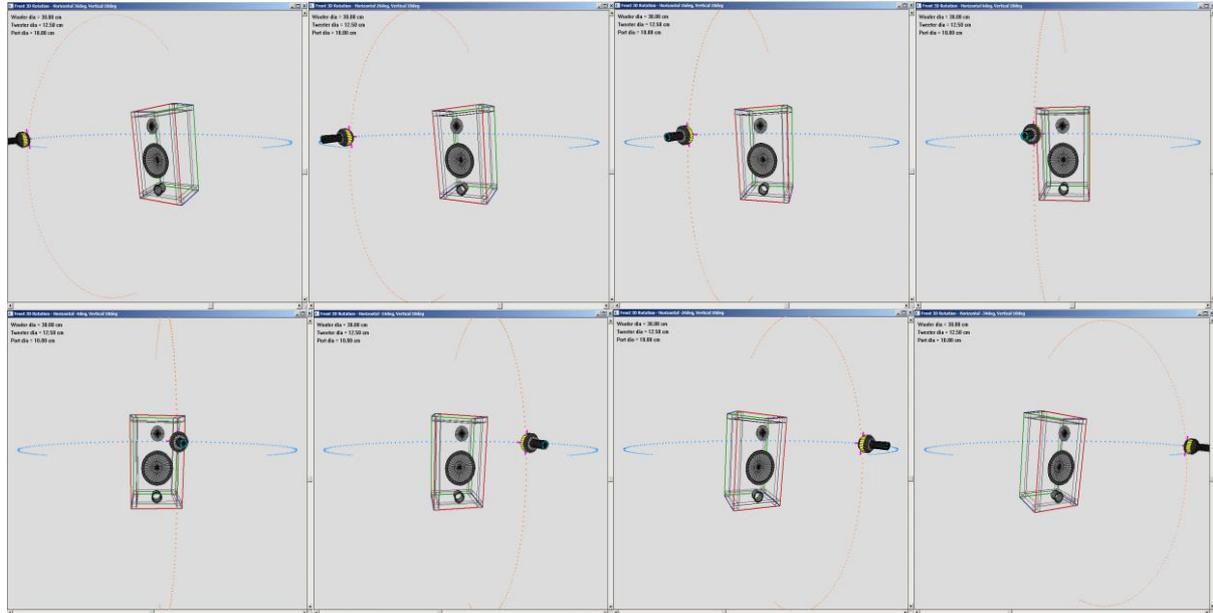


Fig. 12.28 Sliders allow you to rotate the whole measurement set-up.

### 3D System Screen Z - offset

Each driver on the front baffle can be recessed or brought forward by using Z-slider. Positive direction increases the recess. Possibly the best visualization of this process is accomplished by rotating the whole measurement system to the left, by using the Horizontal Slider and moving it fully to the right. The Screen's title bar will display:



Figure 12.29 shows tweeter driver recessed by 20 cm into the enclosure.

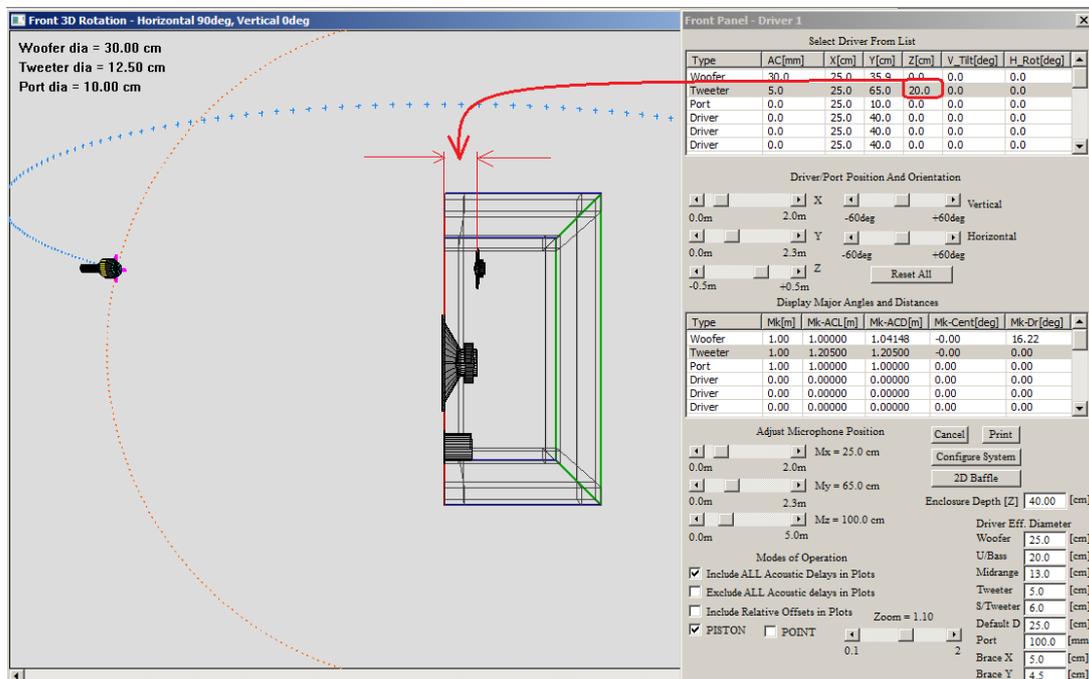


Figure 12.30 Examples of Z-axis offsets shown in 3D Rotation screen.

## System Time Domain Plots

Having uploaded a project file, you can review the time domain performance of the complete system or individual drivers. In the example shown below, only the woofer driver was selected for analysis. This is accomplished by ticking off midrange and tweeter drivers from the “Nodes” TAB – see below. Next, on the “Time” TAB, please press the “Crossover” button to analyse woofer driver’s time domain performance at the nominated frequency – in this example, it is 100Hz entered as “Test Frequency”.

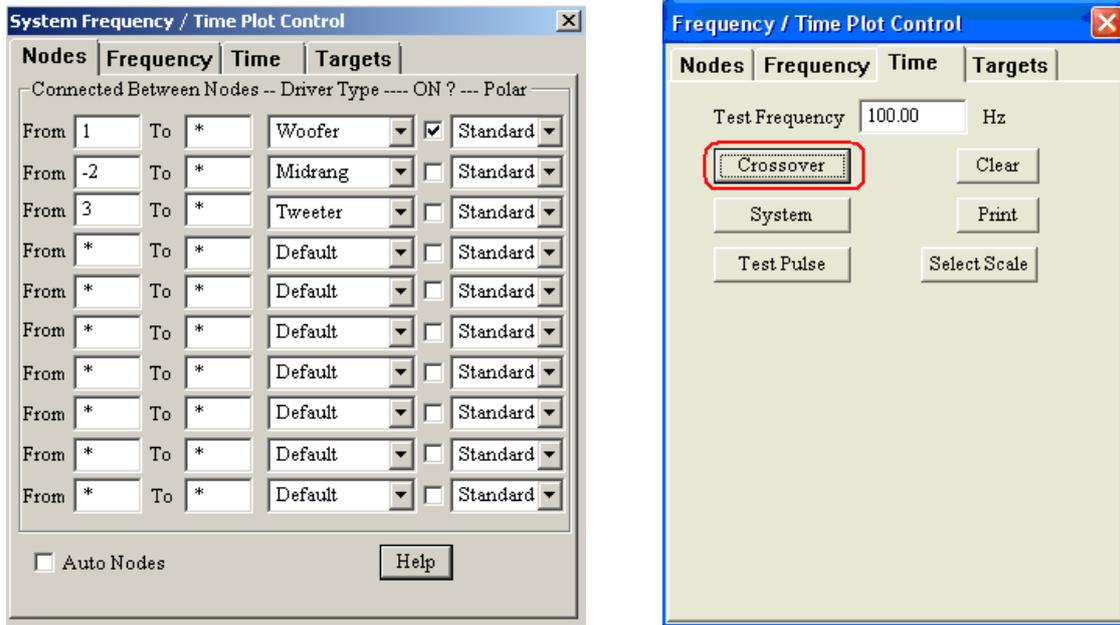


Figure 12.31 Settings for time domain analysis of a woofer driver.

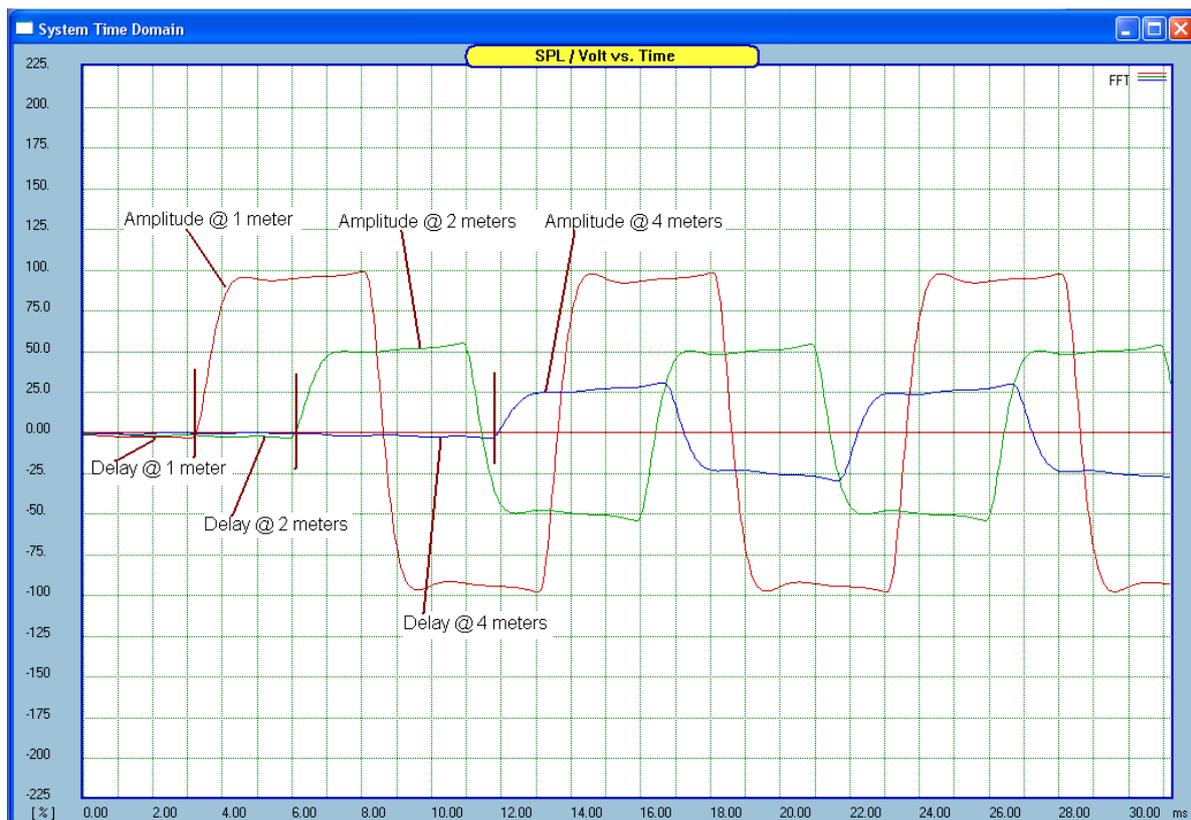


Figure 12.32 Time-domain performance for analysis of a woofer driver.

## Polar Response Spectrogram

There are two ways of displaying polar response data collected over -90deg to +90deg set of angles.

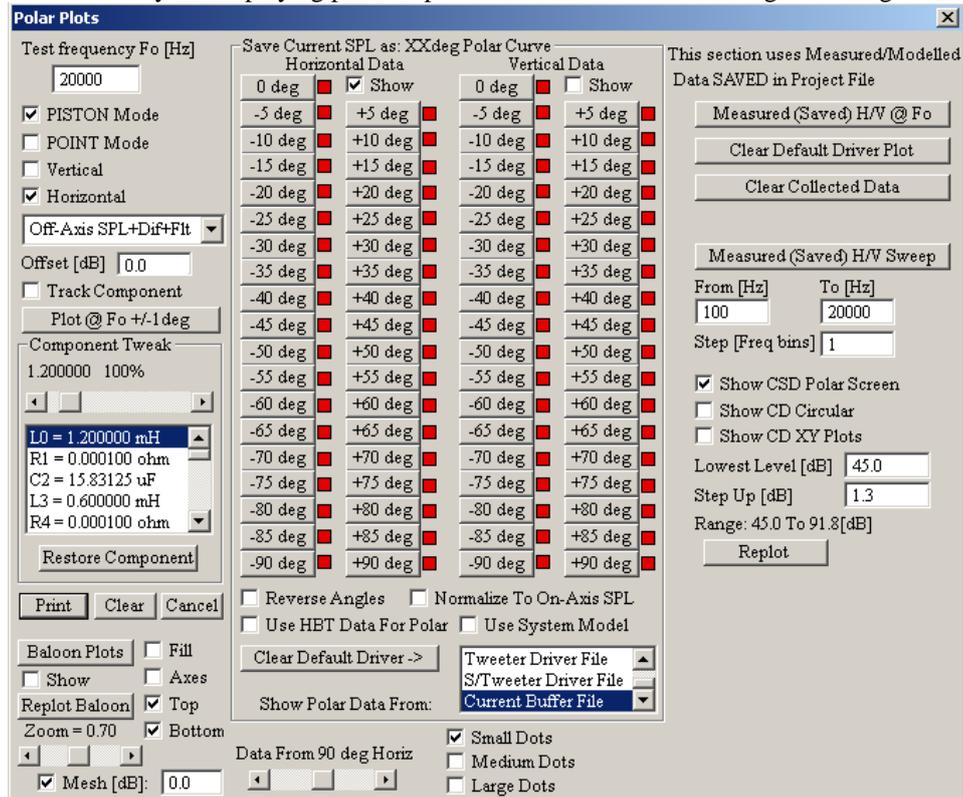


Figure 12.33 Polar Plots control box.

Firstly, standard, 3D polar plot shown below.

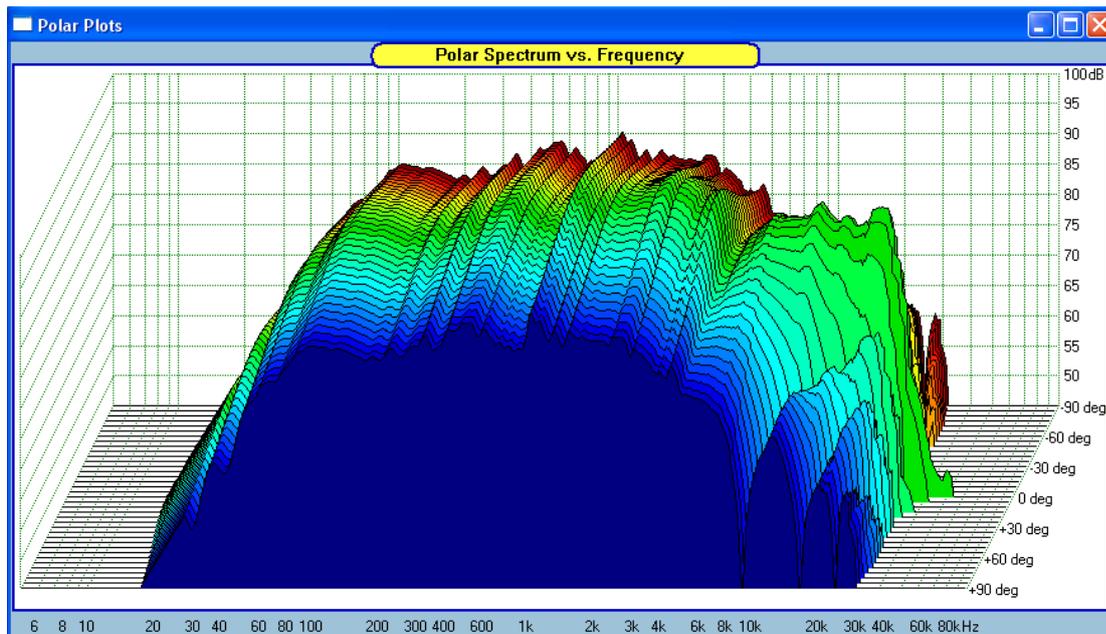


Figure 12.34 3D Polar Plots

Now, please “check” the “Show CD Plots” checkbox - this will the “Polar Plots” display screen to more of the “Constant Directivity” style plots.

The same driver - Polar Plot showing colour-coded Directivity. The lowest level (in dB’s) and the increment size can be set from the data entry fields provided.

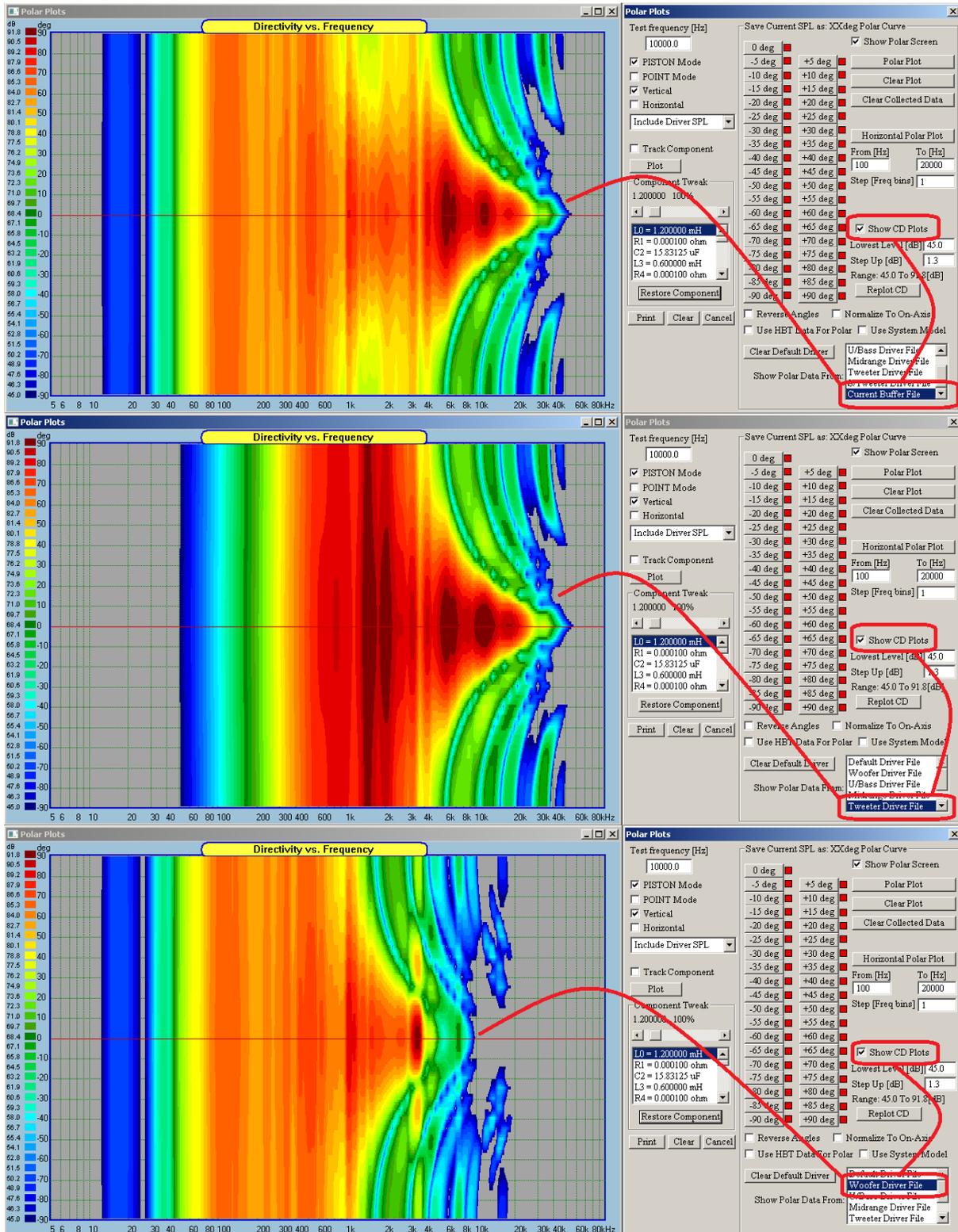


Figure 12.35 “Constant Directivity” style plots – system, tweeter and woofer.

