Balloon Measurement Procedure

General comments.

The Balloon Testing procedure is fully automated. Once all preliminary settings and adjustments are performed, all the user needs to do is to press "**RUN Test**" button and the measurements will commence.

The testing procedure is expected to run 6.5-7 hours for 5deg resolution selected. During this time, there will be 2592 measurements of the SPL performed and collected. For 10deg resolution, there will be 648 SPL measurements performed, and this will take close to 2 hours.

The whole test rig will need uninterrupted power provided for the duration of the test. This includes your computer, amplifier, and the turntables. The test can not be paused and restarted later.

Please make sure, that all cables have good quality, secure termination and connections, which will not come undone or loose during the test.

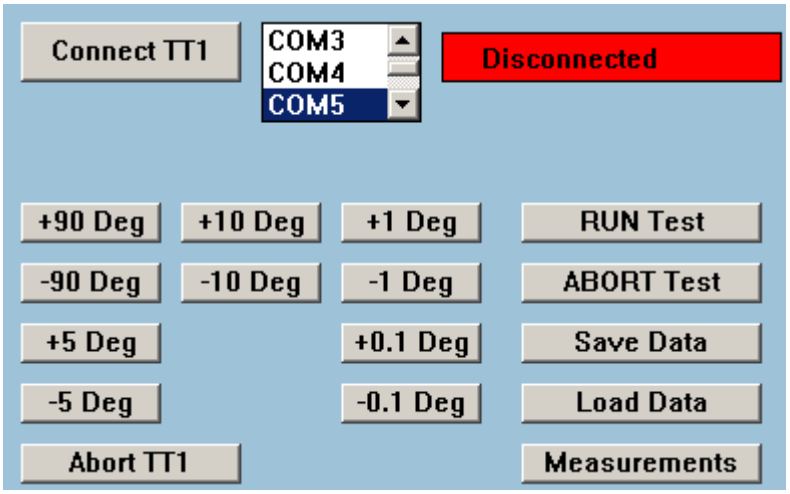
The controlling computer is expected to run for up to 7 hours. During this long period of time, the PC will attempt to run it's own background processes. These processes may interfere with the "real-time" testing signals generated and collected by the testing program.
It is therefore quite possible, that some of the collected frequency responses may exhibit an error. Such error will manifest itself as unusually rapid SPL transition between adjacent data testing points. In plain language – you will see unexpected colour variations between SPL colour mapping on the balloon. These should be disregarded. Current release of the program allows the user to review cross-sections of the balloon and also each individual frequency response collected for each testing angle. It is therefore possible to determine which frequency response looks unusual, and may be in some error. The program also allows the user to replace such frequency response with another SPL curve, perhaps immediately adjacent to the suspect one.

The rotation scheme of the bottom (horizontal) turntable and the testing sequence were designed to rotate the turntable in one direction for 0-360degrees, and then rotate in the opposite direction for 360-0degrees. Such oscillatory scheme allows the connecting cables to be returned to their starting position, thus preventing continual tangling.

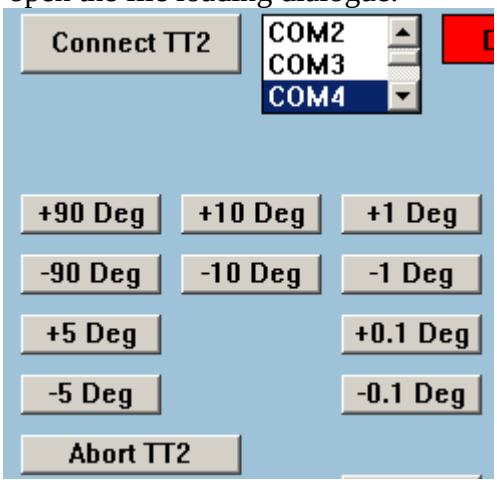
It is strongly recommended to conduct some trial rotations to work out the cabling movements and prevent future cabling problem during the actual testing runs.

Acoustical environment for the balloon testing should be carefully evaluated. The MLS testing functionality includes all standard adjustments and selections for eliminating unwanted room reflections, and this includes Matching Filter Technique. However, for the best results, the distance to the nearest reflecting surface should be maximized, to allow for the longest FFT window to be used for testing.

Description of Controls



"Connect TT1" – Press to connect turntable 1 (must be the bottom turntable) rotating horizontally.
"COM X" – Listbox to select RS232 communication port.
"+90 Deg"……"-0.1 Deg" – selection of buttons to rotate the TT! Into desired position.
"Abort TT1" – Abort rotation of TT1.
"RUN Test" – This button activates the balloon test.
"ABORT Test" – Press to Abort the balloon test.
"Save Data" – Press to open the data file saving dialogue.
"Load Data" – Press to open the file loading dialogue.



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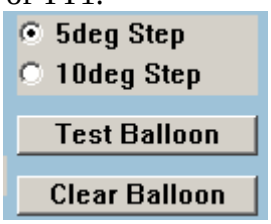
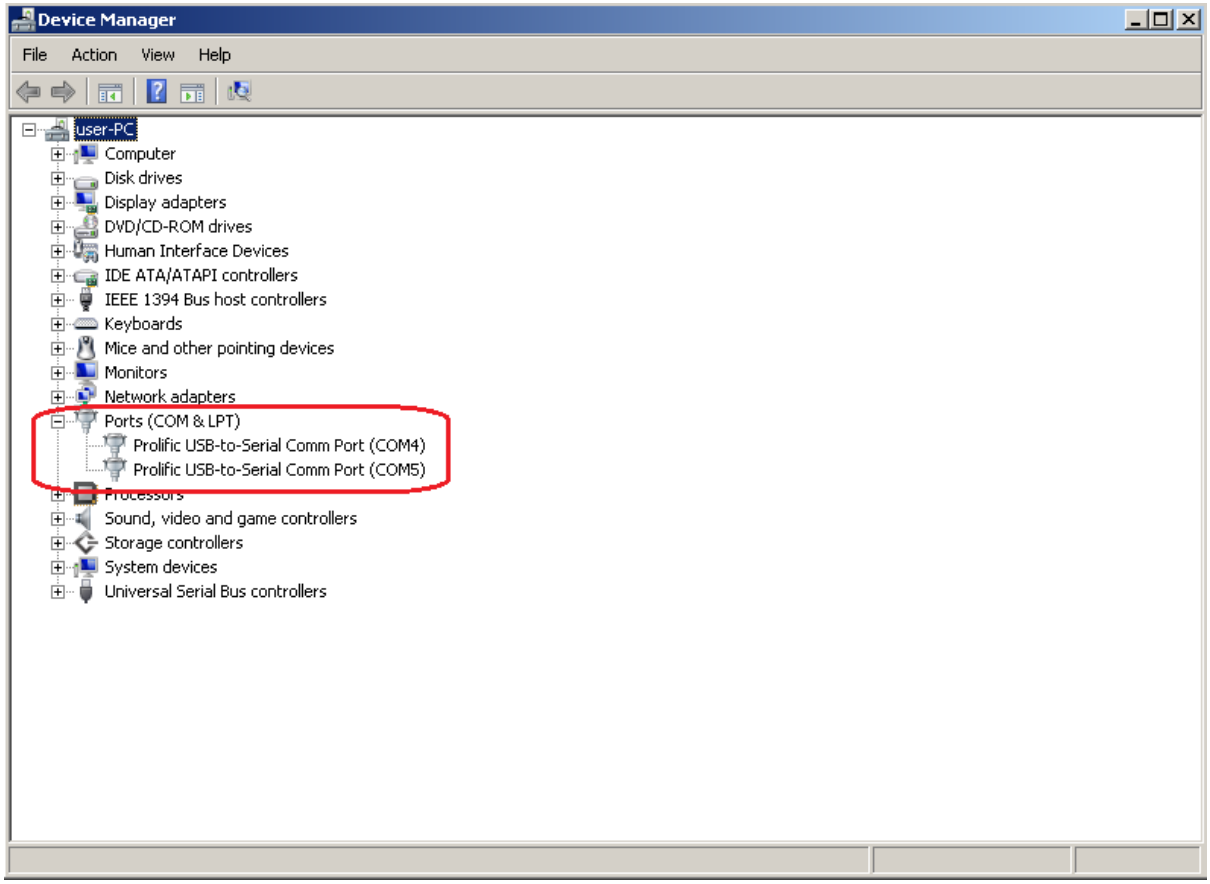
"+90 Deg"……"-0.1 Deg" – selection of buttons to rotate the TT! Into desired position.
"Abort TT1" – Abort rotation of TT1.



"5deg Step", "10deg Step" – Select for desired resolution.
"Test Balloon","Clear Balloon"– Plots/clears the location of testing points on the sphere.

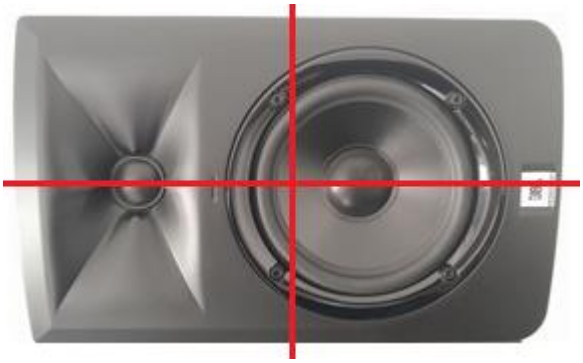
Preparations

1. Install RS232/USB Prolific drivers for the RS232 interface.



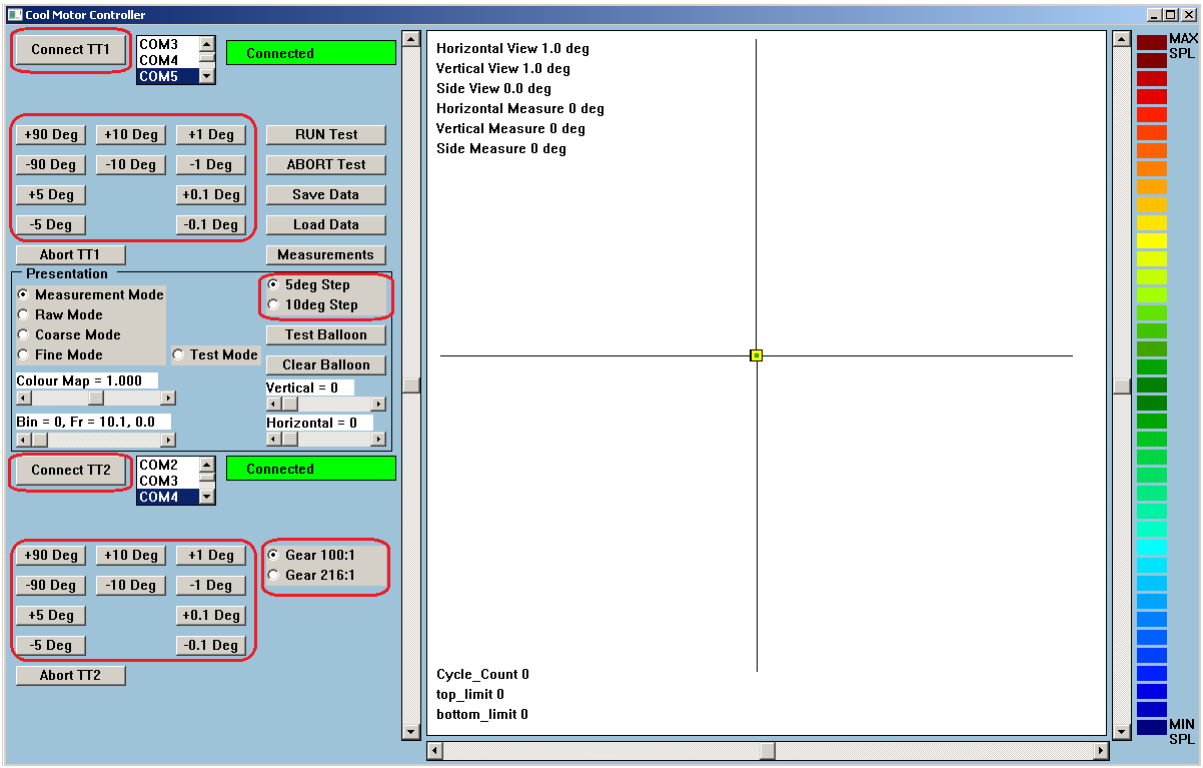
The Device Manager of your computer should display the above information.

2. Connect power supply to both turntables. **TT1** denotes the bottom turntable rotating in horizontal plane. **TT2** denotes vertical (top) turntable rotating in vertical plane.
3. Connect RS232 cables to both turntables.
4. Mount the loudspeaker onto the rig and secure it adequately.
5.

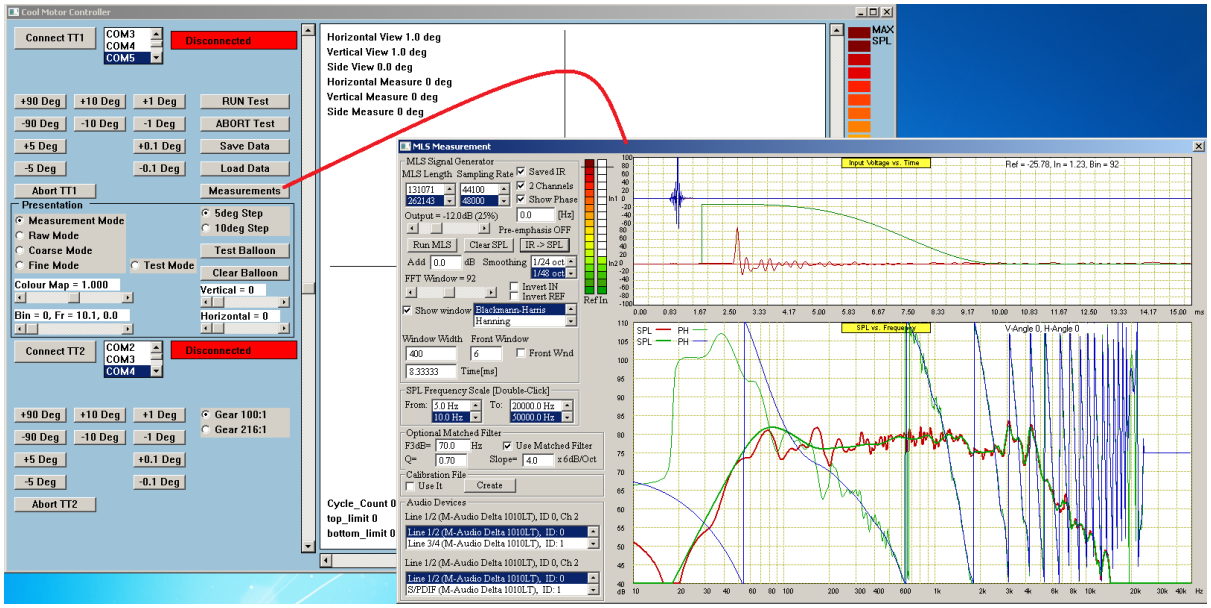


IMPORTANT: the loudspeaker must be mounted in the horizontal position, with the tweeter on the left side. This is the -90deg vertical position. During the testing procedure, the loudspeaker will rotate to the right, moving the tweeter to the top, and then to the right-hand side. This will be the +90deg position. Microphone should be pointing at the **geometrical centre of the front baffle at 1-2m distance**.

6. Start the **Balloon_Test** program
7. Press **“Connect TT1”** button to connect the bottom turntable to the computer. The corresponding green label “Connected” should appear.
8. Press **“Connect TT2”** button to connect the bottom turntable to the computer. The corresponding green label “Connected” should appear.
9. Attach all other cabling, and make sure, that the cables do not tangle during the testing procedure. It is advisable to rotate the turntable into all testing angles (horizontal 0-360, and vertical -90 ….+90 deg), using the buttons provided, to make sure that cables are not obstructing the rotations of both turntables.



10. Press “Measurements” button to open the MLS testing screen.



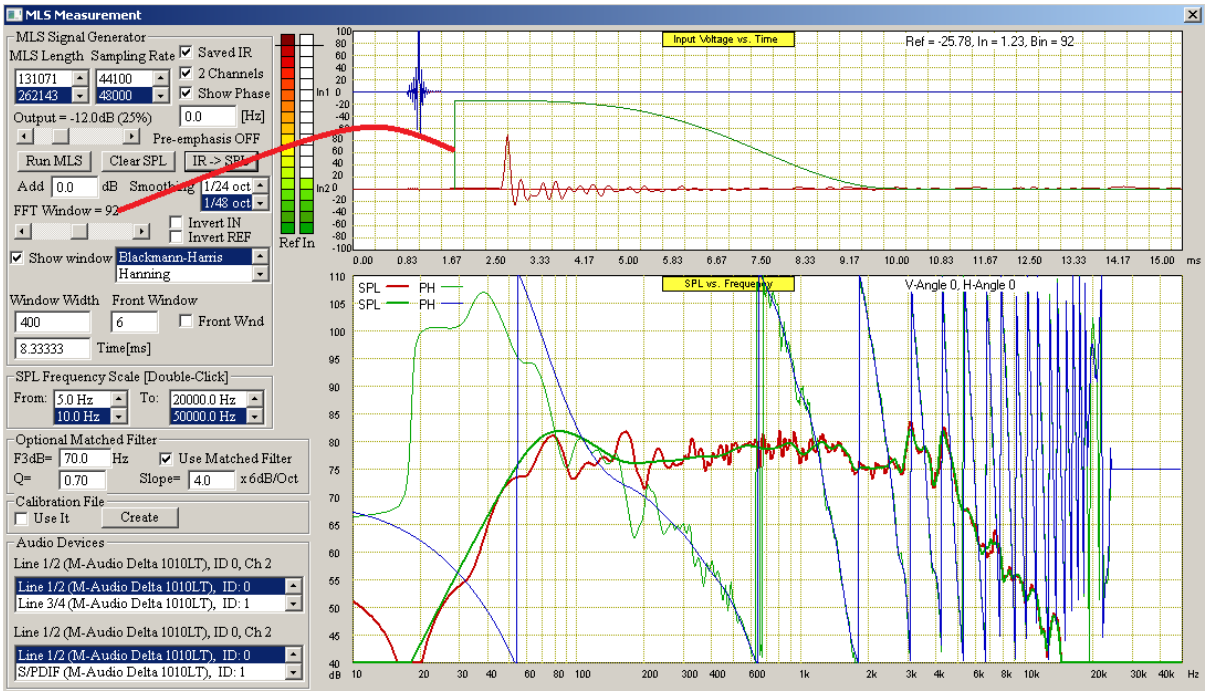
11. There are a number of selection, that must be made before the testing may commence.

MLS Length: 131071 or 262143 options are available, suggested is 131071

Sample Rate: 48000 or 96000Hz options are available, suggested is 48000Hz

FFT Window: select Blackman-Harris window

FFT Window position: use the slider provided to position the start of the window on the time scale. This selection is important, as you should attempt to remove much of the "time-of-flight" delay, without cutting off the front of the impulse response when the loudspeaker is rotated. This will require rotating the loudspeaker through several angles and taking MLS measurement for each angle to ensure, that the impulse response is NOT truncated.



Window Width: select accordingly to your testing environment.

Front Window: Not necessary to engage.

SPL Frequency Scale: select by double-clicking LMB on the desired start and stop frequency range. Typically 10Hz-50000Hz is recommended.

Optional Matched Filter: Select the parameters for the best expected match of the measured SPL to the ideal (expected anechoic) frequency response.

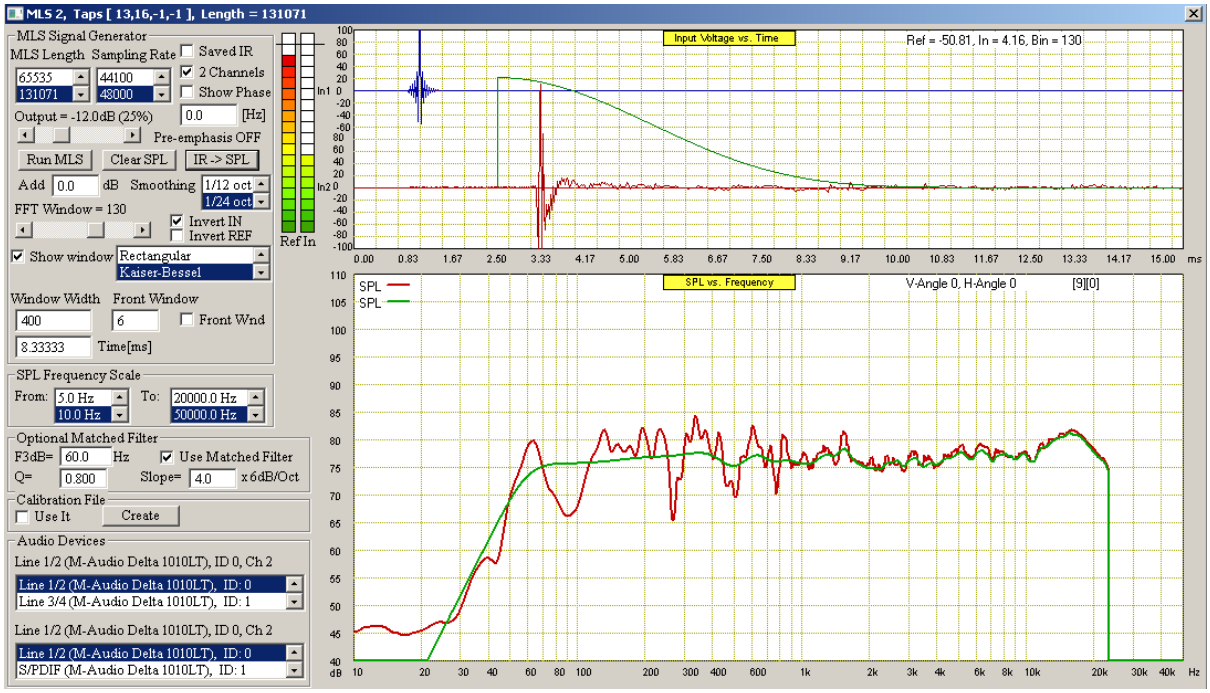
Audio Devices: Select accordingly to your computer audio hardware.

Saved IR: uncheck this box for all MLS measurements.

Example measurements are shown below. The loudspeaker was a book-shelf , two-way vented loudspeaker with port at the back.