The above plot is activated by a **checkbox** labelled “Show CD Plots”. It is perhaps easier to visualize symmetrical aspects of the polar response using CD Plots option.

### Adding Port in System Screen

In order to help in visualizing the front panel layout and the aesthetics of the design, it may be beneficial to add ports to the layout. The ports are only visual elements and do not contribute to any curves displayed. Several ports can be added by selecting them from the drop-down list box in the Nodes TAB – see below.

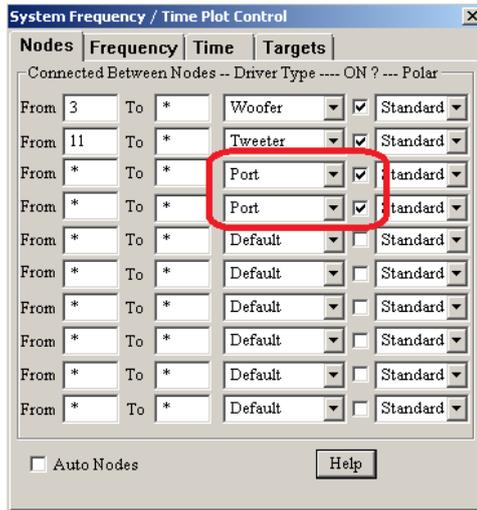


Figure 12.36 Selecting Port icon for display in the System screen.

The ports can be moved around using the same controls as for the drivers. Diameter of the port can be selected from the data field labelled as “Port” under “Driver Eff. Diam” data column.

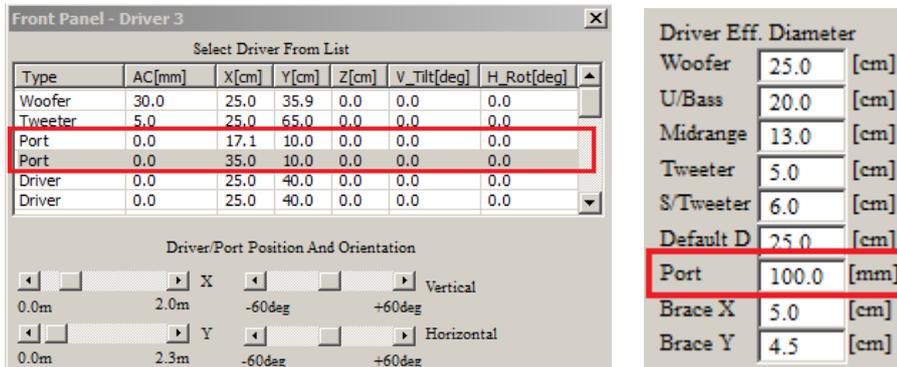


Figure 12.37. Selecting port's diameter and location.

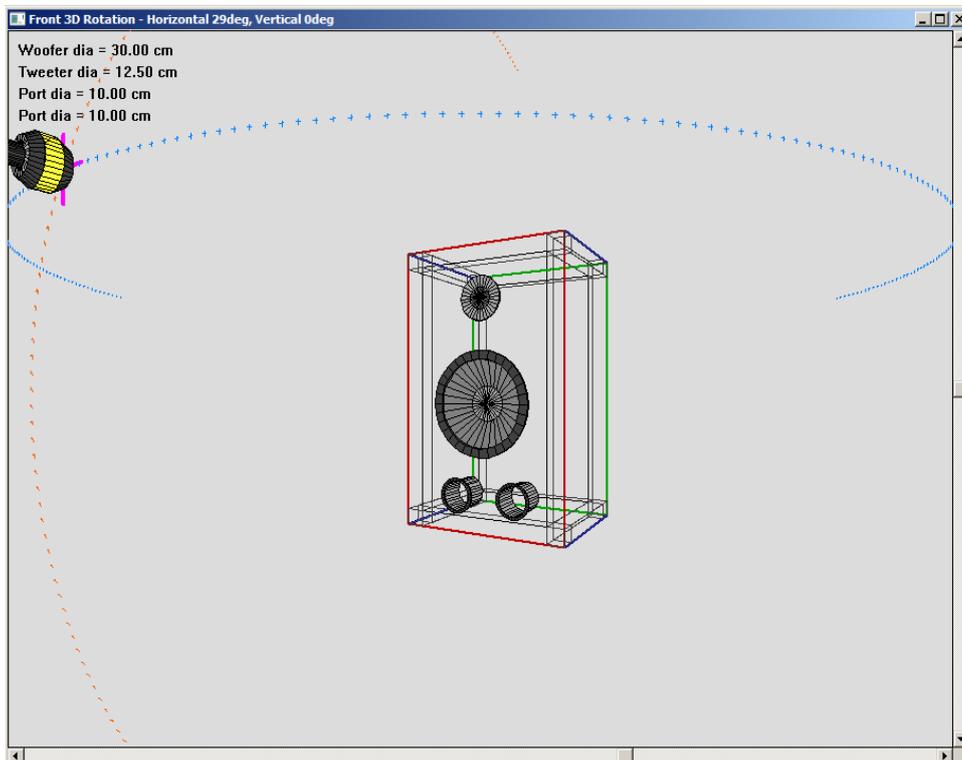


Figure 12.38. Ports are displayed in the System screen.

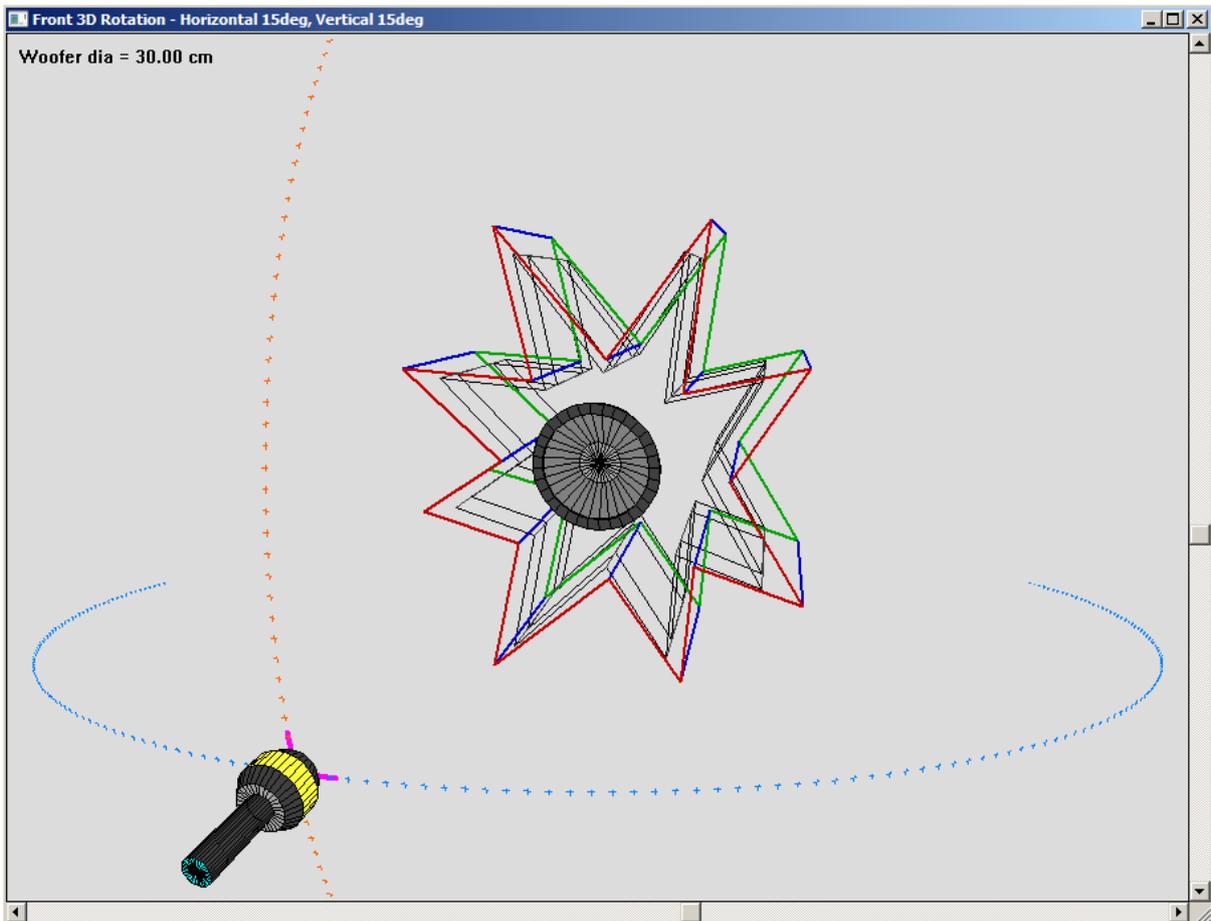
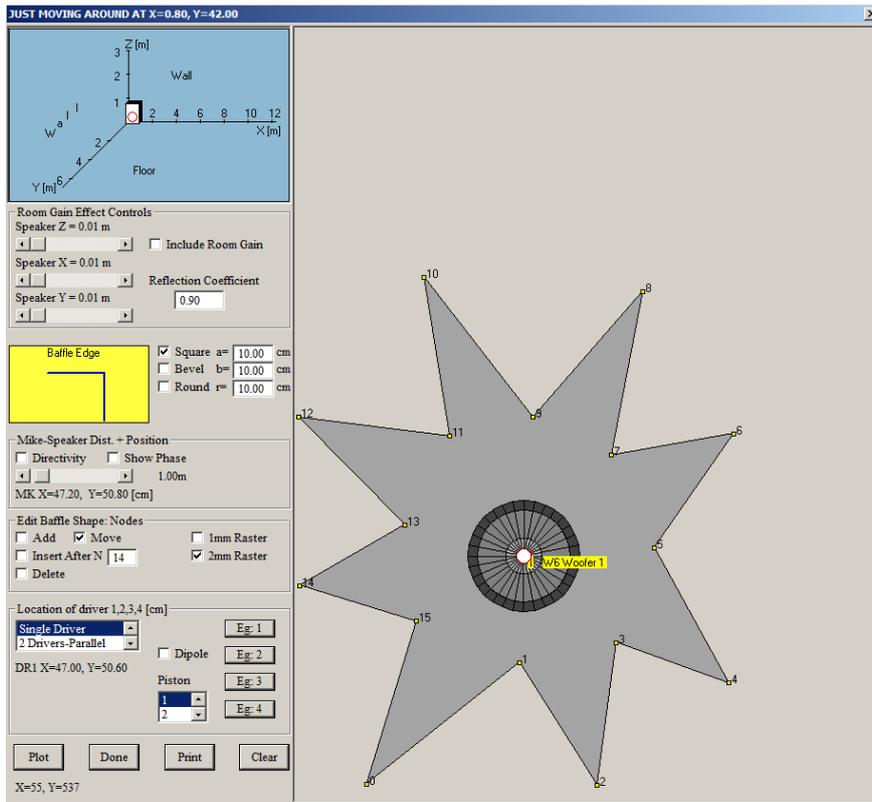
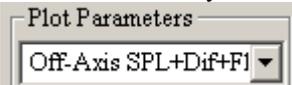


Figure 12.39. Example of somewhat “esoteric” front baffle.

## Power Response & Directivity Index

Performing polar SPL measurements over frontal 180deg angle with 5deg increments, allows you to plots the results as “Polar Plots” and also calculate Measured Power and Directivity Index. Both curves can be obtained by modelling the front baffle and corresponding microphone locations, or by measurements. This functionality is available in System Module.

Power Response and Directivity Index are available from “Power/Directivity” TAB in the System

Module. Please select  for capturing correctly calculated DI.

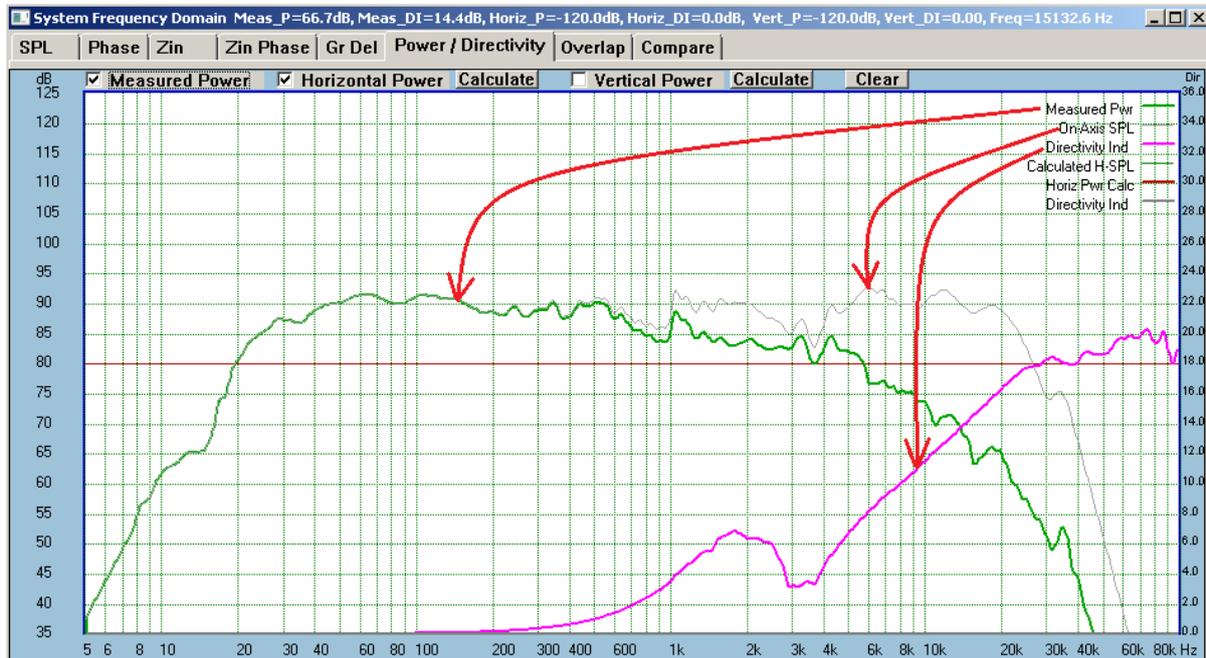


Figure 12.40. Power Response and Directivity Index.

“**Measured Power**” – shows power response as measured.

“**Horizontal Power**” + “**Calculate**” – shows power response calculated over horizontal plane.

“**Vertical Power**” + “**Calculate**” – shows power response calculated over vertical plane.

“**Clear**” – clears the display.

## Ribbon and Planar Drivers Icons

With the advent of ribbon and planar drivers, it is beneficial to actually display the icons of those when modelling the system. The icons will automatically change to ribbon or planar when the “**Ribbon Width**” and “**Ribbon Height**” parameters are both entered – see Figure 12.41 below.

**Driver Parameter Editor**

T/S Editor | **Amplitude Model** | Impedance Model | Hilbert-Bode Transform

Electrical Parameters			Mechanical		[Metric]	[Imperial]	Parameters		[Metric]	[Imperial]
DC Resistance Re	8.0	ohm *	Mechanical Qm	2.0	*		AC Centre Offset	0.0	mm	0.000 in
Electrical Qe	1.1523	*	Compliance Vas	.0250		Lt * 0.00 ft^3	Magnetic Gap Height	0.0	mm	0.000 in
Total Qt	0.7311		Effective Diam.	7.0000	cm *	2.76 in	Voice Coil Height	0.0	mm	0.000 in
Coil Inductance	0.10	mH *	Effective Area	38.485	cm^2*	5.97 in^2				
B*L Product	9.992	Wb/m *	Suspension	1.0	mm	0.039 in				
Eddy Resistance	30.0	ohm	Dynamic Mass	2.500	gm *	0.09 ounce				
Power Handling	50.0	Watt	Free Air Res. Fs	915.527	Hz *					
Efficiency	90.0	dB	<b>Ribbon Width</b>	5.0	cm	0.197 in				
Calculated 4PI Efficiency = 91.2 dB			<b>Ribbon Height</b>	10.0	cm	0.394 in				

Driver Type/Model: New

Model: Driver

Type: Super Tweeter (selected), Tweeter

Use TS Wizard:

Buttons: Print, Help, Save File, Repair Impedance, Edit Amplitude, Repair Amplitude, Edit Impedance

**Front Panel - Driver 0**

Select Driver From List

Type	AC[mm]	X[cm]	Y[cm]	Z[cm]	V_Tilt[deg]
Woofers	10.0	18.6	22.2	0.0	0.0
U/Bass	0.0	37.3	47.6	0.0	0.0
Midrang	0.0	15.6	48.2	0.0	0.0
Tweeter	0.0	36.7	68.8	0.0	0.0
S/Tweet	0.0	17.0	68.8	0.0	0.0

Driver/Port Position And Orientation

X: 0.0m to 2.0m, Vertical: -60deg to +60deg

Y: 0.0m to 2.3m, Horizontal: -60deg to +60deg

Z: -0.5m to +0.5m

Buttons: Reset All, Show Tilt Window

Display Major Angles and Distances

Type	Mk[m]	Mk-ACe[m]	Mk-ACd[m]	Mk-Ctx[deg]	Mk-Cty[deg]
Woofers	1.00	0.97592	1.07114	3.79	24.33
U/Bass	1.00	0.96592	0.99074	-7.26	10.72
Midrang	1.00	0.96592	0.98646	5.56	10.37
Tweeter	1.00	0.96592	0.97341	-6.91	-1.73
S/Tweet	1.00	0.96592	0.96966	4.73	-1.73
Port	1.00	1.00000	1.00000	0.00	0.00

Adjust Microphone Position

Mx = 0 deg, My = 15 deg, Mz = 100.0 cm

Buttons: Print, Cancel, Configure System

Enclosure Depth [Z]: 40.00 [cm]

Driver Eff. Diameter

Woofers	25.0	[cm]
U/Bass	15.0	[cm]
Midrange	10.0	[cm]
Tweeter	7.0	[cm]
S/Tweeter	7.0	[cm]
Default D	25.0	[cm]
Port	100.0	[mm]
Brace X	5.0	[cm]
Brace Y	4.5	[cm]

**Ribbon Size**

X	8.0	Y	12.0
X	5.0	Y	10.0
X	2.5	Y	8.0

Modes of Operation

Include ALL Acoustic Delays in Plots

Exclude ALL Acoustic delays in Plots

Include Relative Offsets in Plots

PISTON  POINT

Zoom = 1.50

Figure 12.41. “Ribbon Width” and “Ribbon Height” parameters are both entered.

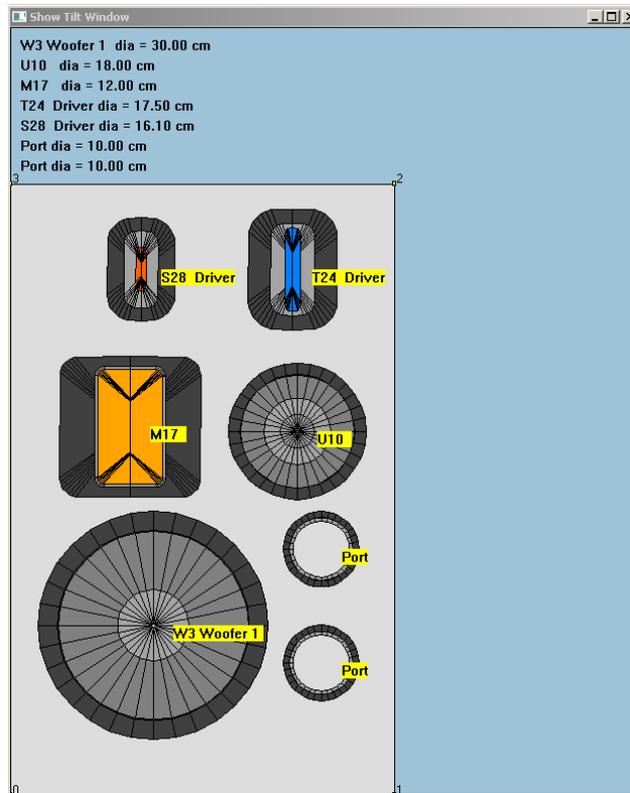
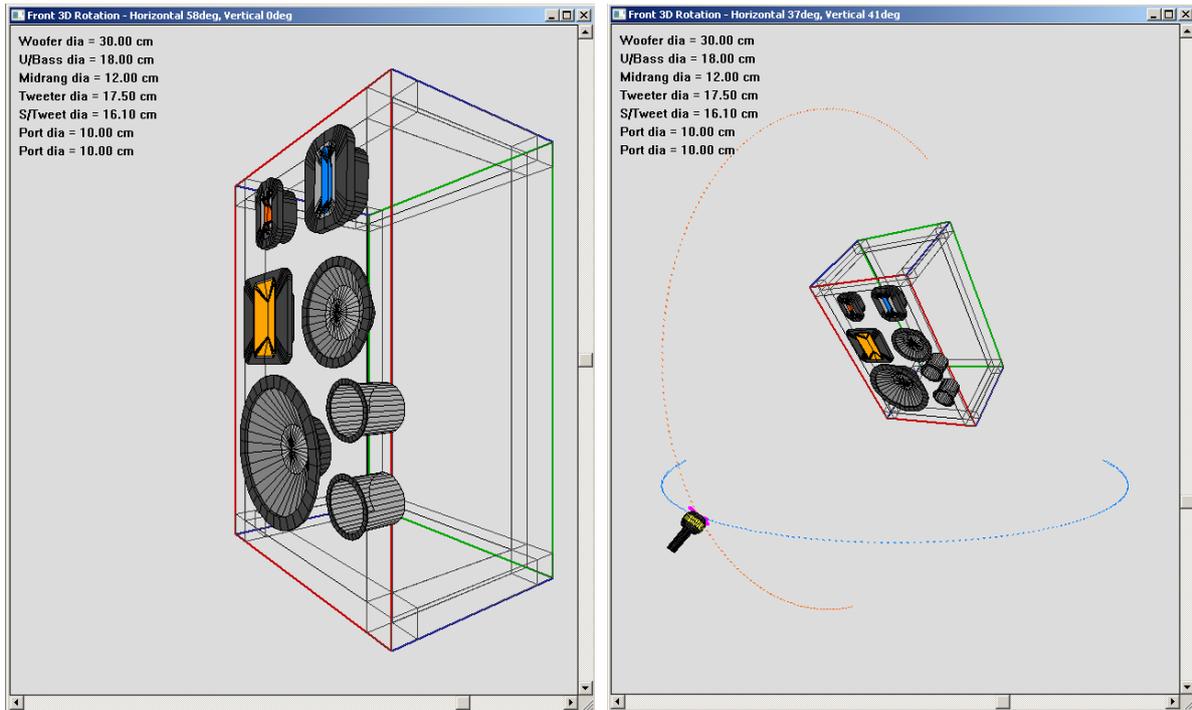


Figure 12.42. Here are the actual icons, as displayed in the System 3D and Tilt Window screens.

## Automated generation of horizontal and vertical polar plots for -90....+90deg angles

Horizontal and vertical polar plots can be simulated automatically in System Module. The plots can be generated for each driver in the system, or the whole system, so each driver needs to be loaded one-by-one into the program and have their polar plots simulated and saved into the driver file. Polar plots are referenced to the current microphone location. Therefore, while generating **horizontal polar plots**, the **vertical location** of the microphone will not be changed. The same approach is true while generating vertical polar plots. This process will be illustrated in the following example below. But first, two important issues.

1. Diffraction effect is position-dependant. Therefore, it must be included in simulating off-axis diffraction, as the microphone is moved around the front hemisphere of enclosure. Example of -90deg....+90deg diffraction is shown on figure below.

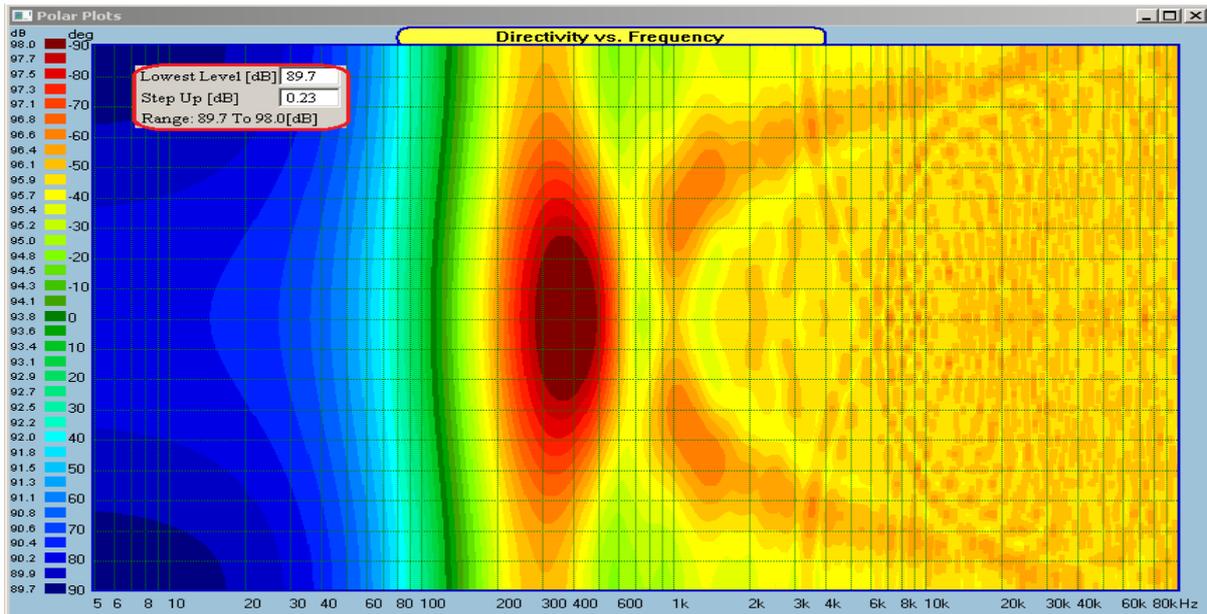


Figure 12.43. 90deg....+90deg diffraction of a 80cm X 50cm enclosure.

2. Microphone is automatically moved in the front spherical hemisphere, **referencing to the pivotal point**. The coordinates of the pivot point are now editable on the Front Panel Layout screen.

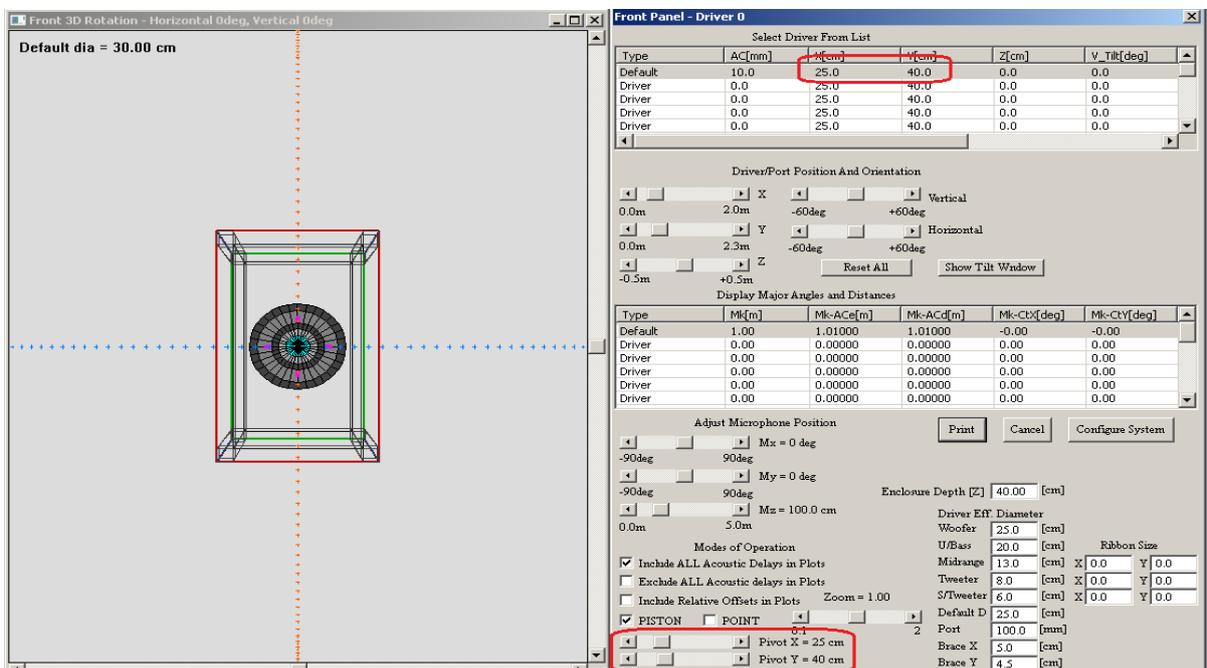


Figure 12.44. Pivot coordinates adjusted to coincide with driver's on-axis radiation.

Since we attempt to account for ever-changing diffraction while modelling 36 angles of radiating SPL, all based on single, on-axis measurements, **this single curve provided for the algorithm must be supplied with diffraction measured for each driver at the microphone pivotal point.** While you measure the SPL of a driver, the diffraction will be embedded into the SPL curve.

1. Load driver file.

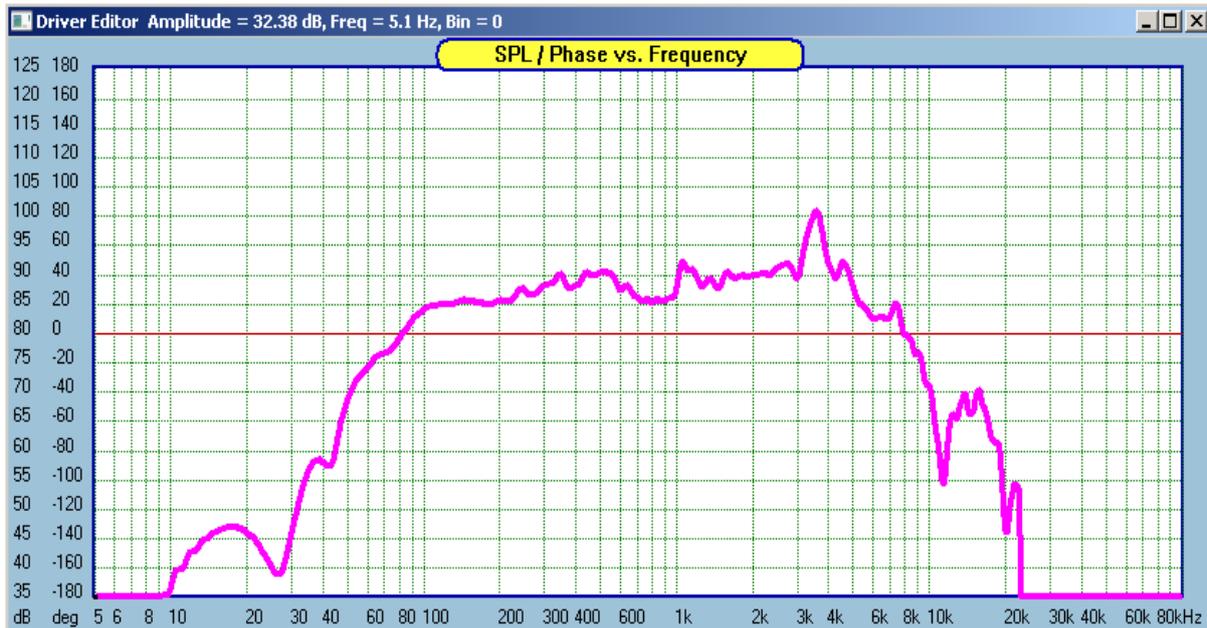


Fig 12.45. Load driver file into the program

2. Go to **System -> Front Panel Layout** and press **Configure System** button.
3. Turn **ON** the driver Node.
4. **Adjust microphone pivot location to the desired position.**

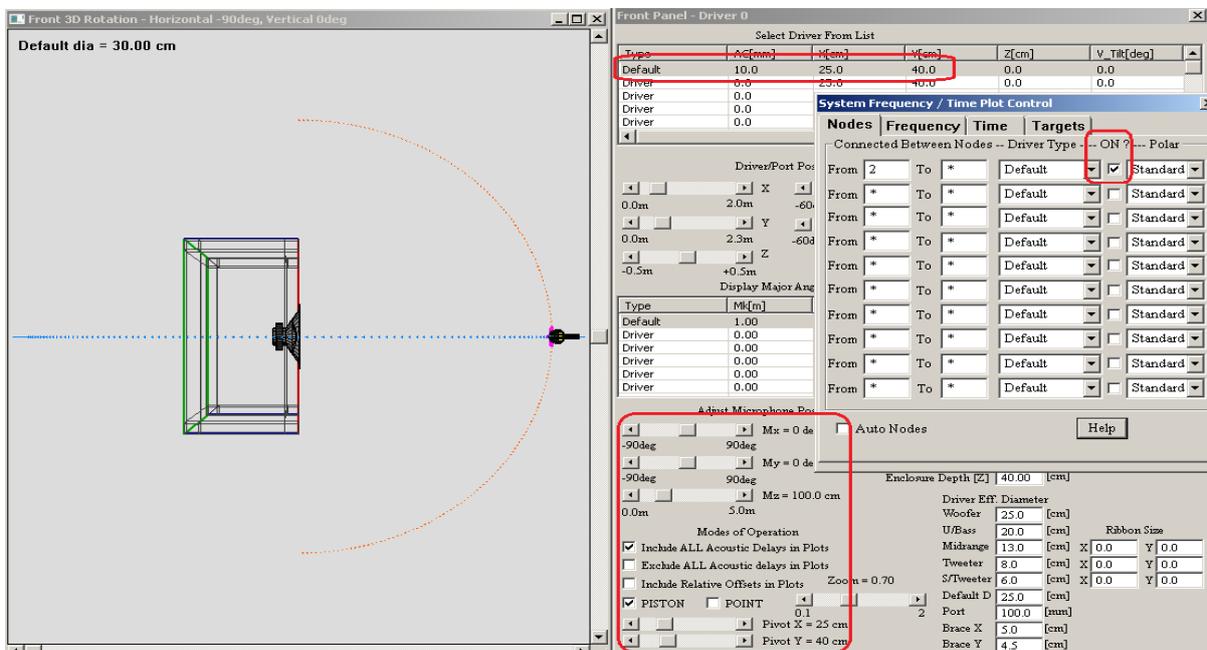


Fig 12.46. Adjust microphone location to the desired position

5. Select "Frequency" tab.
6. Select "**SPL of Driver Type**" option shown below.
7. Press **Plot** button to see the On-Axis SPL plot corresponding to the location of the microphone.

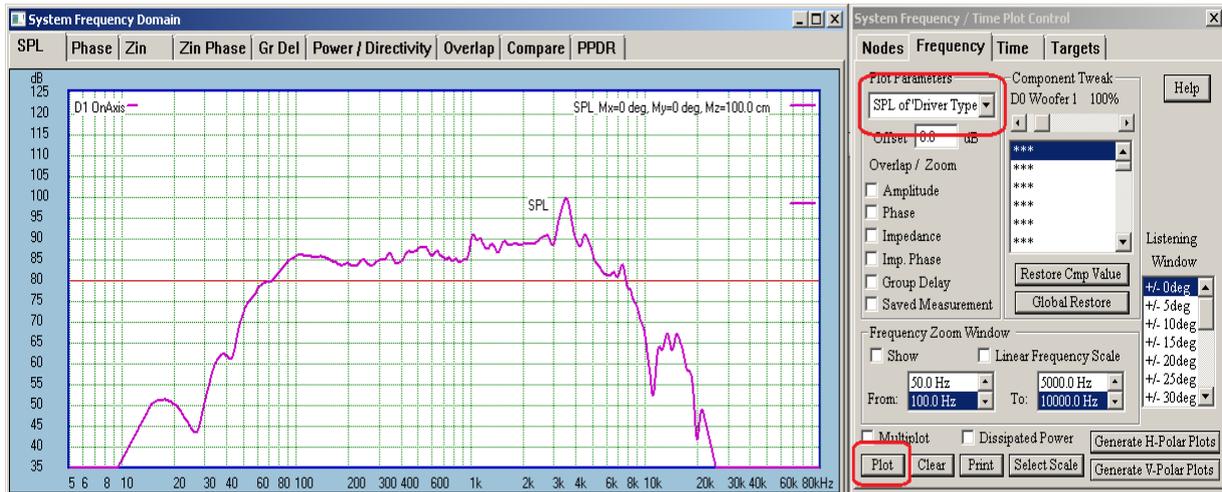


Fig 12.47. Select “SPL of Driver Type” option and press Plot.

8. Select “Off-Axis SPL + Diff” option as the Plot Parameters.
9. Press **Generate H-Polar Plots** button. This action will create -90deg.....+90deg polar plots for the current vertical microphone location. Save the driver file now.