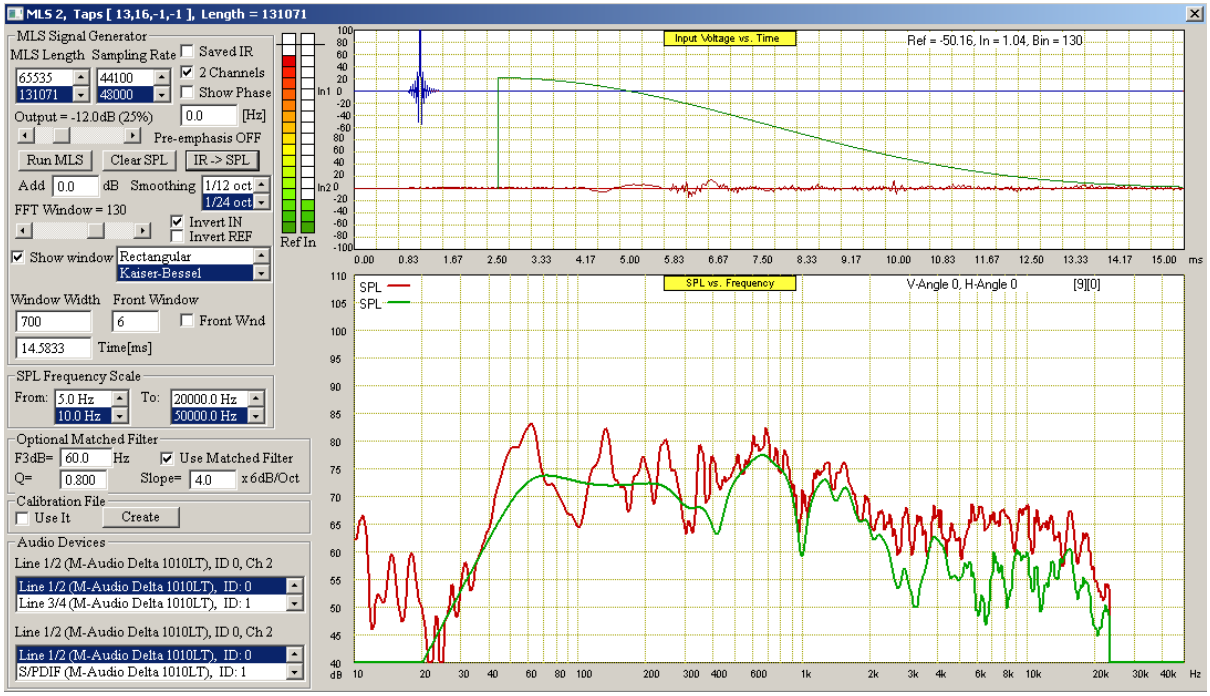
MIKE AT FRONT, PORT AT REAR

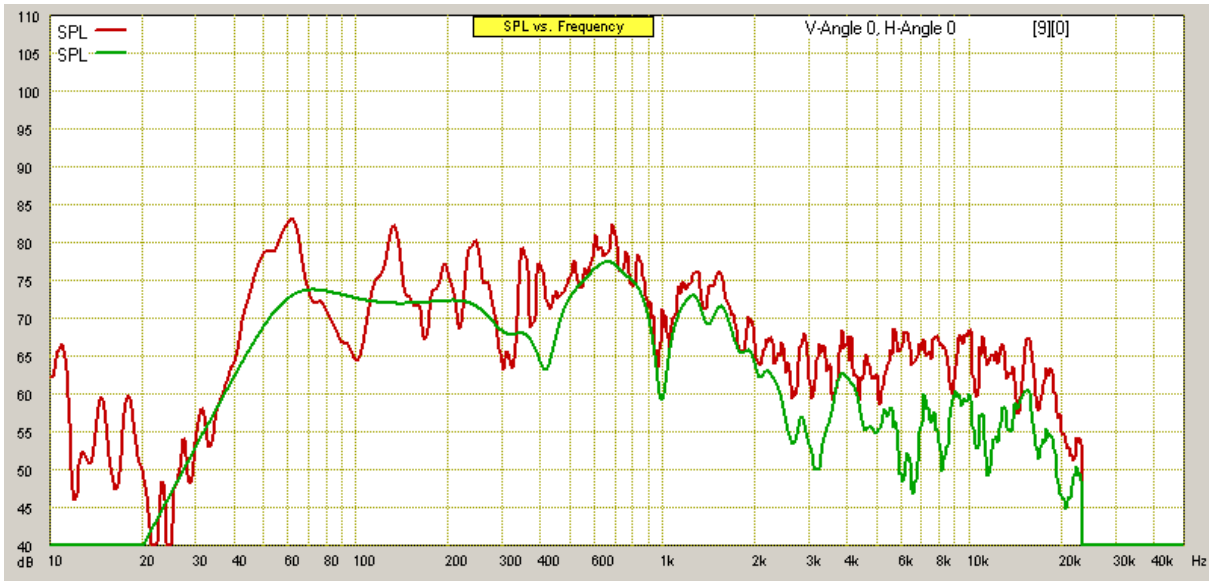
No window – Brown curve
8.3ms window + Matched filter – Green curve



MIKE AT BACK, PORT AT REAR

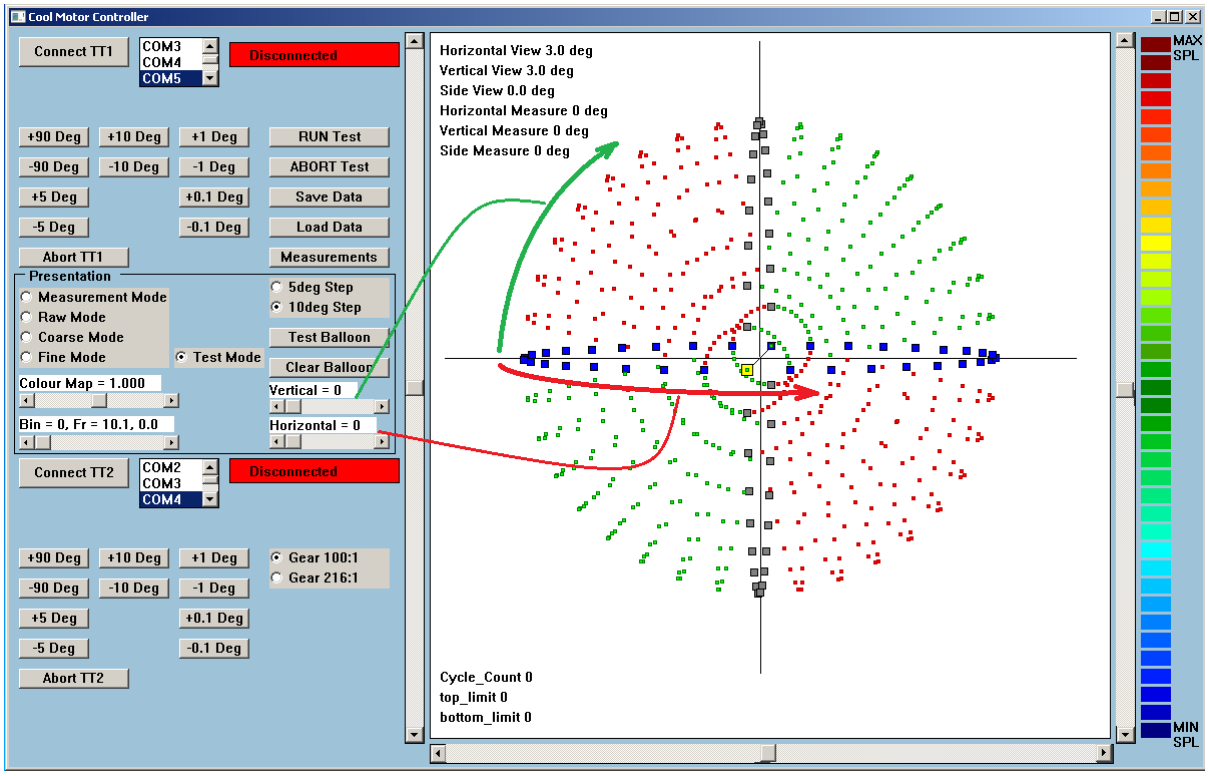
No window – Brown curve
14.53ms window + Matched filter – Green curve

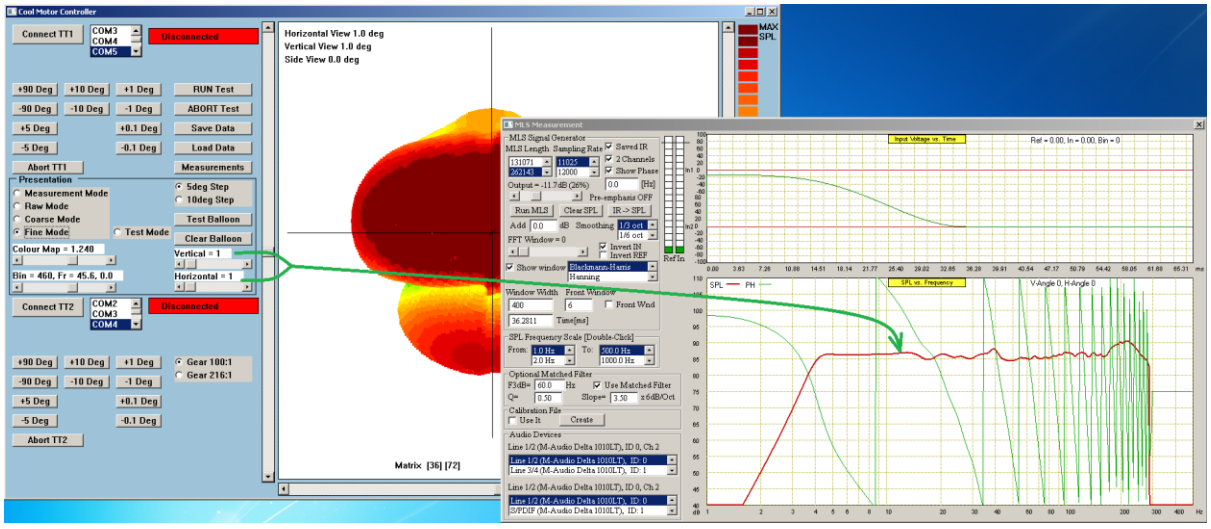




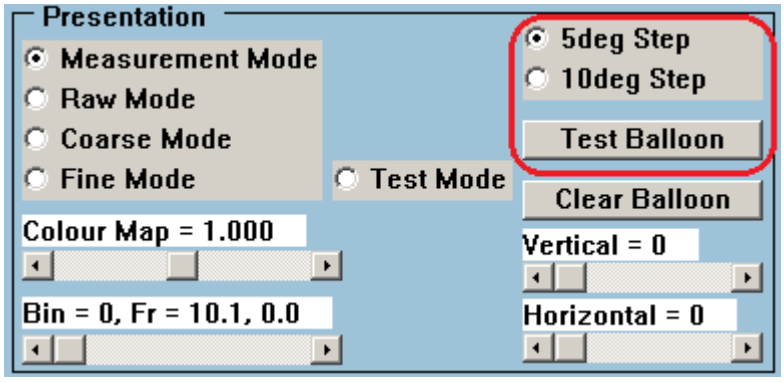
During the tests, the procedure will collect 2592 complete frequency responses for 5deg setting, and 648 complete frequency responses for 10deg setting.