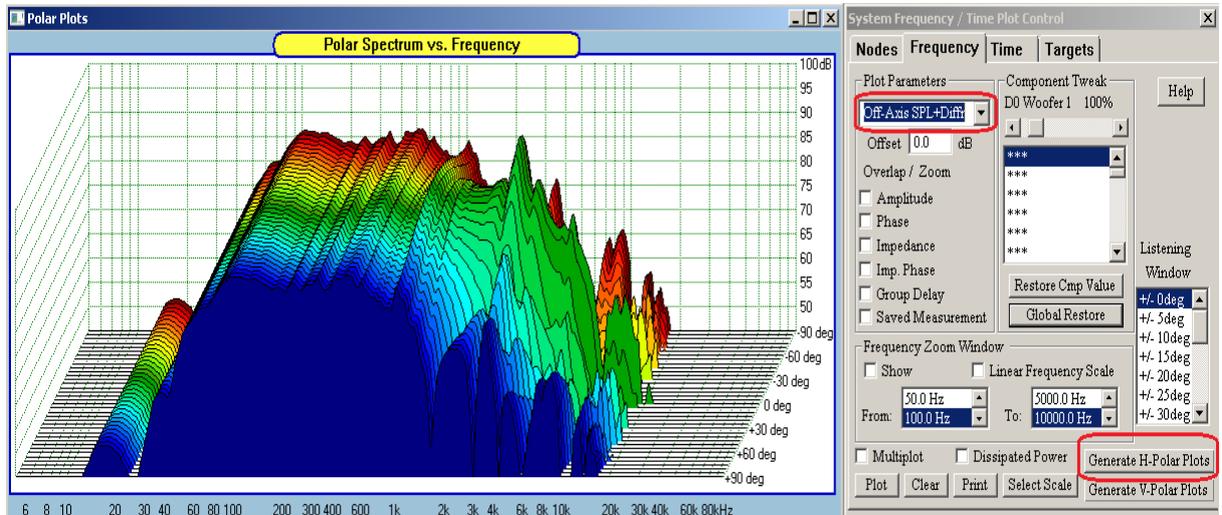


Fig 12.48. Press **Generate H-Polar Plots** button.

## Polar Plots Representations

Dispersion characteristics can be visualized in several different ways:

1. CSD plots, as regular and normalized versions
2. CD Rectangular plots, as regular and normalized versions
3. CD Circular plots, as regular and normalized versions

Shown below are all six types of plots, selectable from Polar Plots dialogue.

1.  Show CSD Polar Screen

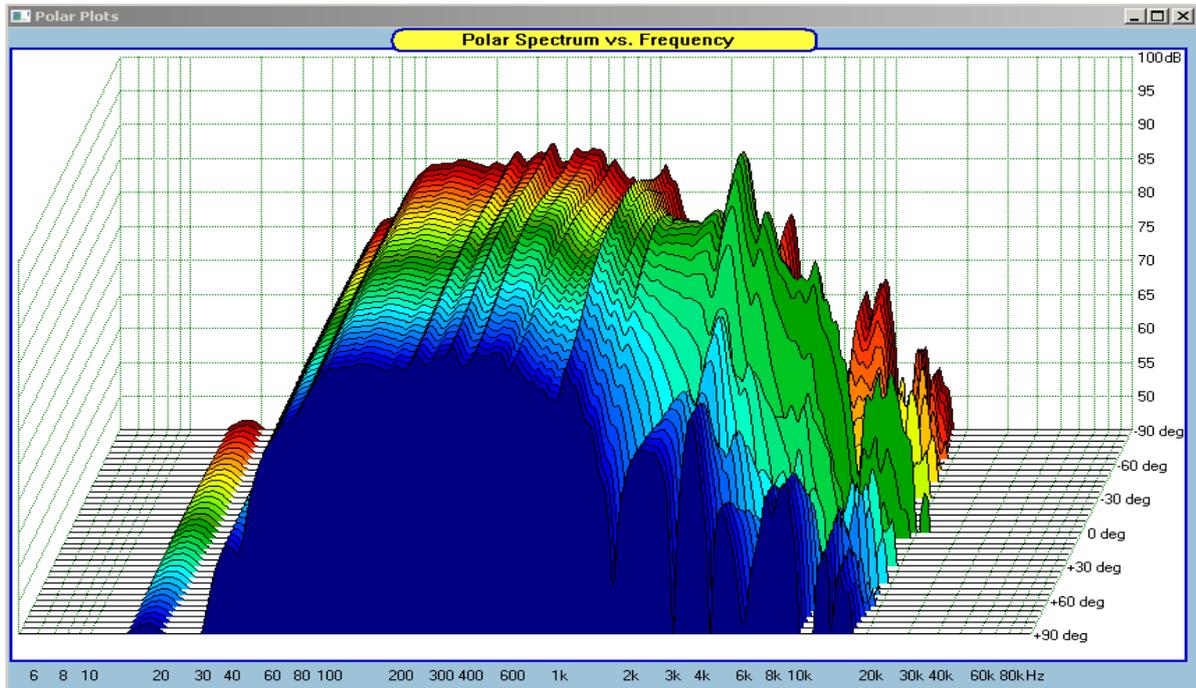


Fig 12.49. CSD plots, as Standard version

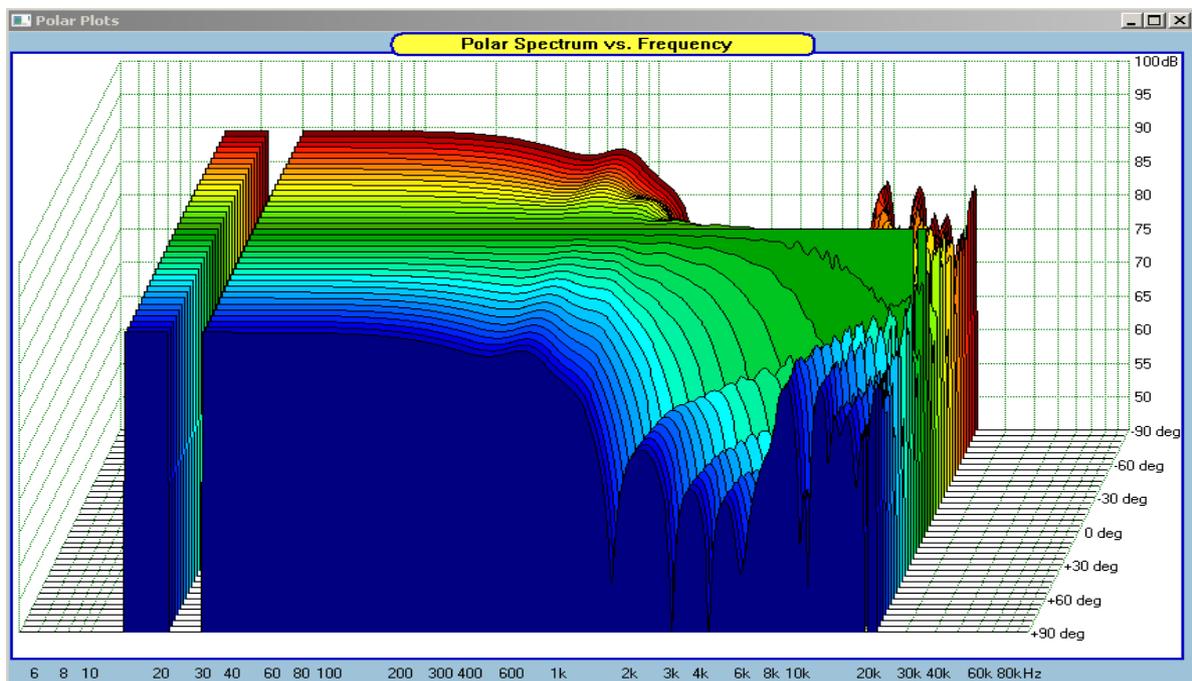


Fig 12.50. CSD plots, as Normalized version

2.  Show CD XY Plots

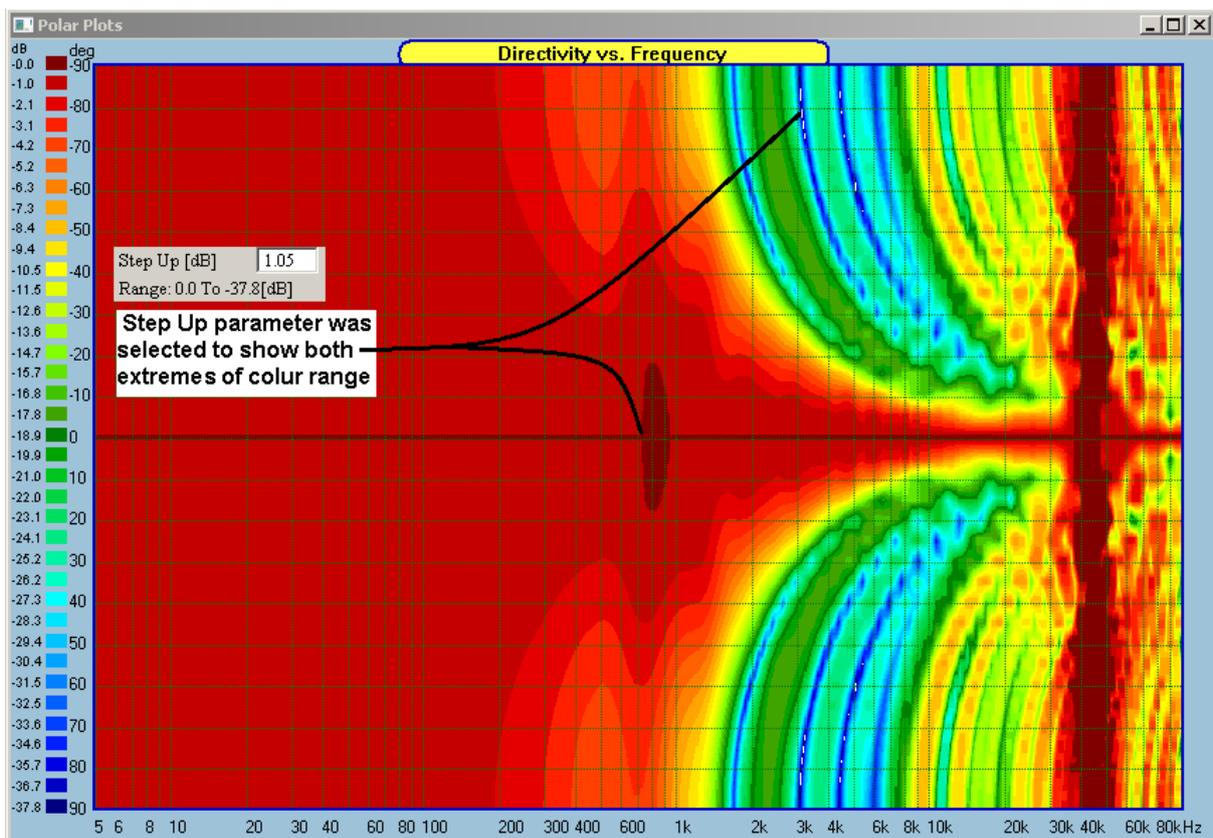
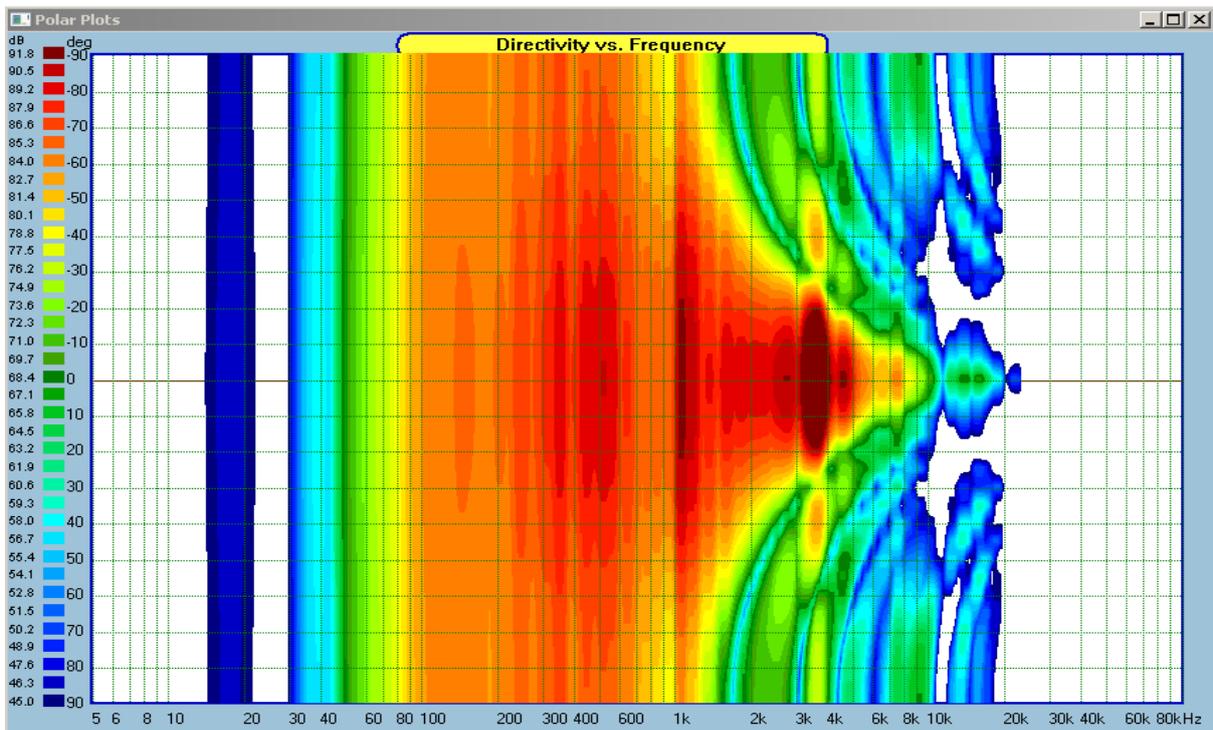


Fig 12.51. CD Rectangular plots, as Standard and Normalized versions

3.  Show CD Circular

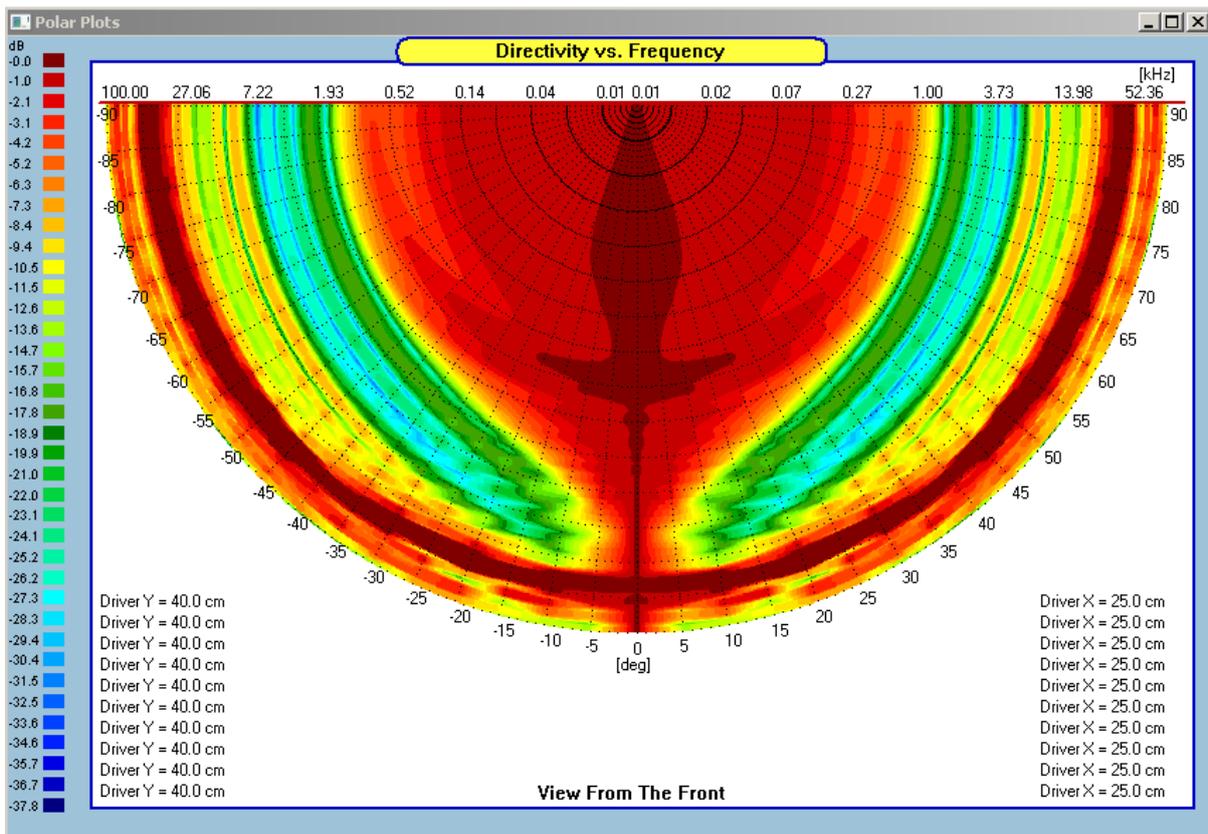
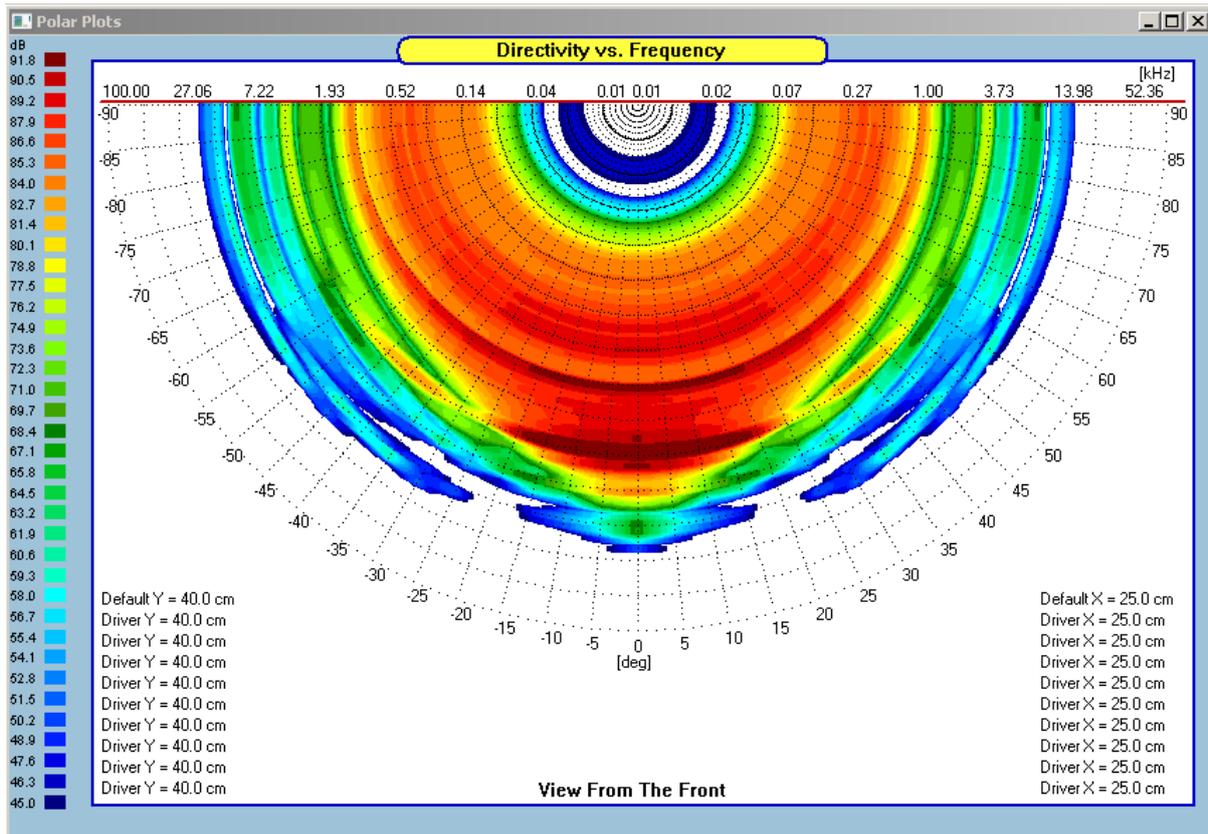


Fig 12.52. CD Circular plots, as Standard and Normalized versions

Please note, that normalized versions must have the same colour line at 0deg radiation angle.

## Evaluating Diffraction Alone via Polar Plots

Polar plots are best presented if they are shown in full spectrum of available 36 colours. This is easily accomplished by adjusting the “Lowest Level” and “Step Up” editable parameters available in the dialogue box.

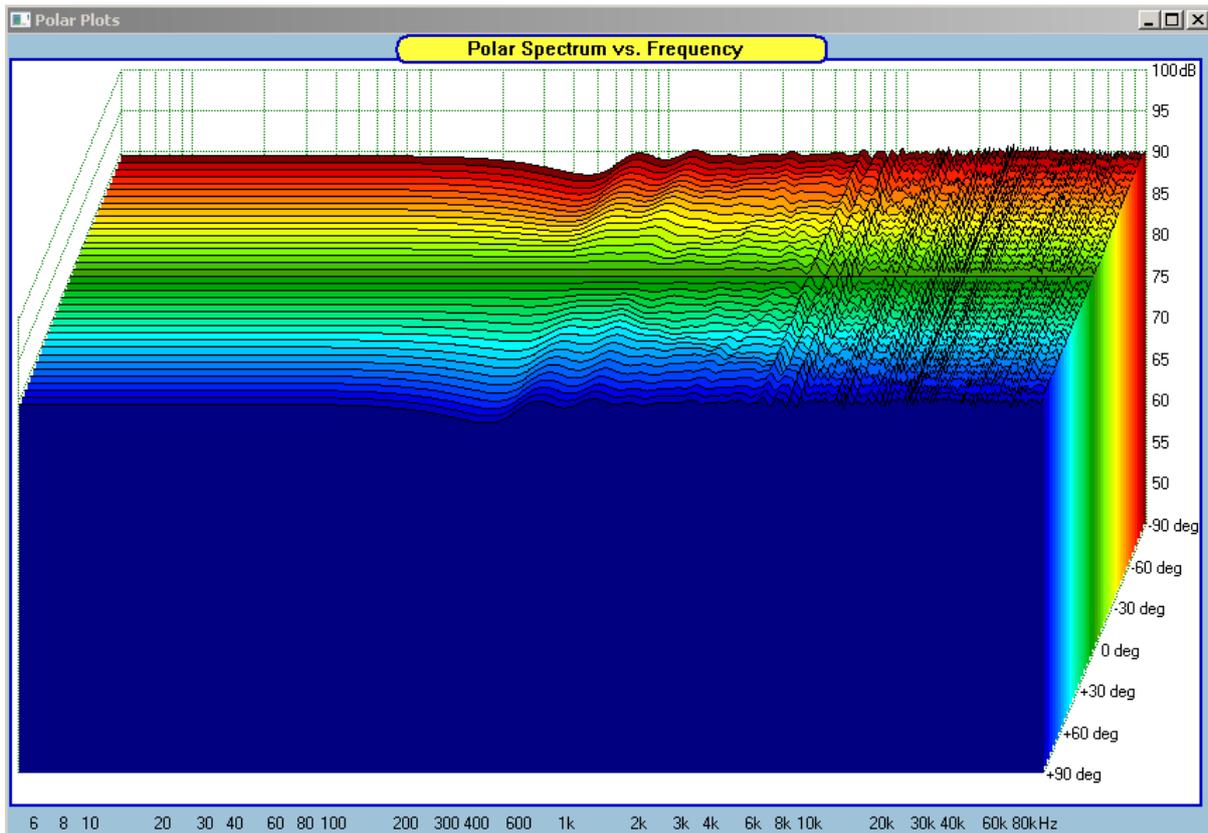
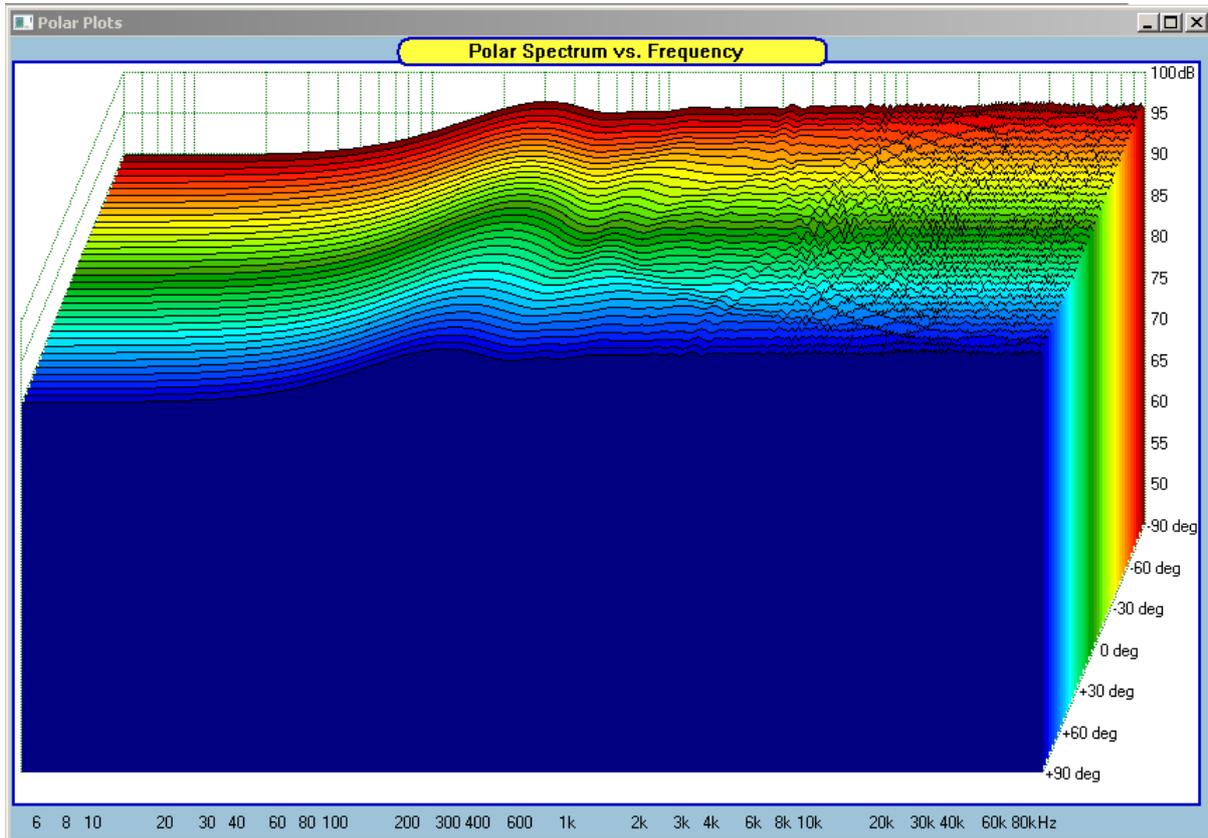


Fig 12.53. CSD plots, as Standard and Normalized versions

This is particularly important when evaluating diffraction of your enclosure in standard and normalized versions. Please review the “Lowest Level” and “Step Up” editable parameters for CD and CD Circular plots presented below.

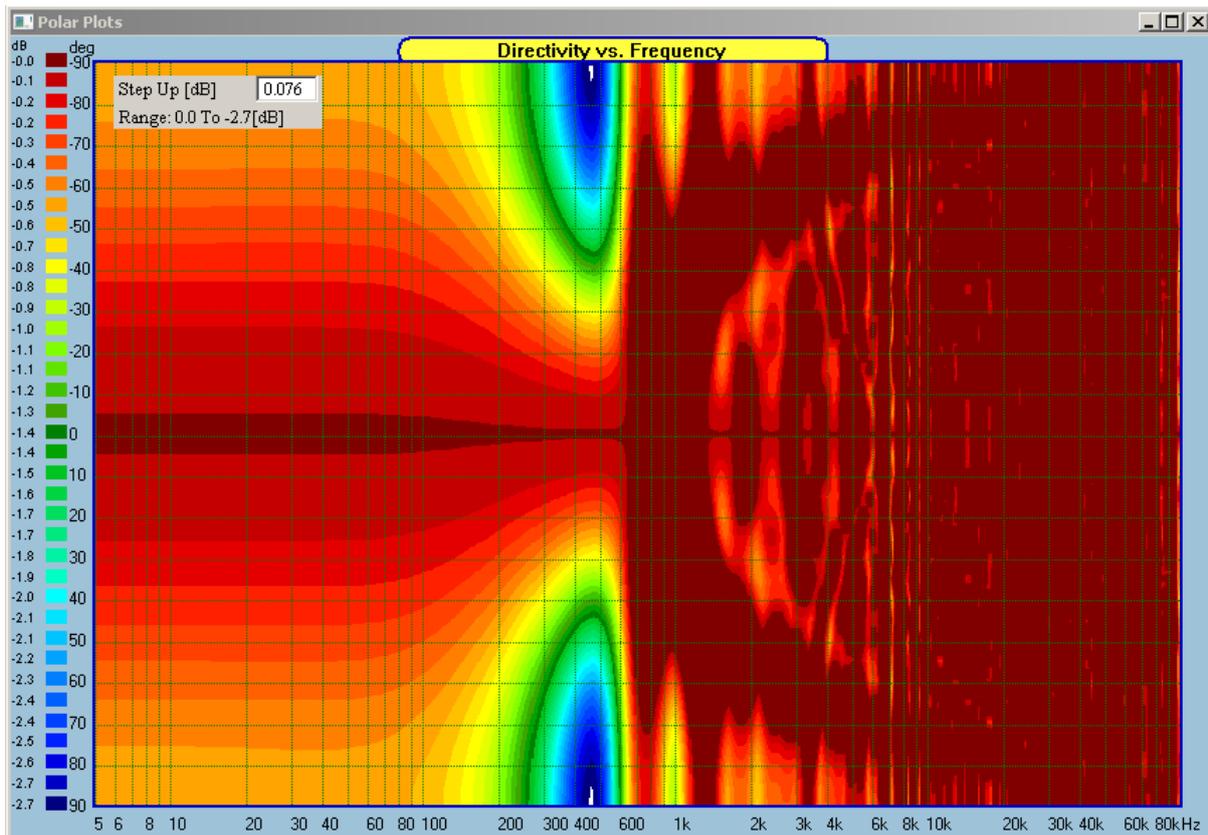
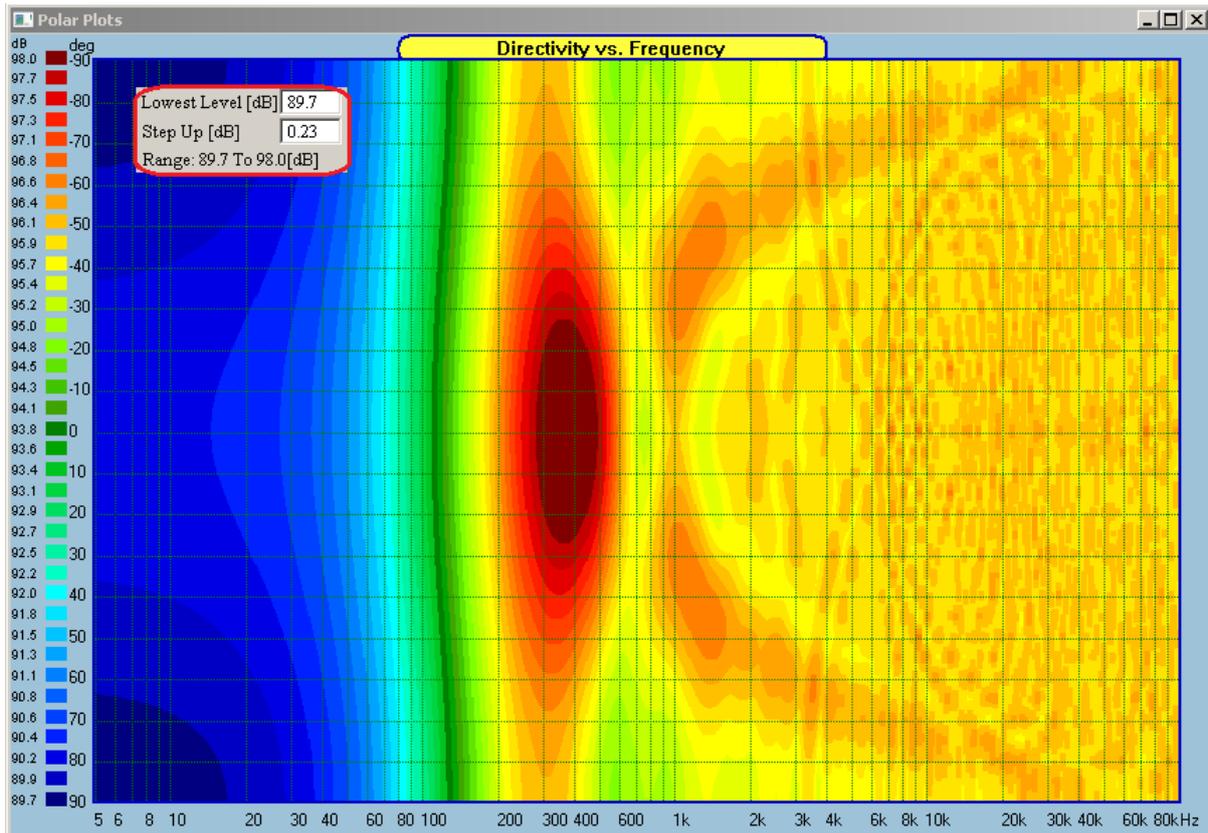


Fig 12.54. CD plots, as Standard and Normalized versions

Diffraction is frequency dependant and may vary by as much as 9-10dB along the frequency axis. However, the diffraction varies only by 2-3dB from on-axis level across -90.....+90deg angles. In order to utilize all 36 colours to cover 2.7dB range, the Step Up parameters has to be very small. In this case it was 0.076dB.

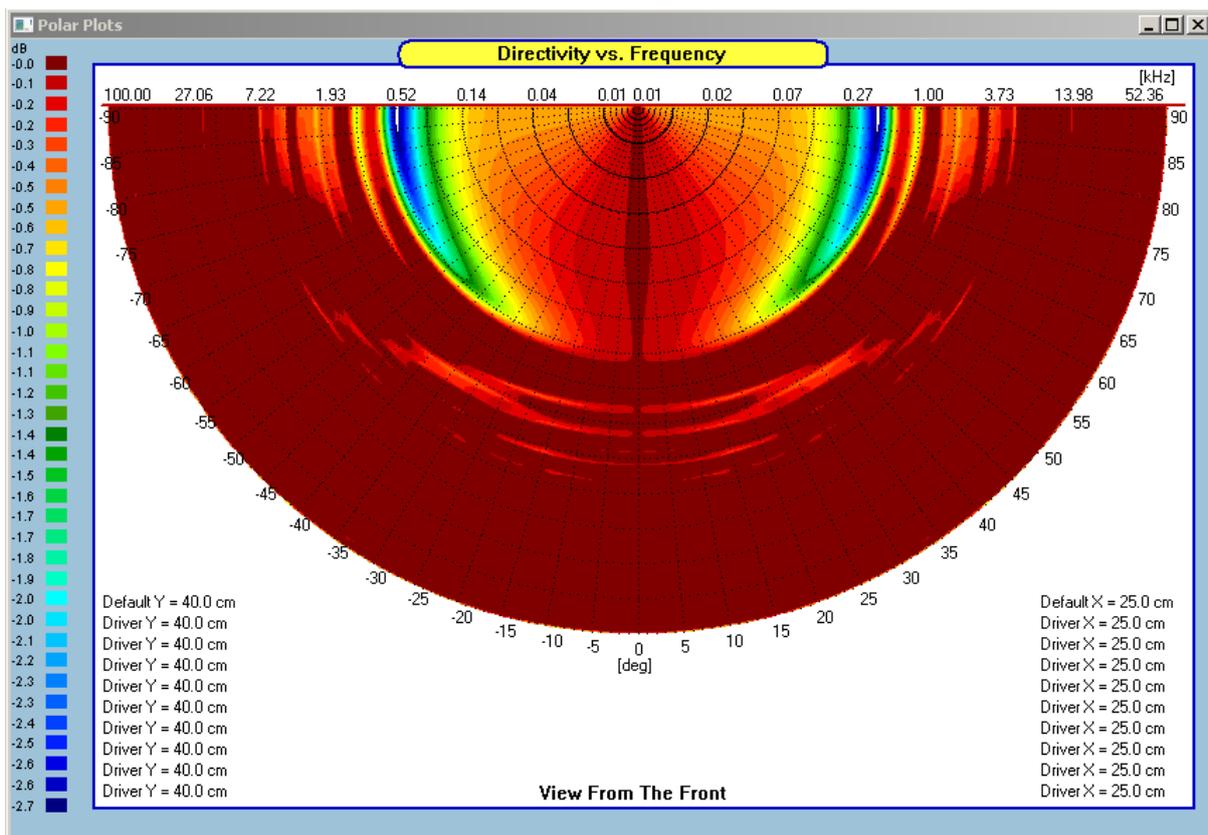
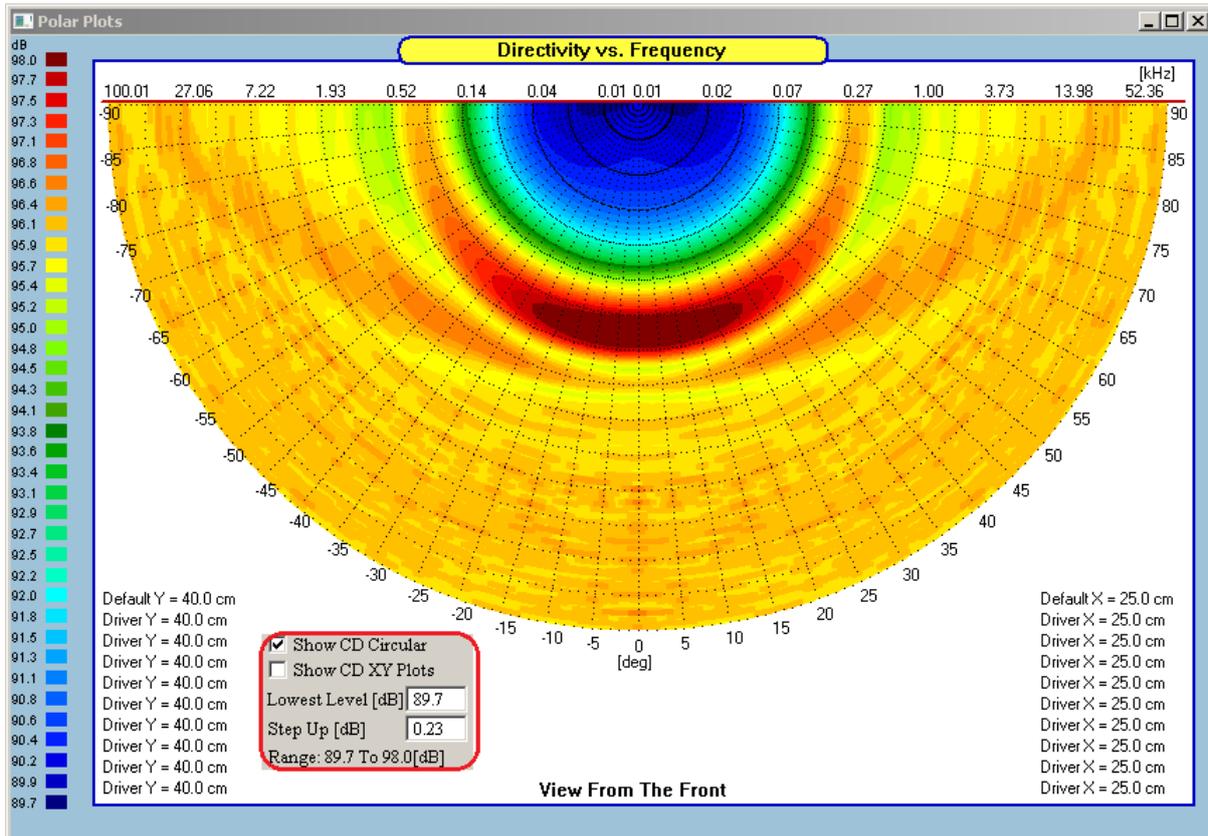


Fig 12.55. CD Circular plots, as Standard and Normalized versions

## Balloon Polar Plots

Final way of displaying polar data are the Balloon Plots. This technique depicts data as 3D “balloon” object. For example, the balloons can be modelled as 180 x 180 mesh of data points over front spherical coordinates. There are also some necessary additional tools, that help make the best visualization of the collected polar data:

1. Reference mesh and X/Y/Z axis are switchable ON/OFF on the balloon plots.
2. Balloons can be zoomed in/out, rotated over -90...+90deg, and screen is resizable.
3. “Only top” or “only bottom” of the balloon can be selected for viewing.
4. Balloons can be displayed in selectable three sizes of dots. Display is SPL colour-coded.
5. Interpolation of data points process is optional, and can be used to enhance the presentation.
6. “Max SPL” radiation level at horizontal and vertical angle is displayed and correlates with horizontal and vertical polar plots.