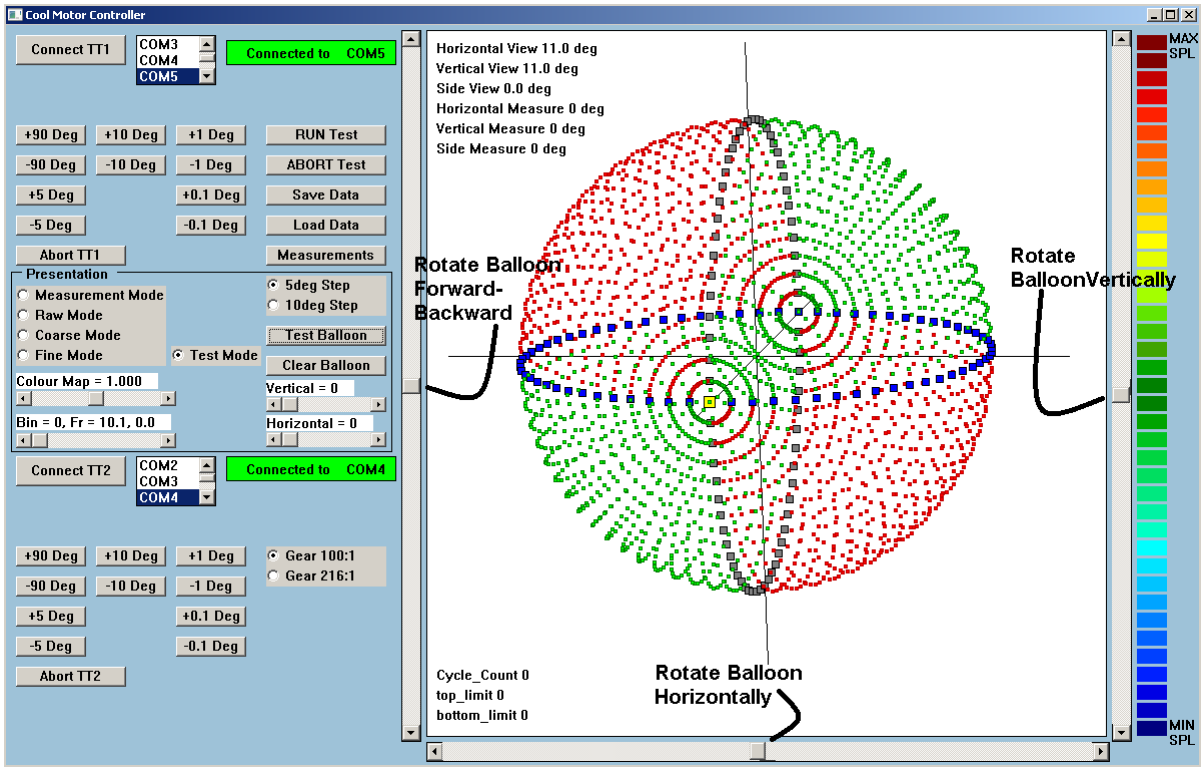
When the tests are completed, each of the collected frequency response is available for review on the MLS screen, using “Vertical” and “Horizontal” sliders – as shown on the picture below.





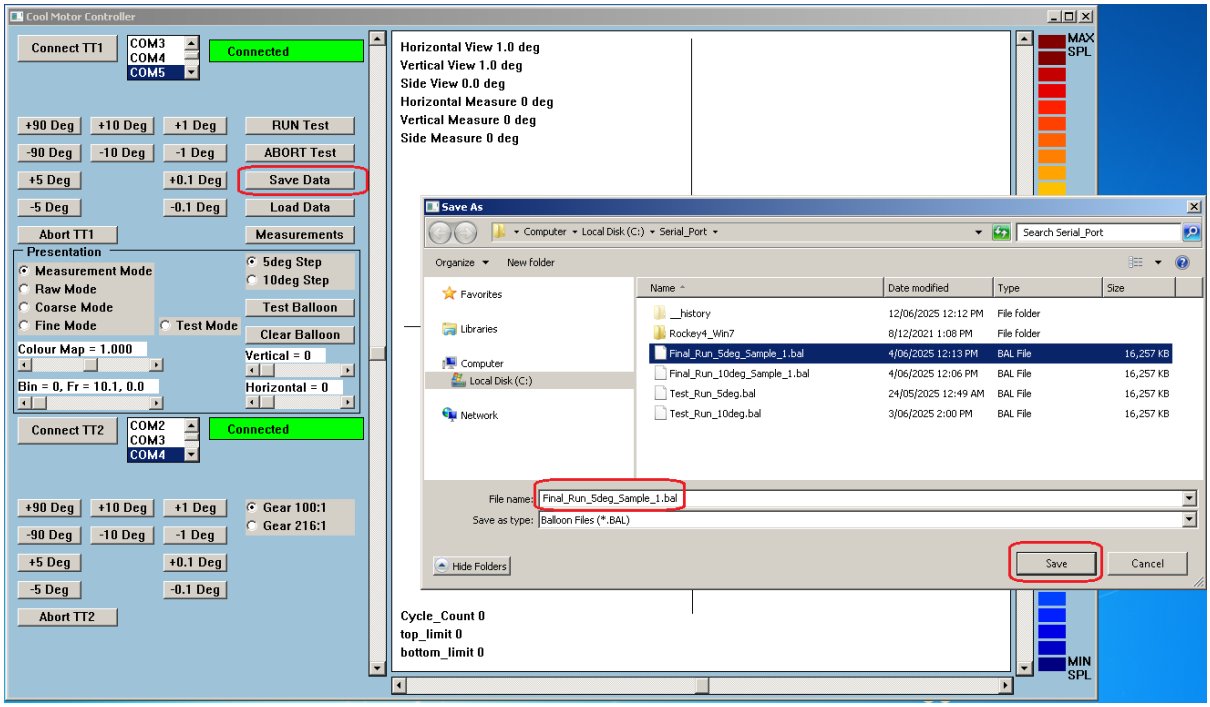
Spherical location of the test points for the collected SPL frequency responses for 10deg setting is shown above, and for the 5deg settings is shown below.





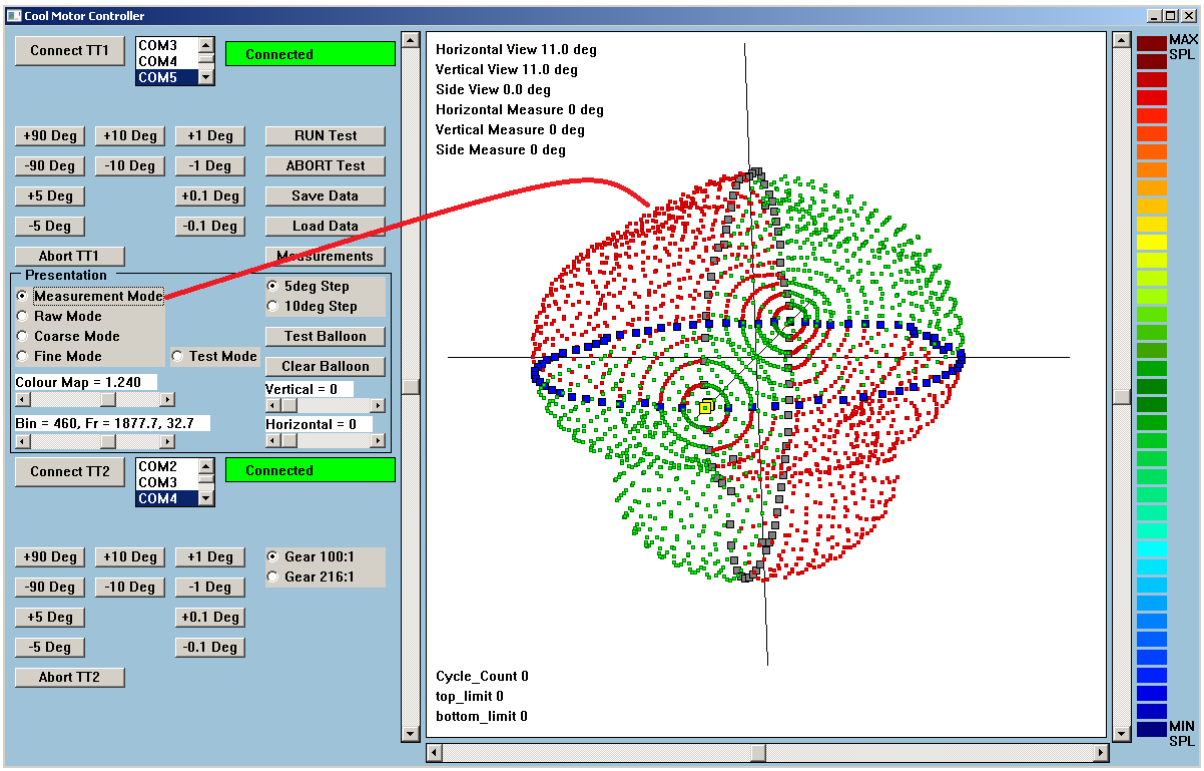
Basic Data File Display

Test results must be saved into a data file using standard Windows file saving mechanism.

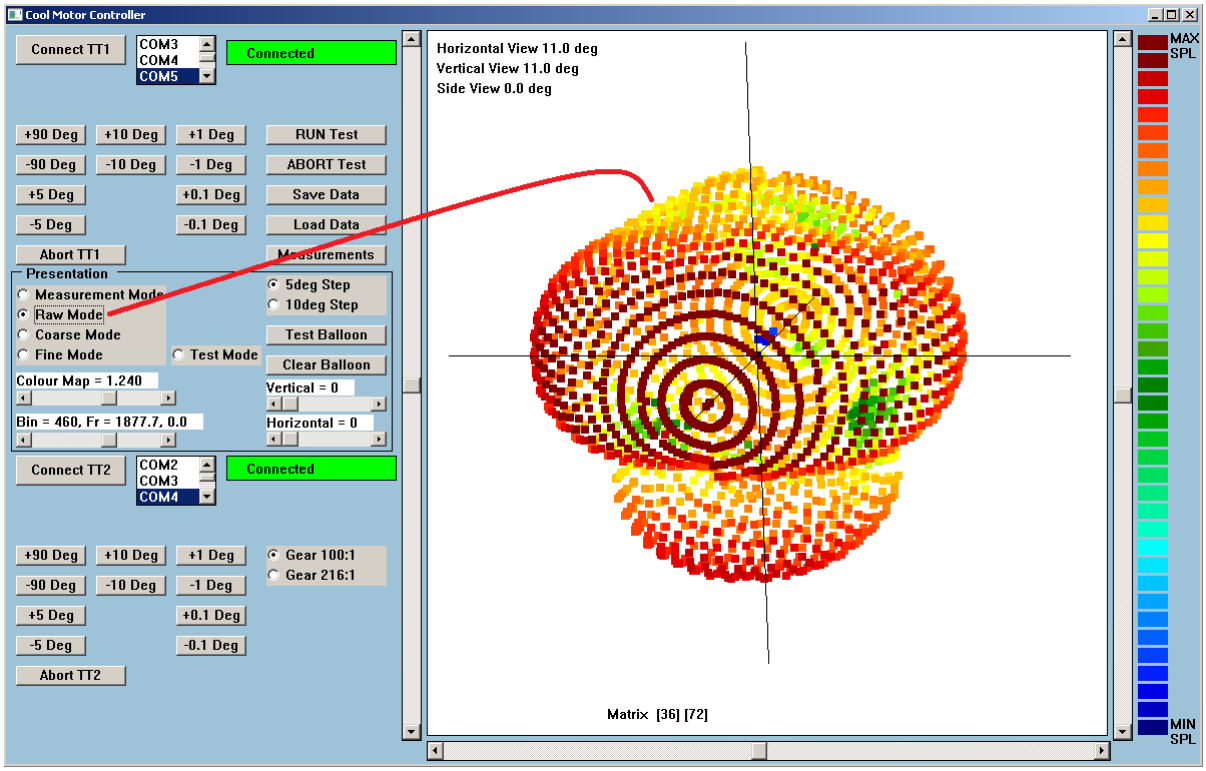


Saved data can be viewed in several modes and from several angles.