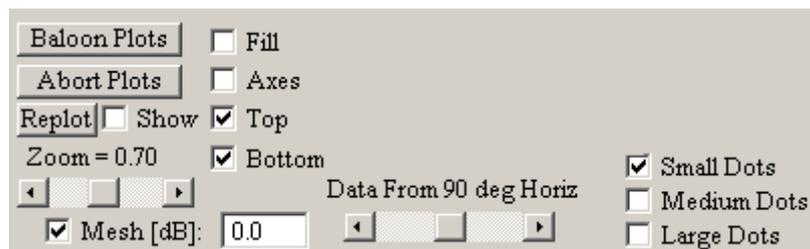


Fig 12.56. Balloon plotting controls.

For example, Balloon 3D visualization of the 2000Hz performance of the 2-way loudspeaker is shown below.

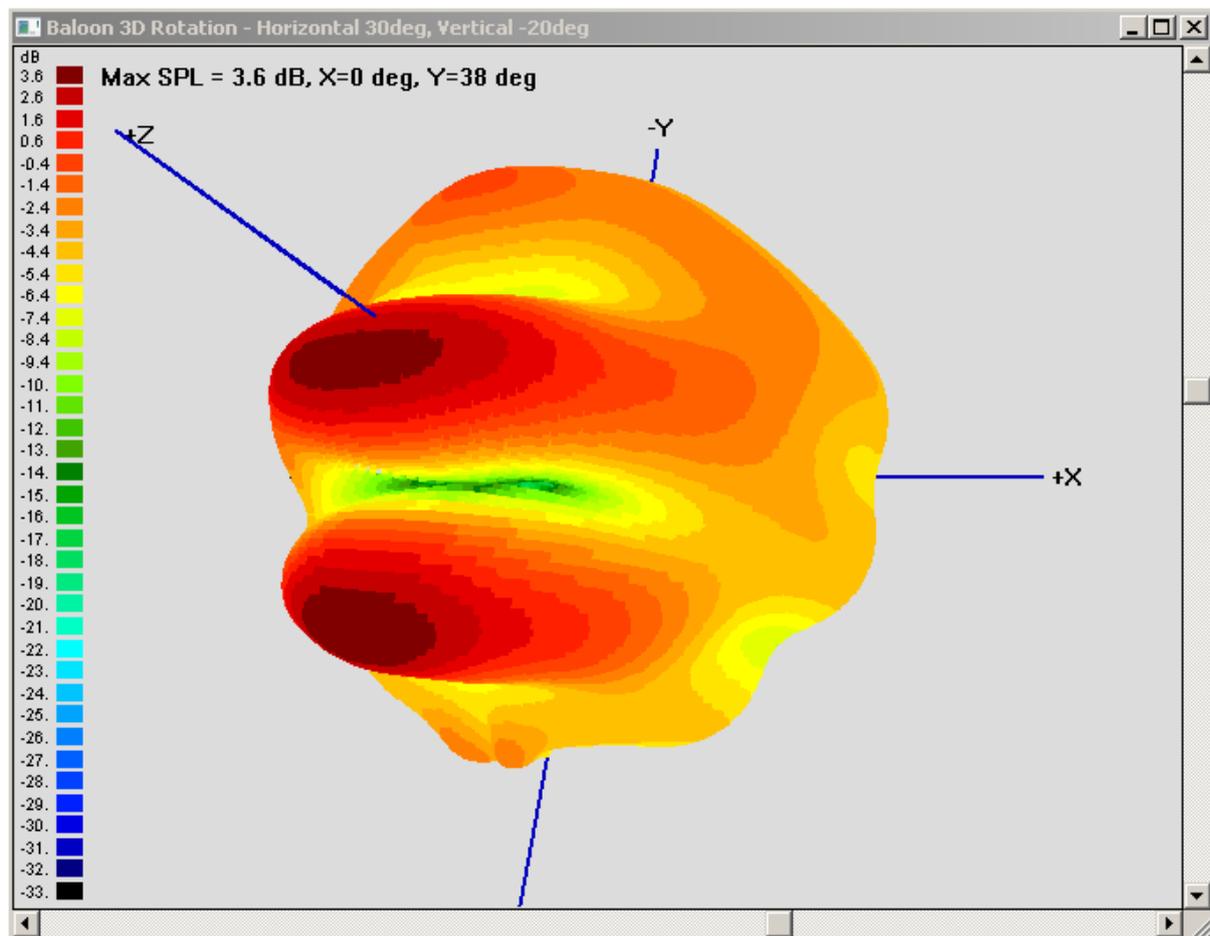


Fig 12.57. Balloon 3D visualization of a system, at 2600Hz.

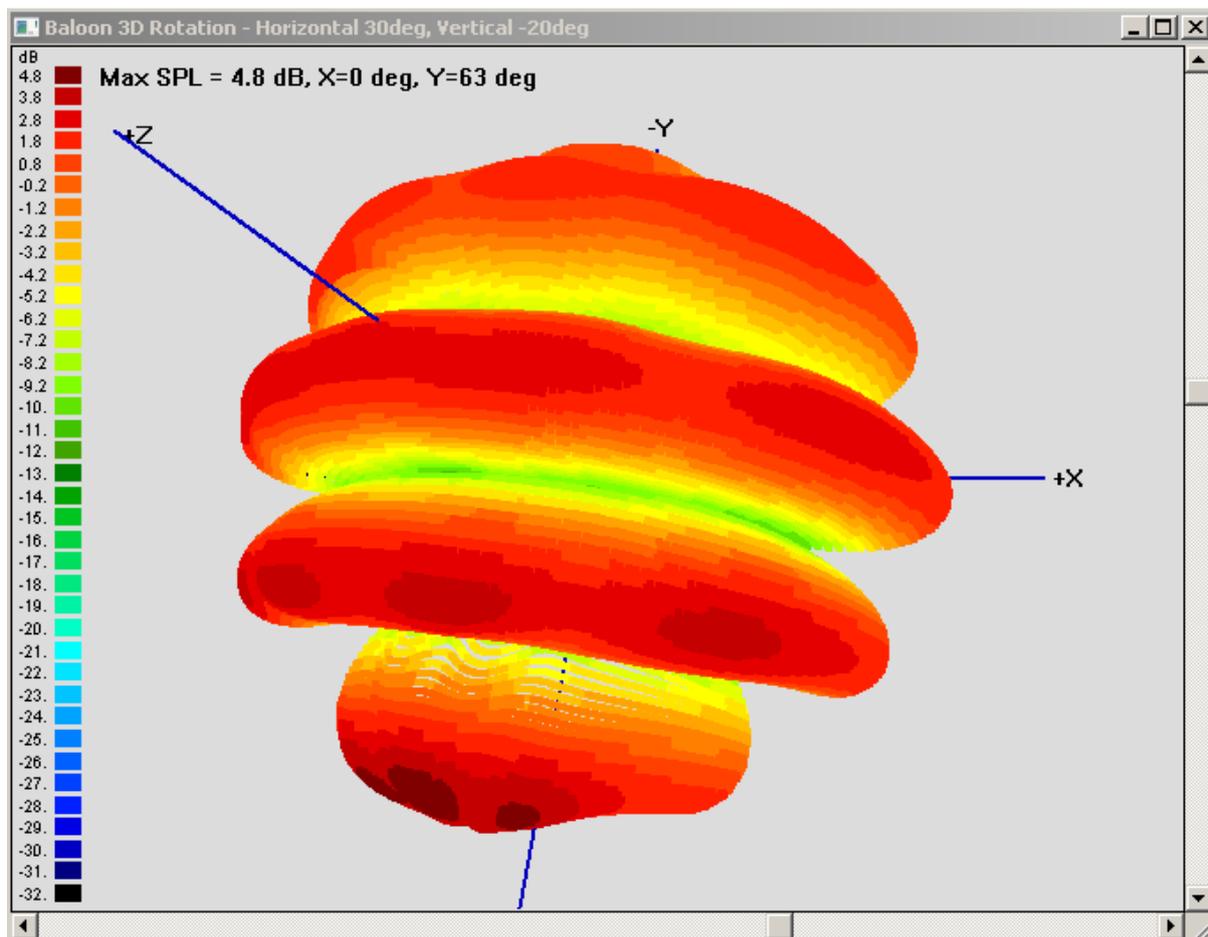


Fig 12.58. Example of balloon 3D visualization of a system.

The process of generating Balloon Plots can be repeated at a number of frequencies of interests. Generally, one would expect the radiation pattern to be spherical at low frequencies. Then the pattern would change, as we approach crossover frequency. The plot collected at this point, can be quite interesting. Typically, both drivers will contribute equal SPL at the crossover point. As the frequency increases, the low-frequency drivers are becoming irrelevant, and the radiation pattern becomes exclusively controlled by the tweeter.

**“Baloon Plots”** – This button activates Baloon modelling process. It is expected, that the loudspeaker and microphone are correctly set-up in the System Front Panel section.

**“Abort Plots”** – The process of generating high-resolution balloon plots may take some time. If you run out of patience, press this button to abort.

**“Replot”** – This button replots the balloon image, even if the “Show” checkbox is not checked.

**“Show”** – Opens the balloon 3D Rotation window.

**“Zoom”** – Slider to zoom-in/out the graphics.

**“Mesh”** – Checkbox displays the mesh pattern.

**“dB”** - Editable field to expand the mesh. Re-activate the checkbox to re-display the new mesh.

**“Data From XXX deg Horiz”** – Slider that allows you to hide the left side of the balloon display.

**“Fill”** – Checkbox to allow for double density display of balloon dots.

**“Axes”** – Turns ON/OFF the XYZ axes.

**“Top”** – displays only the top portion of the balloon.

**“Bottom”** - displays only the bottom portion of the balloon.

**“Small Dots”** – Sets the display dots to small size.

**“Medium Dots”** – Sets the display dots to medium size.

**“Large Dots”** - Sets the display dots to large size.

Baloon data for each frequency of interest, is stored in the Project File. Multiple project files are required to be saved for each balloon graphics.

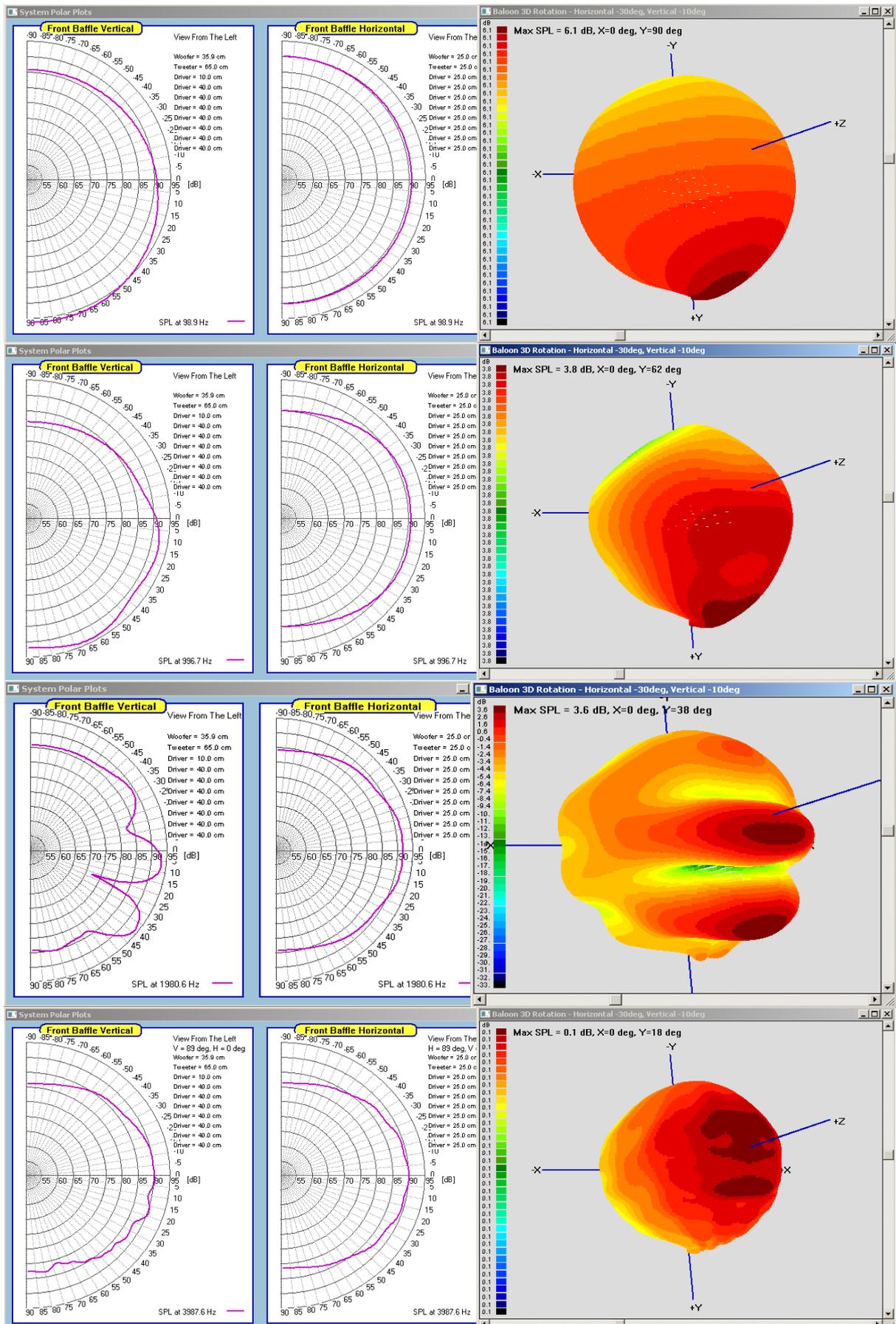


Fig 12.59. Example of balloon 3D visualization of a system at several frequencies.

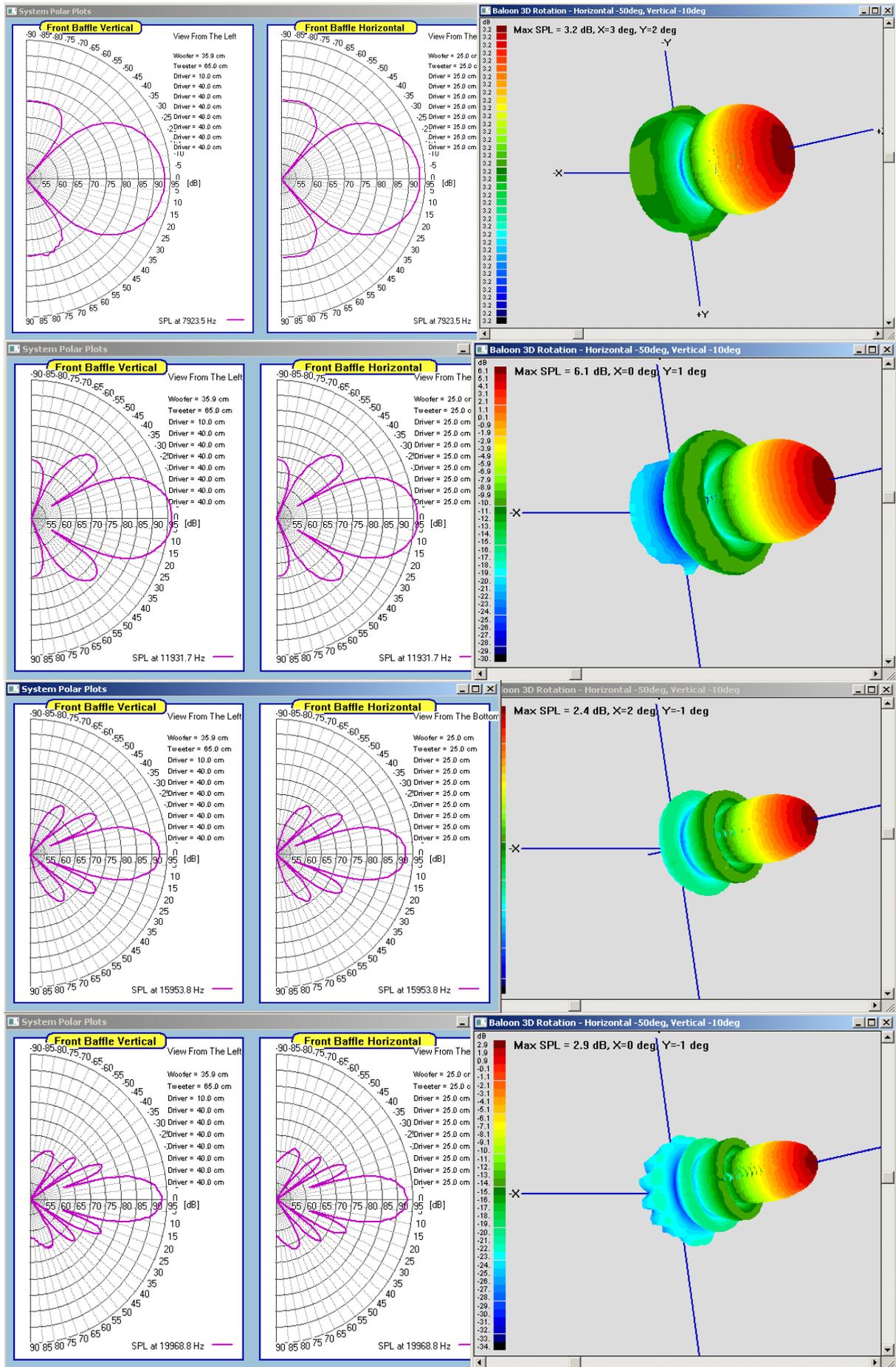


Fig 12.60. Example of balloon 3D visualization of a system at several frequencies.