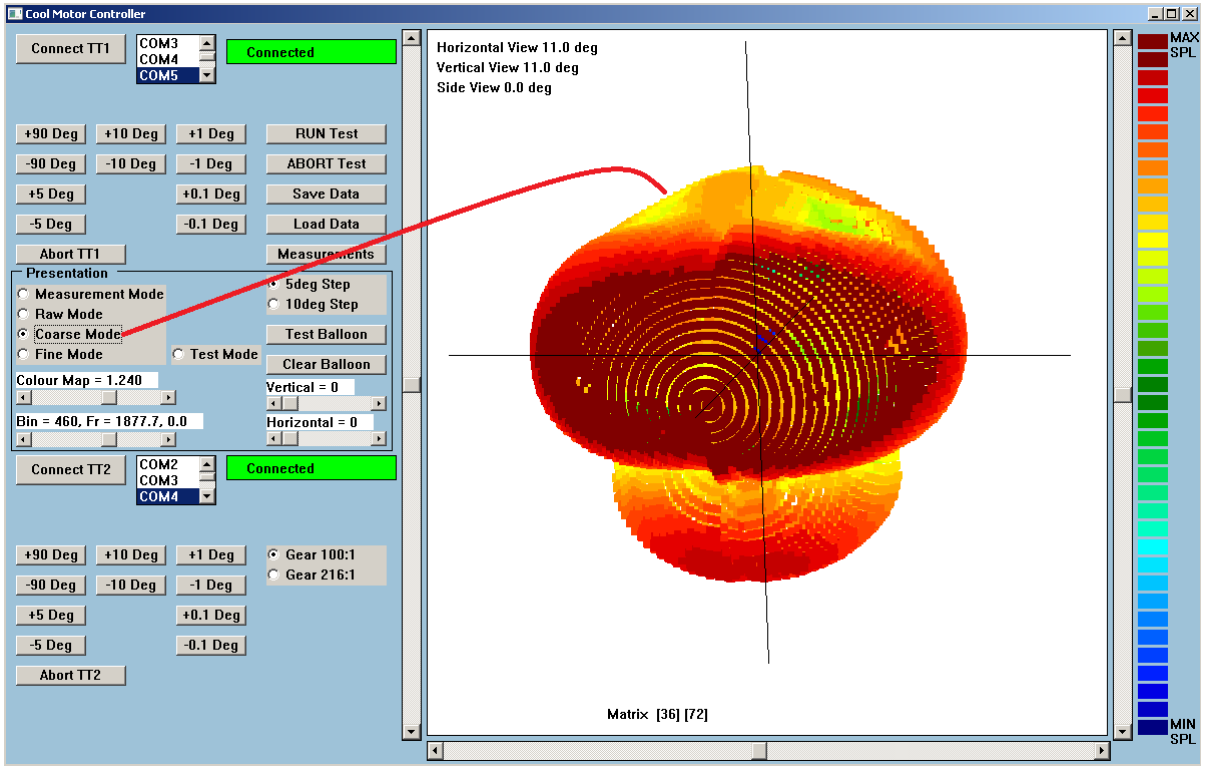
1. Measurement Mode is selected via a corresponding radio-button, and shown below.



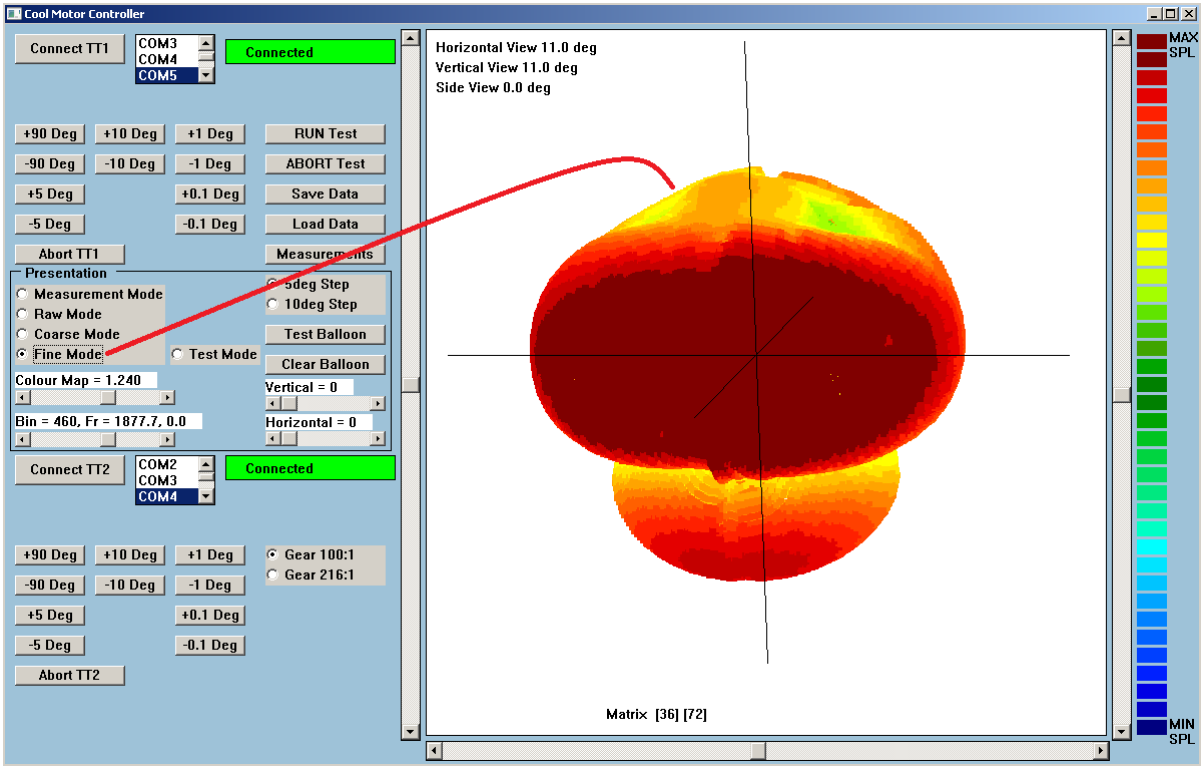
2. Raw Mode is selected via a corresponding radio-button, and shown below



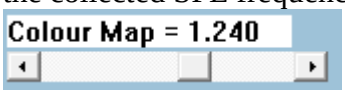
3. Coarse is selected via a corresponding radio-button, and shown below



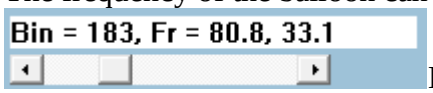
4. Fine Mode is selected via a corresponding radio-button, and shown below



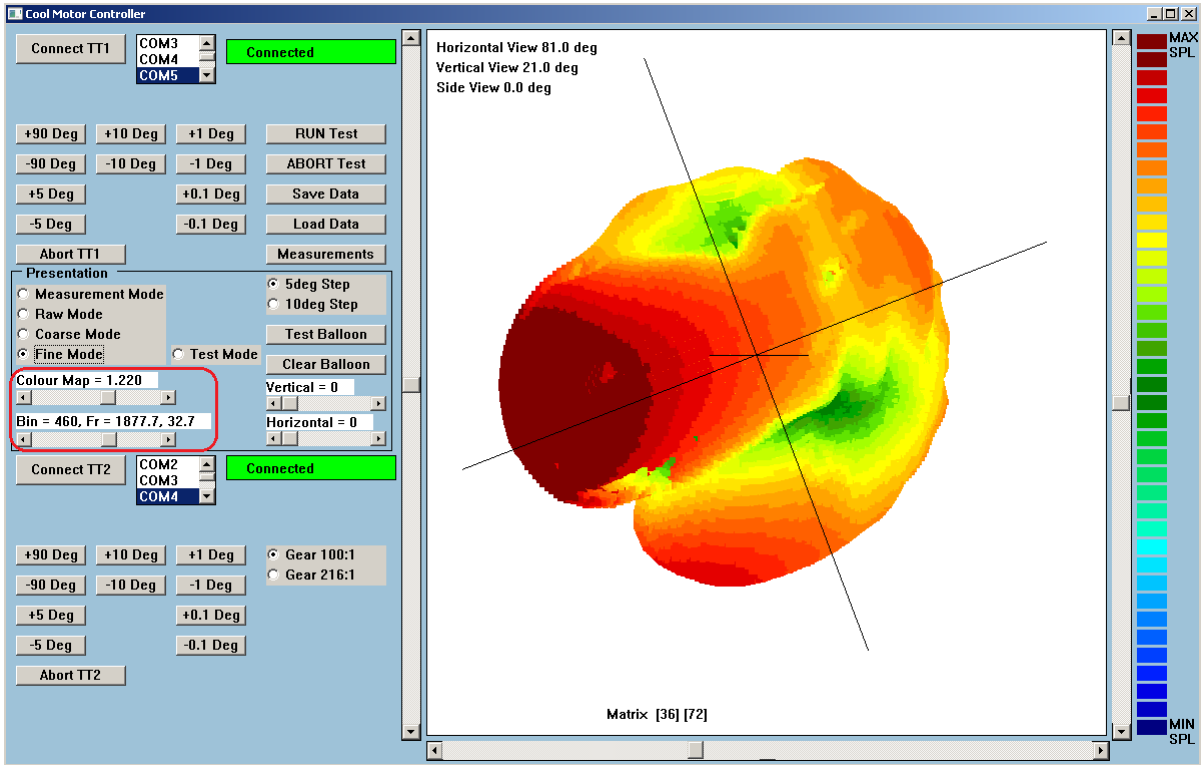
The balloon can be displayed for any of the 750 frequencies of the collected SPL frequency responses. Colour Map can be adjusted using provided slider



The frequency of the balloon can be selected via the second slider provided – see below.

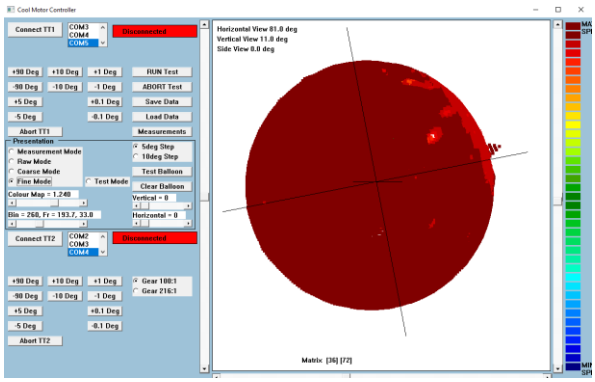


Bin is one of the 750 frequencies. Fr is the actual frequency.

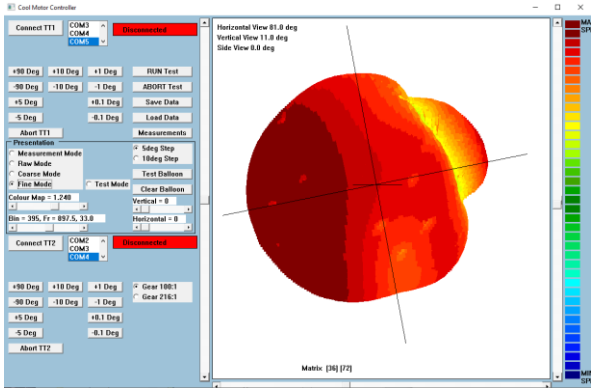


Balloon presentation at -81deg for several different frequencies

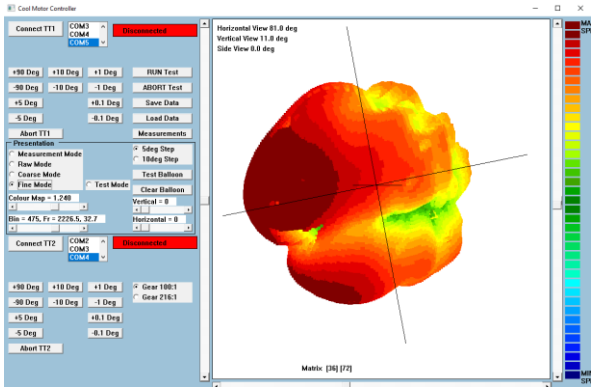
193.7Hz



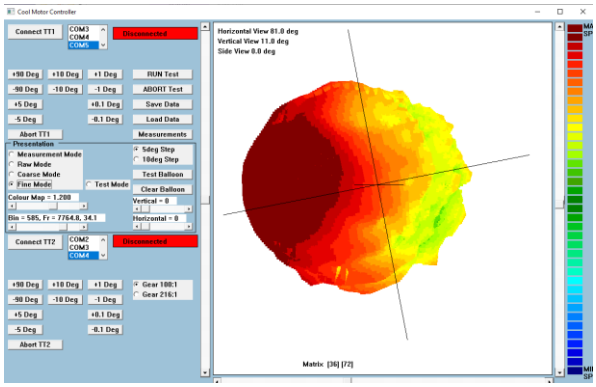
897.5Hz



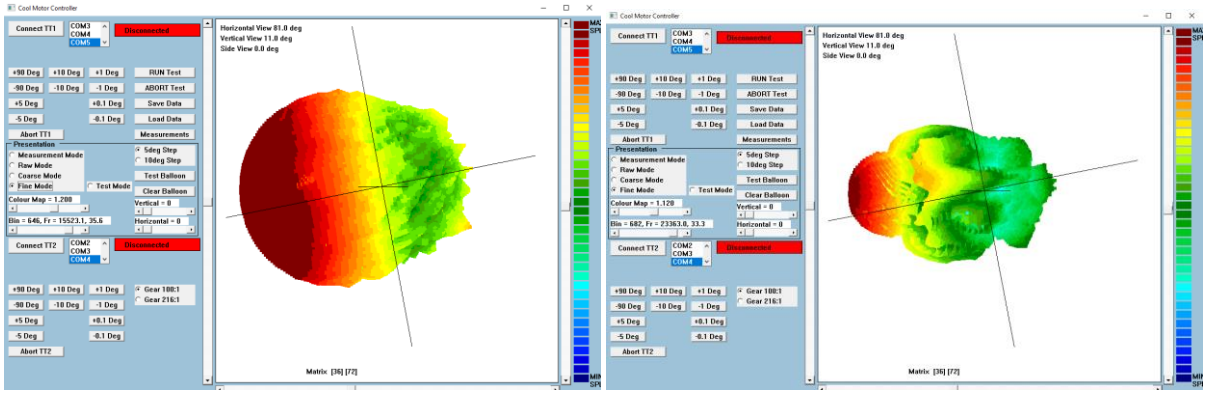
2226.5Hz



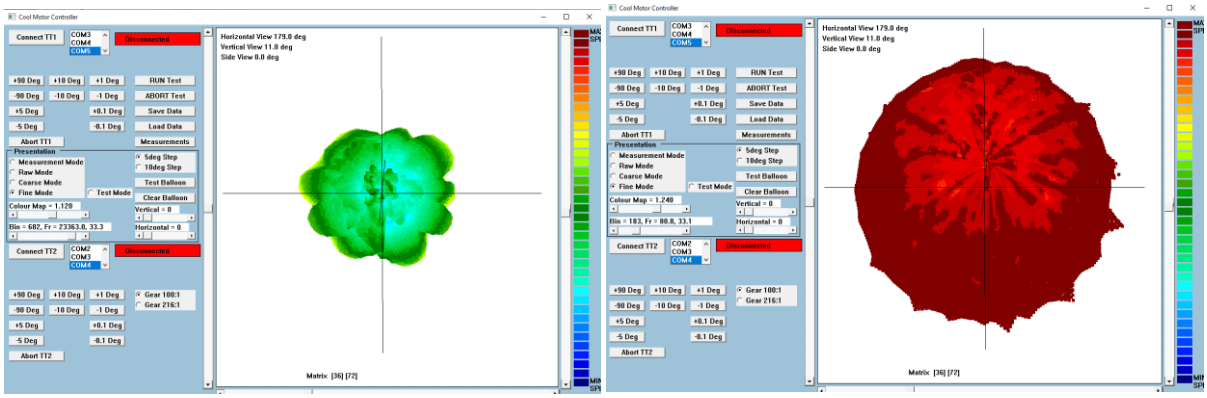
7764.8Hz



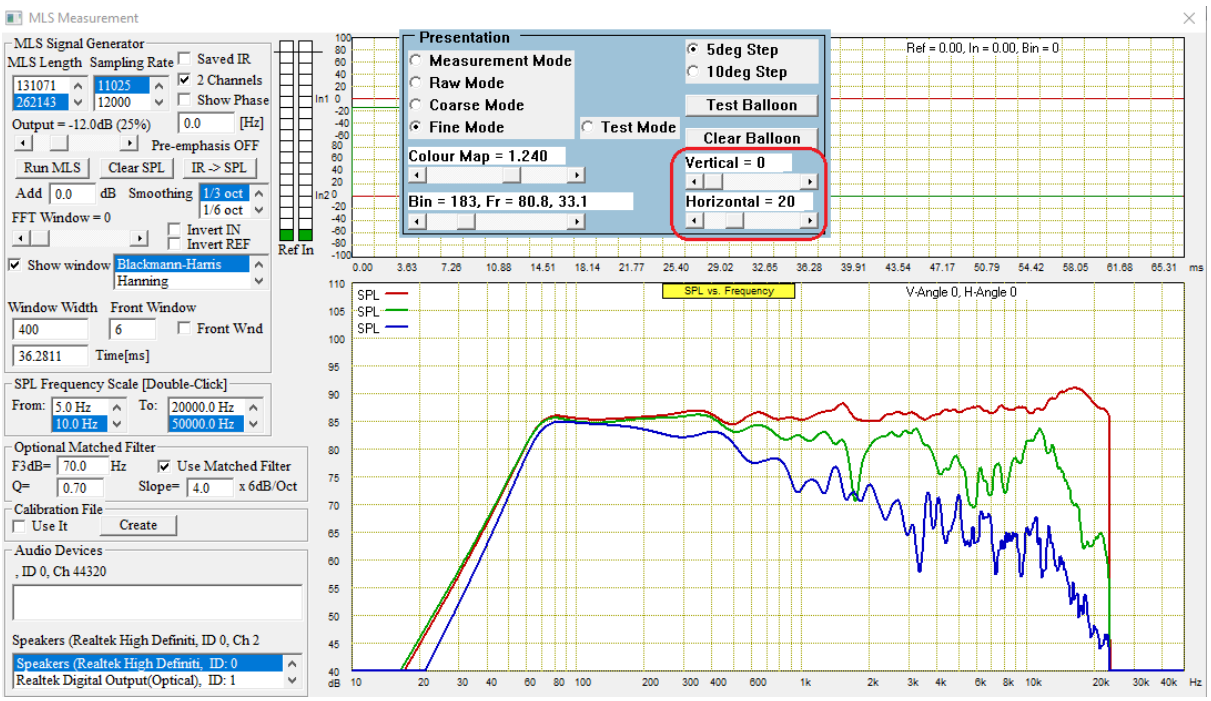
15523.1Hz **23363.0Hz**



Rear View (179deg) 23363.0Hz **Rear View (179deg) 80.8Hz**



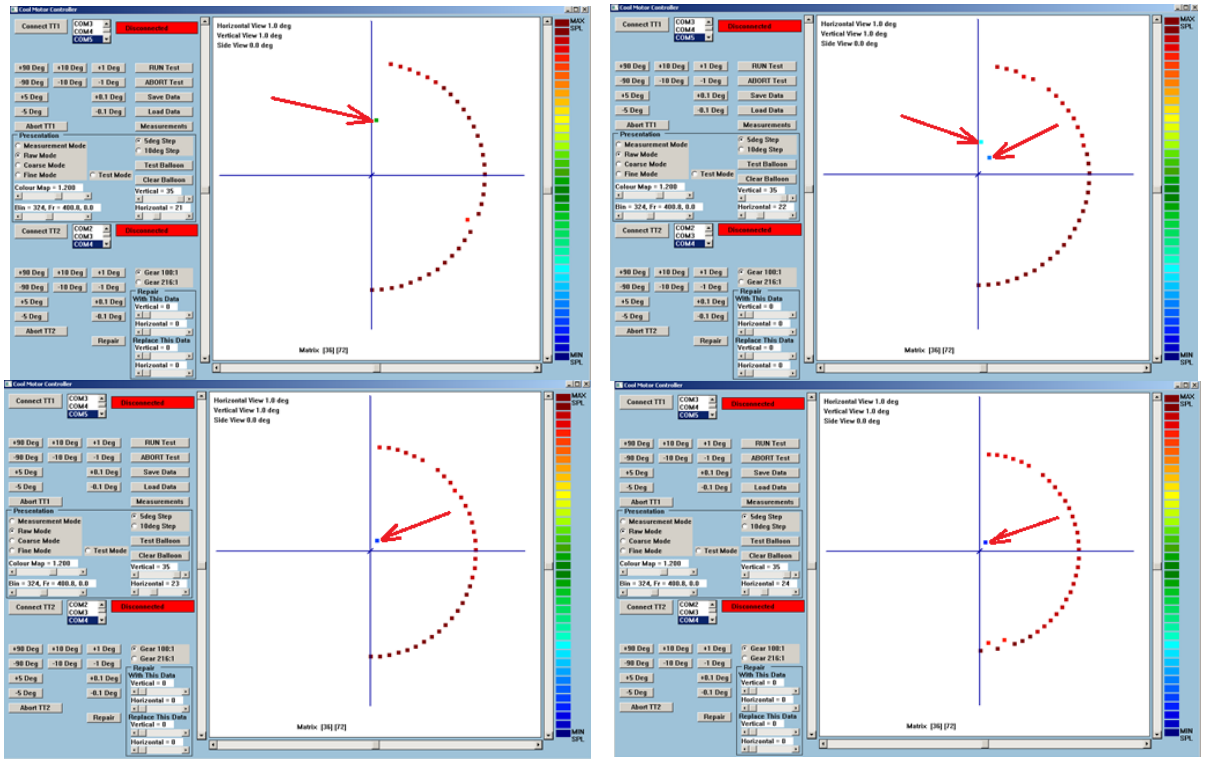
Individual SPL frequency response for every angle tested can be viewed on the “MLS Measurement” dialogue box by adjusting Vertical/Horizonta sliders – see figure below. The three example SPL curves were plotted for vertical angle of 0deg, and horizontal rotation of 0deg (brown), 10x5=50deg (green) and 20x5deg=100deg (dark blue).