The last example of polar performance presentation is provided by **D'Appolito configuration** of drivers on the front panel. Here we have a simple system of tweeter in the middle, with two woofers on each side. Interestingly, the horizontal and vertical polar plots for this type of configuration are symmetrical, but obviously not the same.

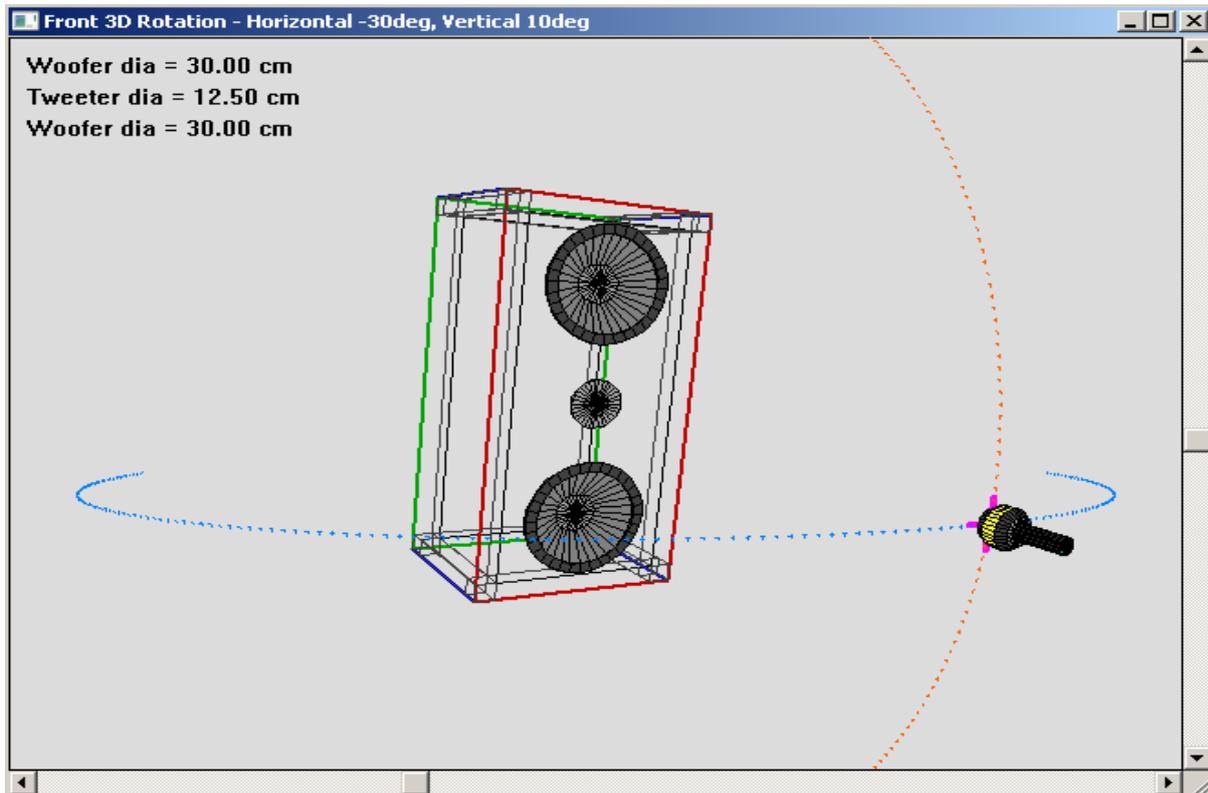


Fig 12.61. Example of system settings.

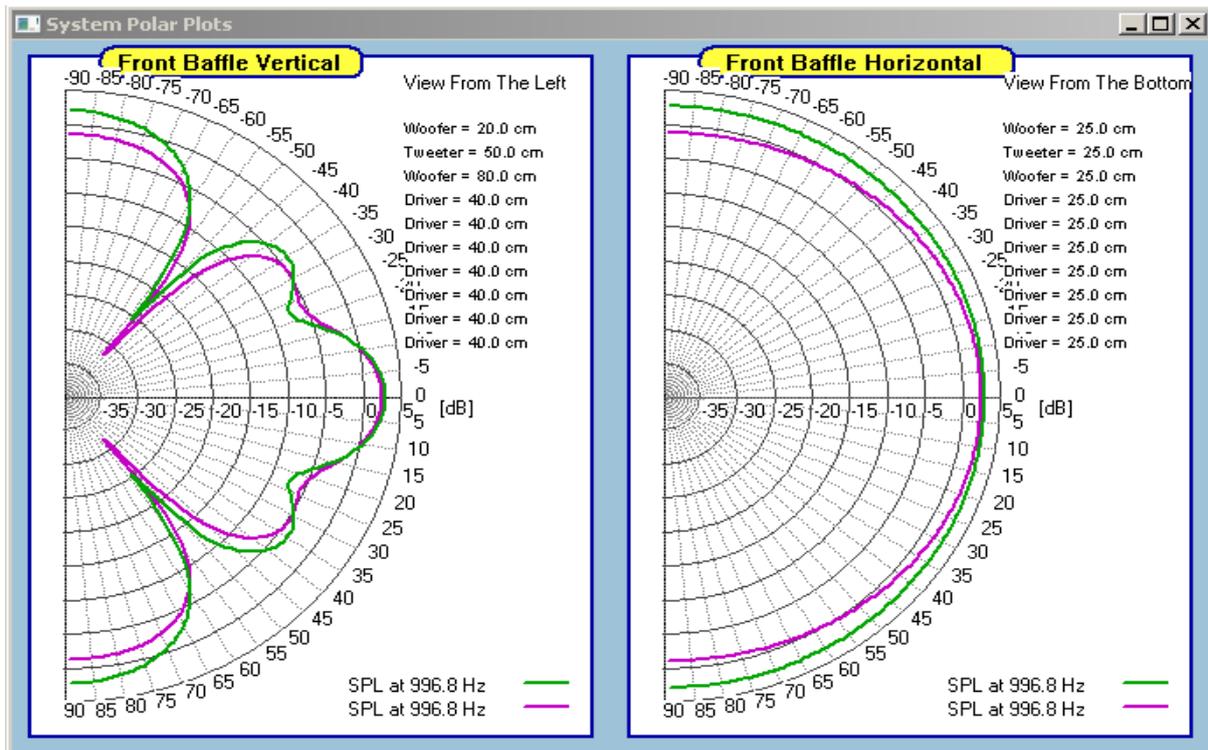


Fig 12.62. Standard V/H polar plots: Pink – Piston Mode, Green – Point Mode

We can now present 3D Balloons for a number of test frequencies, and observe the ever-changing sound-field generated by the D'Appolito configuration.

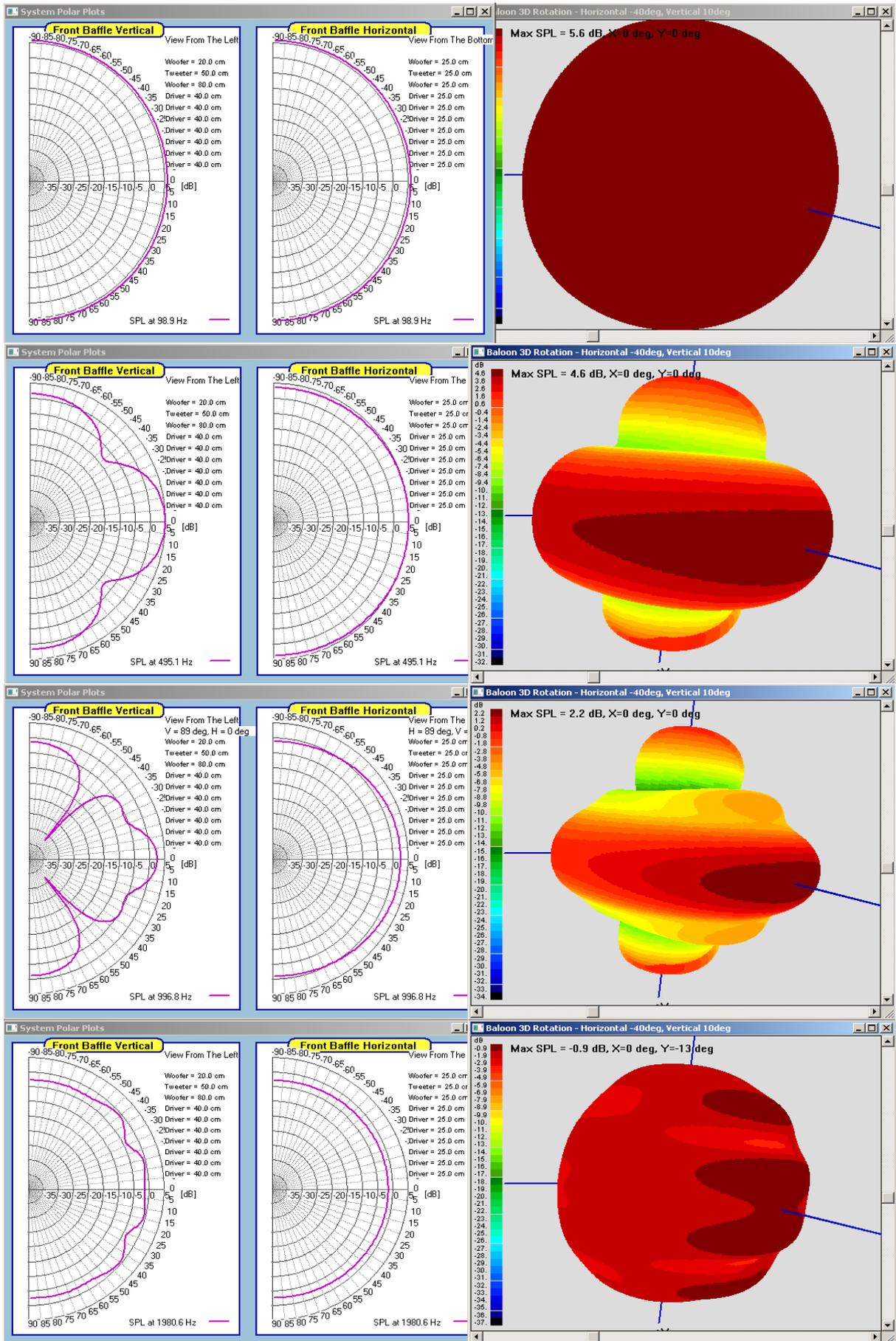


Fig 12.63. Example of balloon 3D visualization of a system at several frequencies

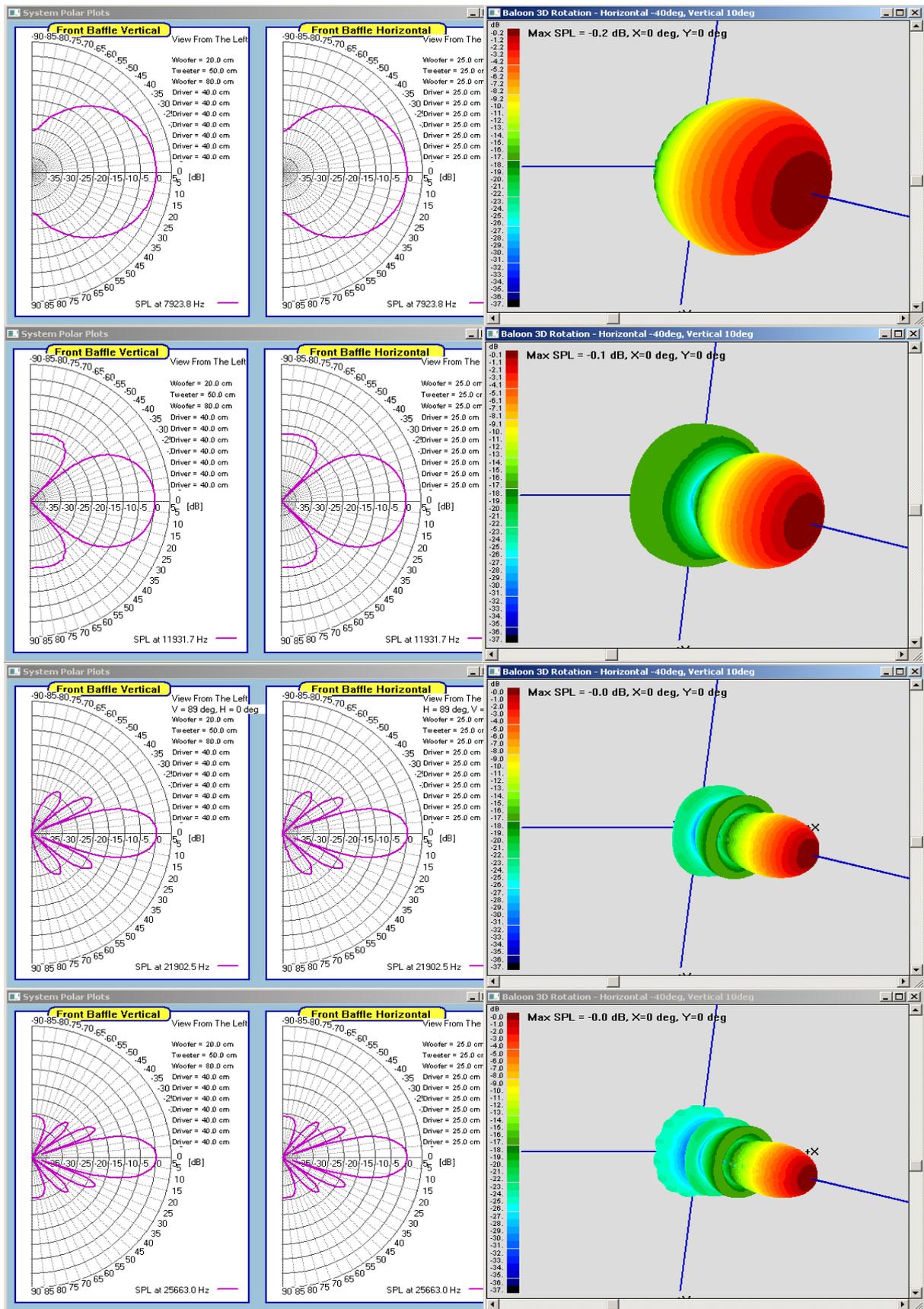
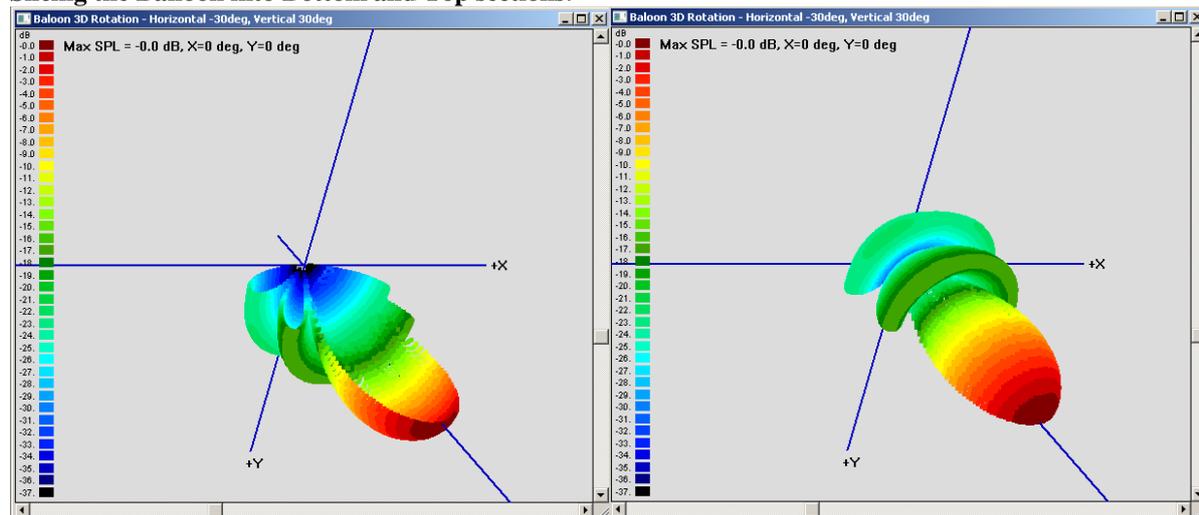


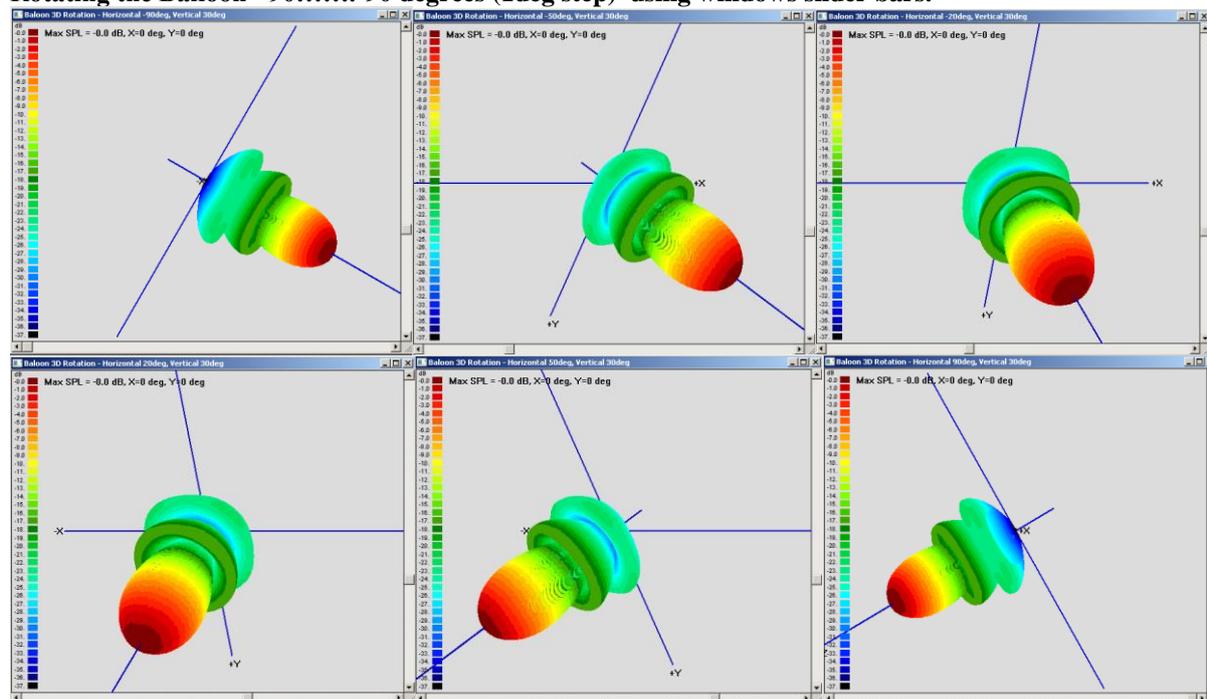
Fig 12.64. Example of balloon 3D visualization of a system at several frequencies