Correcting Problematic SPL Measurements

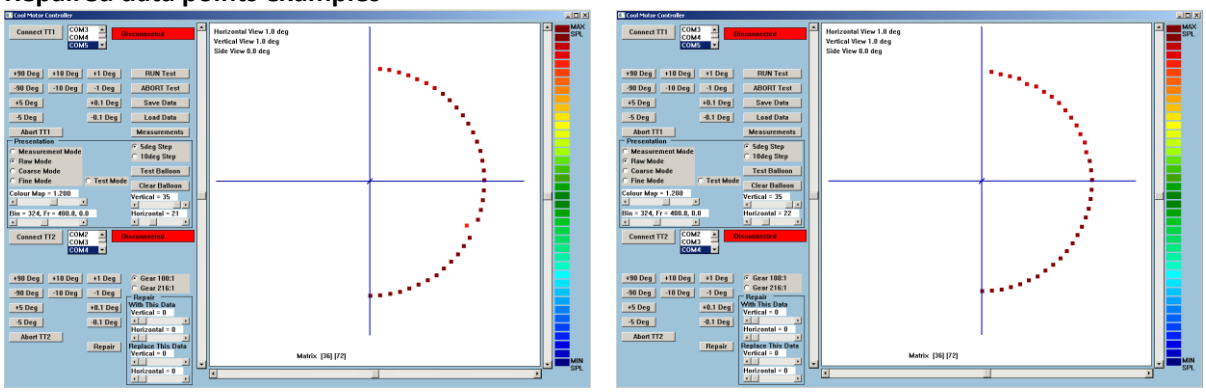
As mentioned in the introduction section, the controlling PC or the measurement equipment being in constant state of movement, may introduce undesirable SPL measurements. These will manifest themselves as unusual colour-coded data points on the balloon sphere. In addition, since colour-coding is related to balloon radius, and the radius relates to SPL level, these data points will be located at the wrong distance from the balloon's centre. Several examples are shown below.

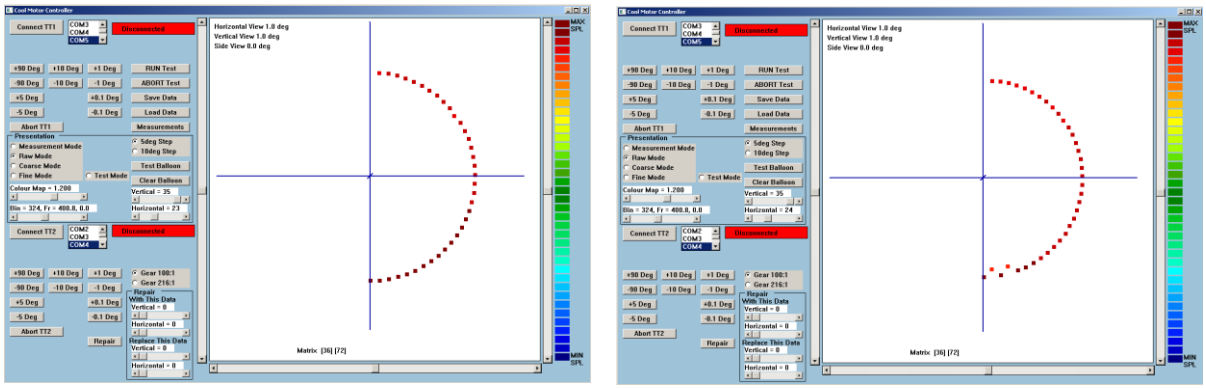
Raw measurements with erroneous data points examples



Fortunately, a mechanism is available for detecting and correcting erroneous SPL responses. After the corrections are completed, the above pictures will be fully corrected. – see below.

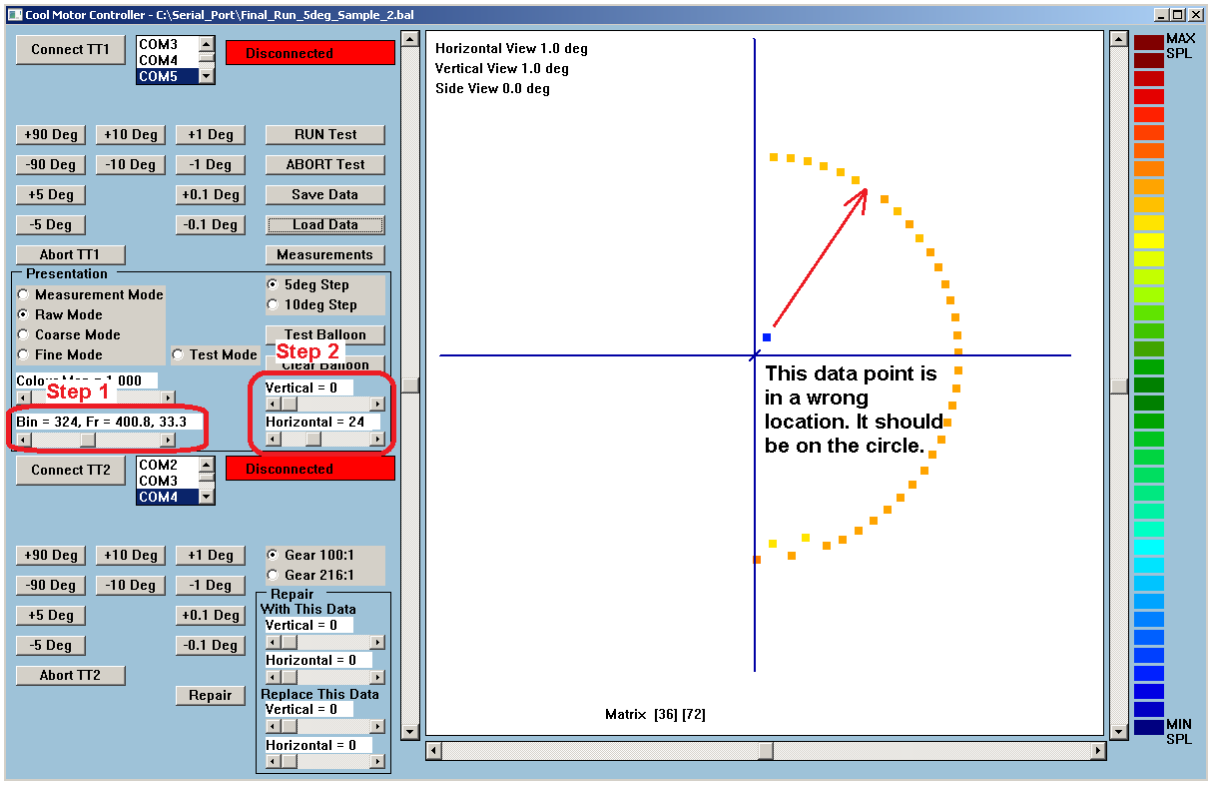
Repaired data points examples

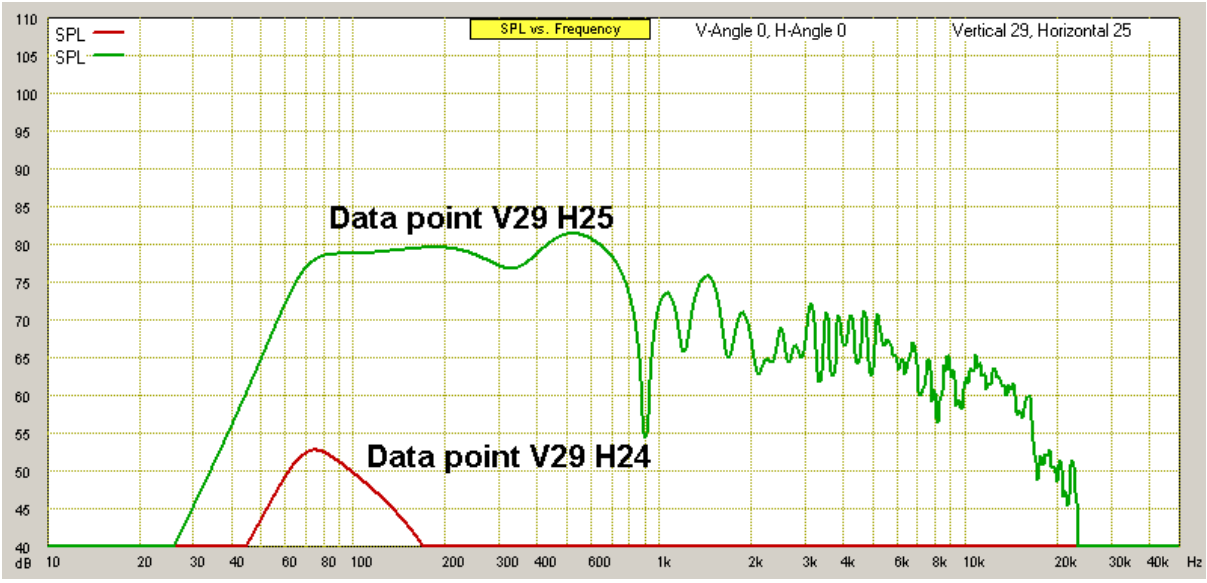




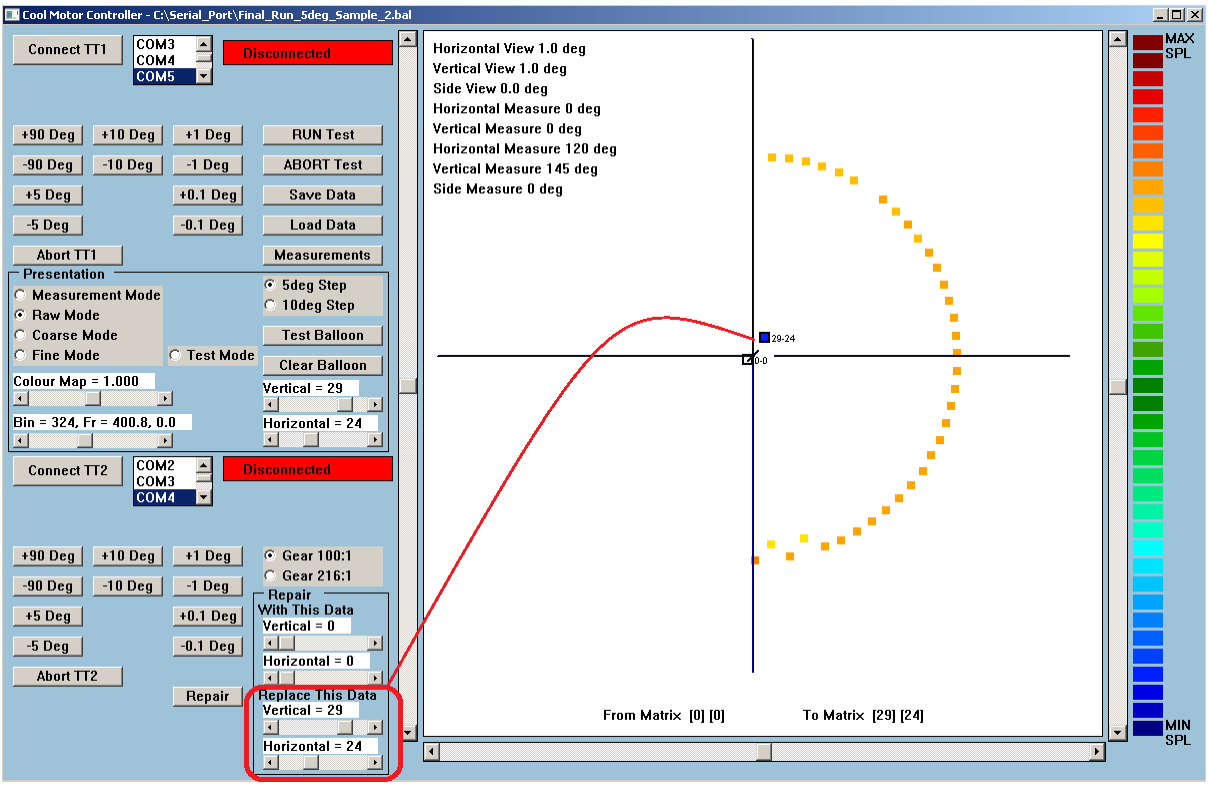
In order to accomplish the above improvements, the location of the erroneous data must be identified first.