To take the full advantage of the 3D Balloons presentation, the display system could accommodate several display options. Here they are:

**Slicing the Balloon into Bottom and Top sections.**



**Rotating the Balloon +90.....-90 degrees (1deg step) using windows slider bars.**



**“Fill” function OFF and ON**

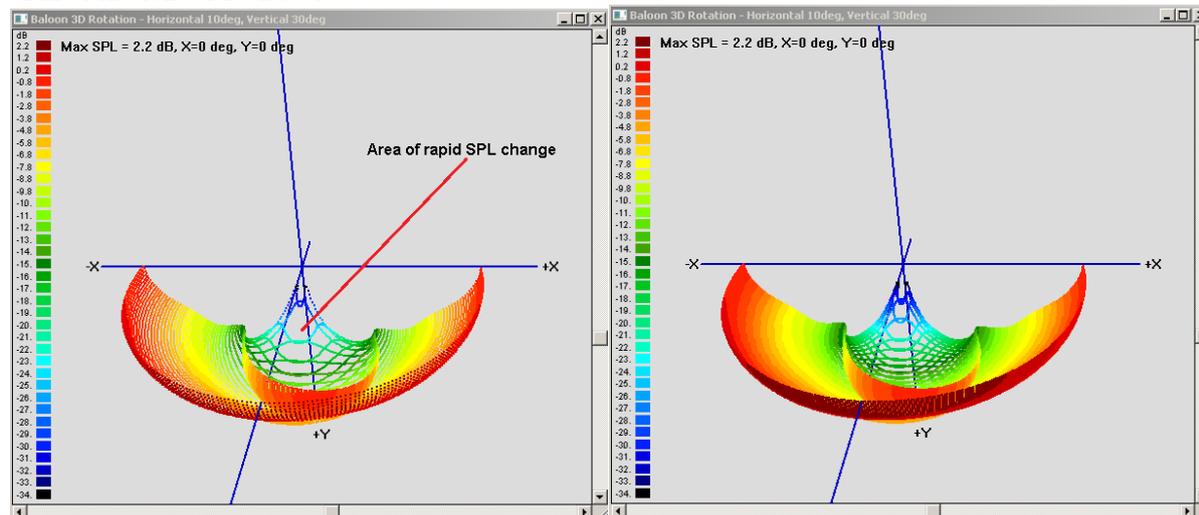
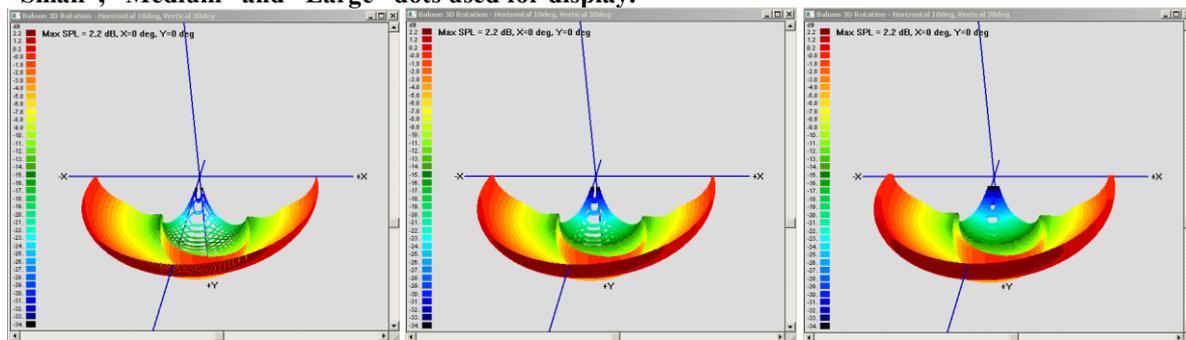


Fig 12.65. Various plotting options applied to balloon presentations.

“Small”, “Medium” and “Large” dots used for display.



Zoom Out and Zoom In functions.

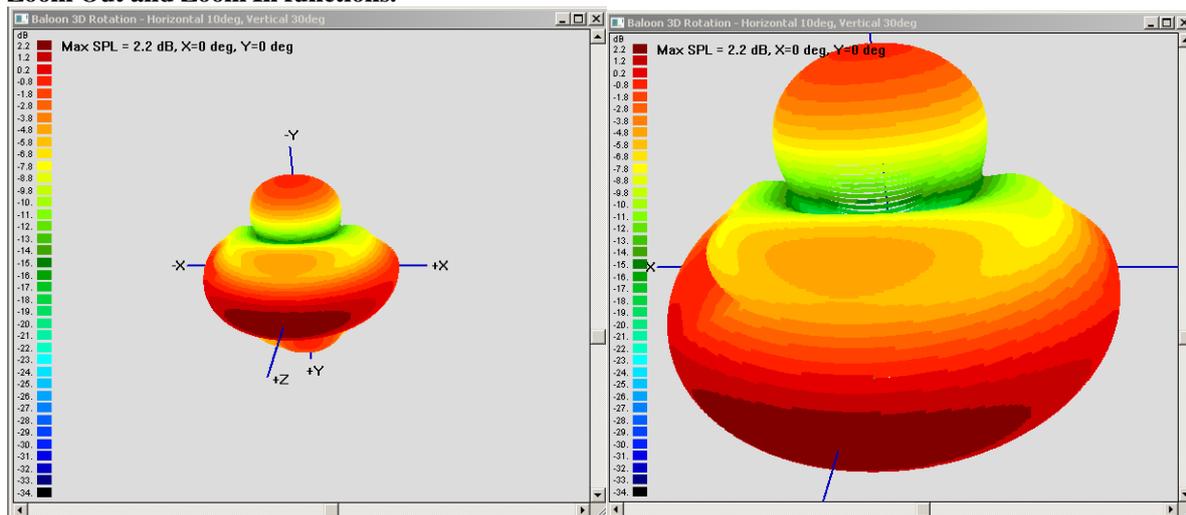


Fig 12.66. Various plotting options applied to balloon presentations.

### Revealing some hidden Balloon details

Rotating, tilting and splicing the Balloon Plot can reveal hidden details, that are not immediately obvious on standard Horizontal and Vertical Polar Plots. In the next example, the microphone pivot point was moved down, to the location 20cm below woofer axis. You would expect, that maximum SPL radiation would then appear shifted upwards.

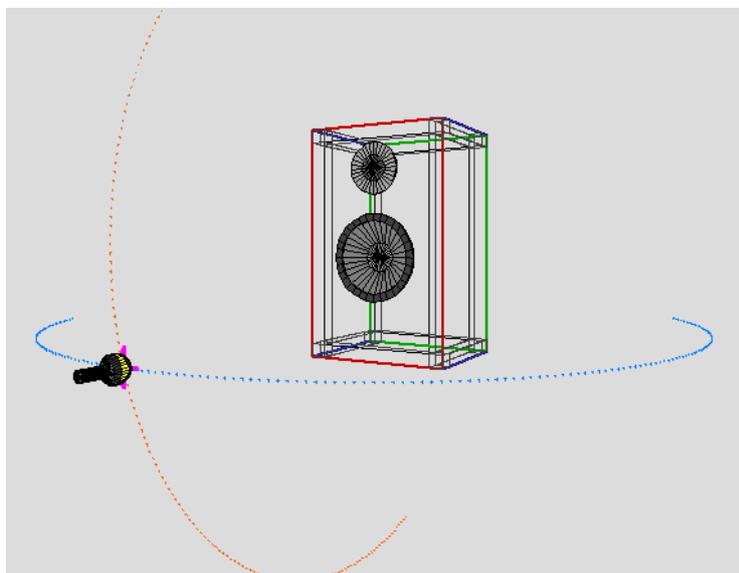


Fig 12.67. Setting up a two-way system.

And indeed, Vertical Polar radiation patten shows, that maximum radiation at 2000Hz occurs at -50-60deg vertical angle.

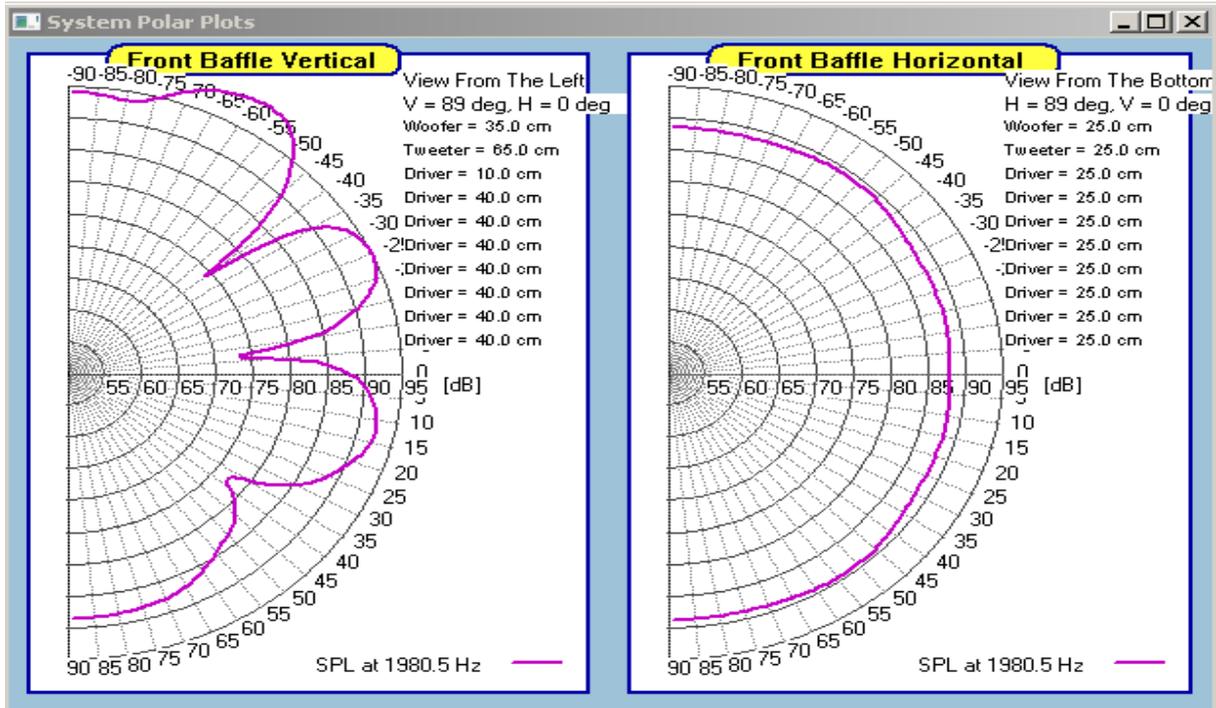


Fig 12.68. Standard V/H polar plots - Piston Mode.

But there are some surprises. The Top Section of the Balloon Plot, when rotated and tilted, reveals unseen radiation pattern outside 0deg horizontal radiation axis – see below.

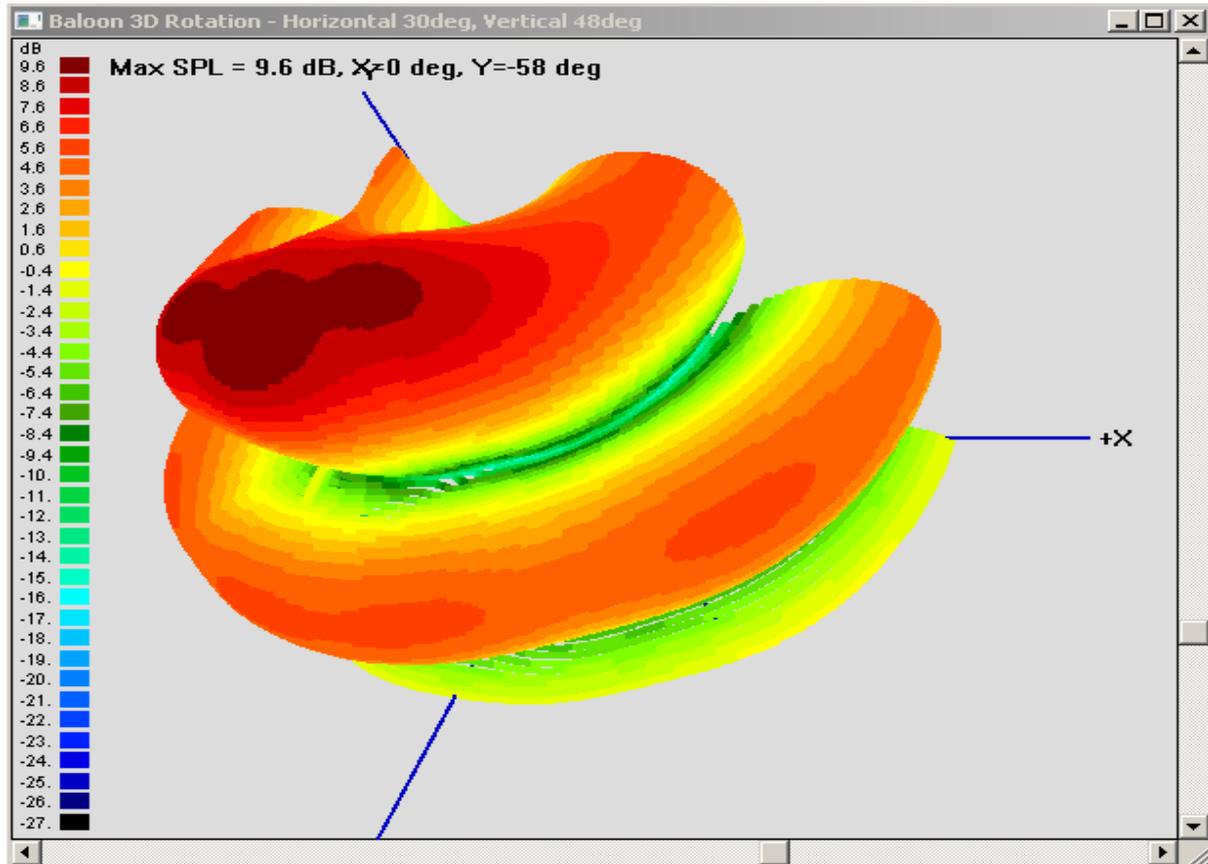


Fig 12.69. Some hidden details revealed by the balloon plots.

The Balloon Plots incorporated several tools allowing displayed 3D plot to be presented in the best or most revealing way. Sometimes changing the size of the display dots, and zooming-in, can make the Balloon Plot semi-transparent, allowing you to see “inside” of the balloon.

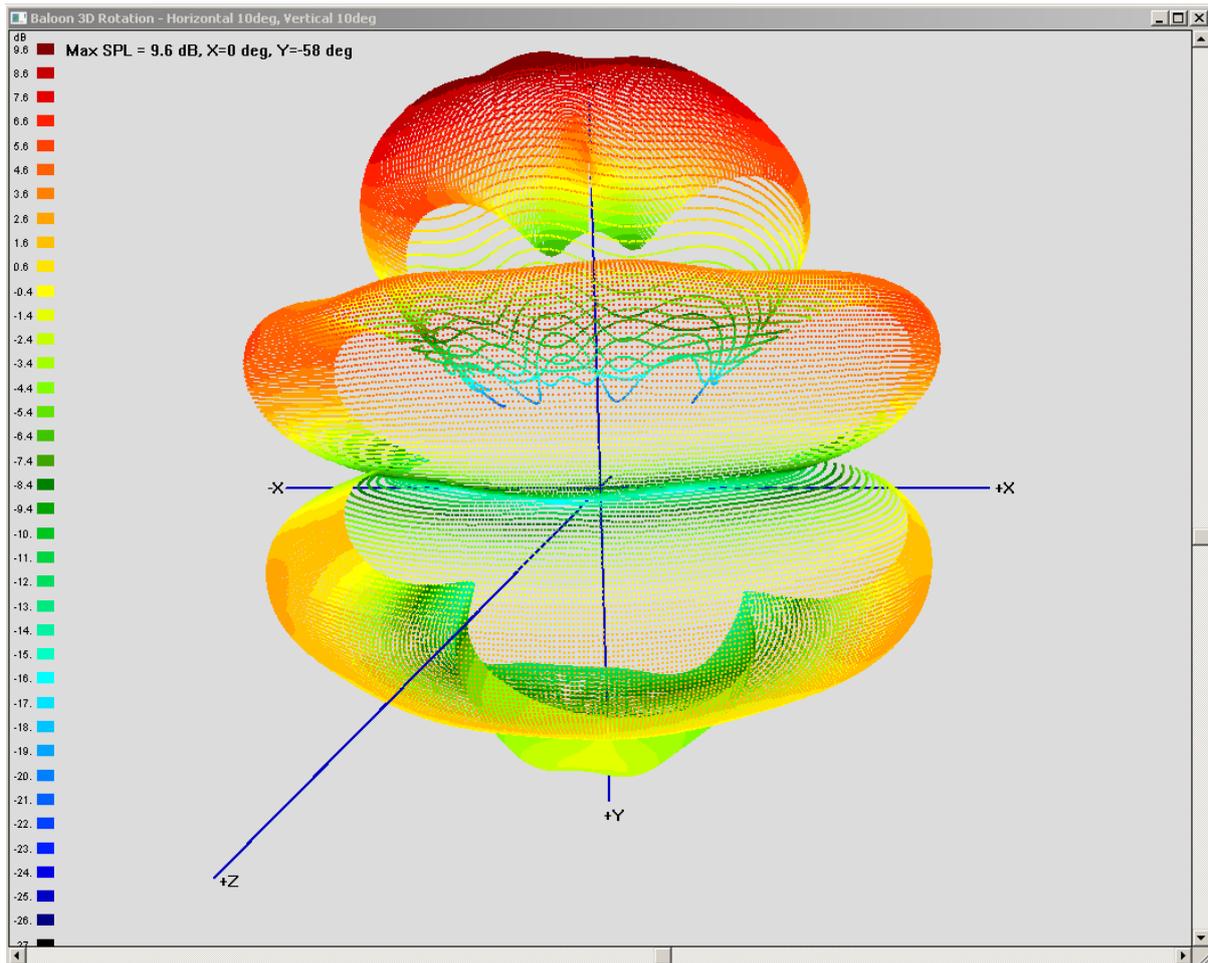


Fig 12.70. More hidden details revealed by the balloon plots.

All the options presented above for generating and presenting Balloons are handled by the dialogue box with several controls - shown below.

As mentioned previously, the presentation method described in this paper, is based on 32400 data points arranged in 180 by 180 matrix. Collecting 32400 points of SPL data without fully automated measurement system would be next to impossible. So, this paper offers a glimpse into what can be done in the future, in terms of collecting and presenting accurate sound-field generated by a loudspeaker.

The number of measurement can be obviously significantly reduced by setting the incremental angle to 5deg, instead of 1deg as in this presentation. The trade-off is, that the process would run significantly faster, but you would miss some of the notches in the sound-field presentation. Now, the measurement matrix would be 36 by 36 data points, which equates to 1296 measured SPL points.