1. Start with loading the desired data file.
2. Using the provided slider (like on picture below), select mid-frequency, say 400Hz.
3. Using "**Horizontal**" slider (press, and keep pressed on the right arrow) run through all selections from 0-72 (0-36 for 10deg). For numbers 0-36, the right-hand half-circles will be displayed. For numbers 37-72, the left-hand half-circles will be displayed. The half-circles are cross-sections of the balloon cut through at the horizontal measurement points.
4. If there is a bad data point (bad frequency response), the data point will be shifted far away from the circle representing balloon's sound field. Corresponding SPL frequency response will be shown on the "Measurement" screen.
5. In the example below, a bad data point happened to be located at horizontal cross-section of 24.

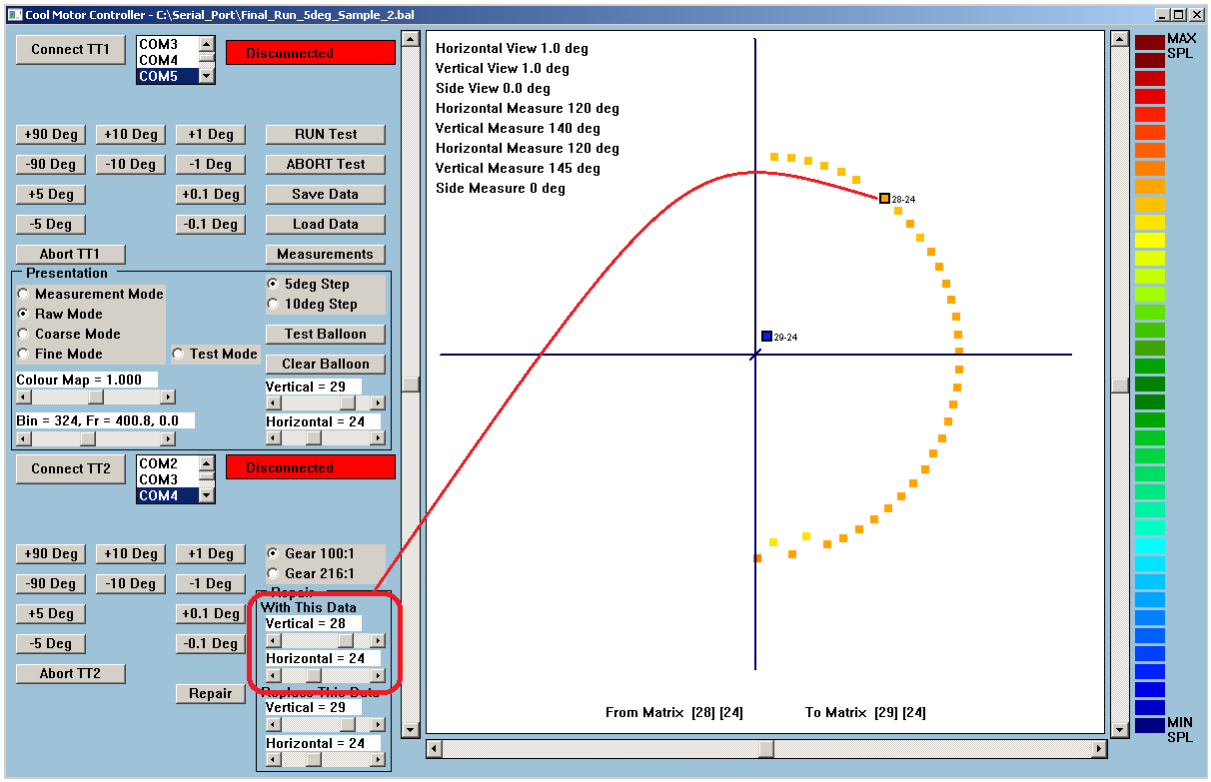




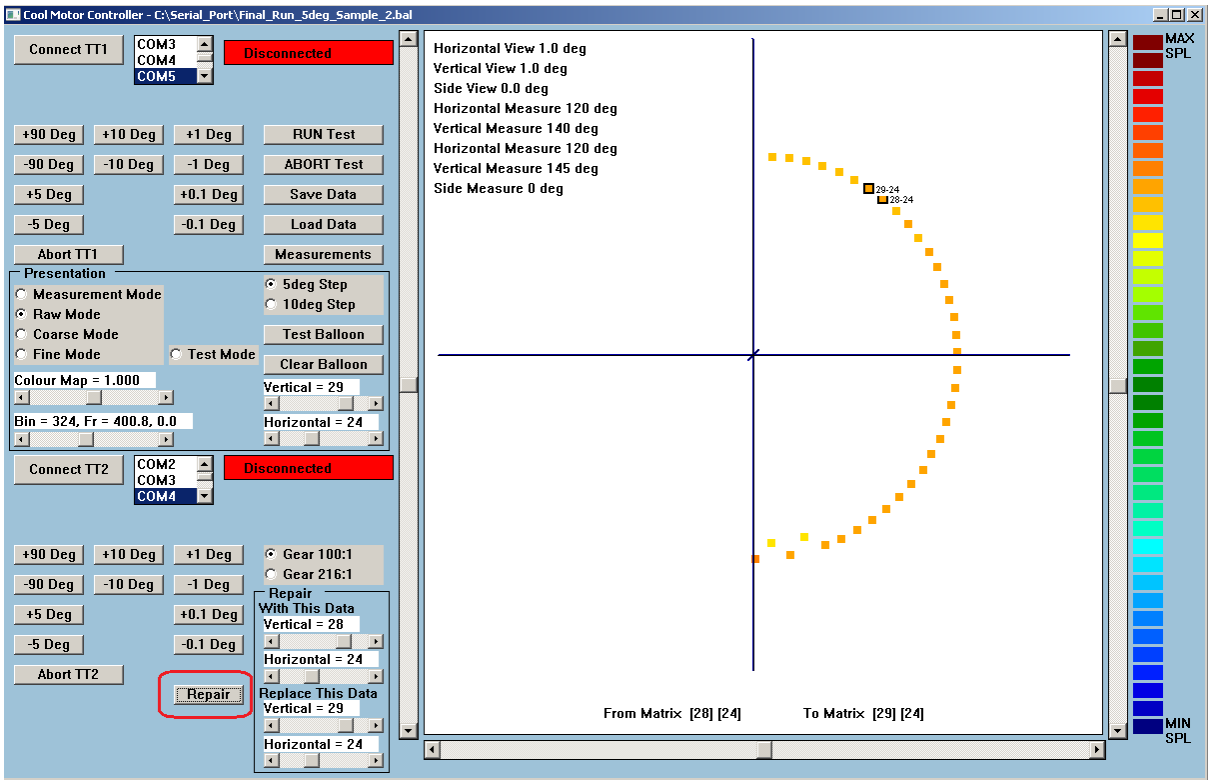
6. To identify the numerical location of the bad data point, please use the "**Replace This Data**" slider, located at the bottom of the screen. Set the horizontal slider to 24, and adjust the vertical slider such a way, that the small movable rectangle **overlaps exactly** the offending blue data point. In the current example, this will happen for **Vertical = 29 and Horizontal = 24** coordinates. Now, we have the spherical location of the erroneous frequency response identified.



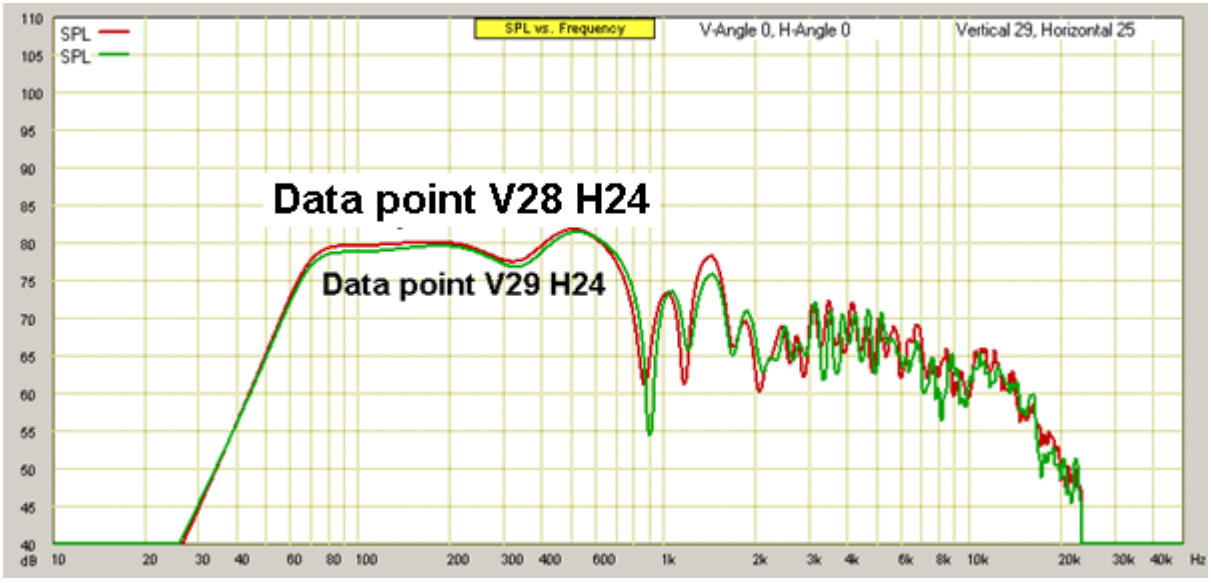
7. In the next step, we need to select the closest usable data point, which will be used to replace the offending data. We decided to use the next immediate good data on the circle by using the same technique and slider **"With This Data**" at **Vertical = 28 and Horizontal = 24** coordinates.



8. Finally, press the "Repair" button. Now, the offending data point at **Vertical = 29 and Horizontal = 24 is replaced by data from Vertical = 28 and Horizontal = 24 coordinates**

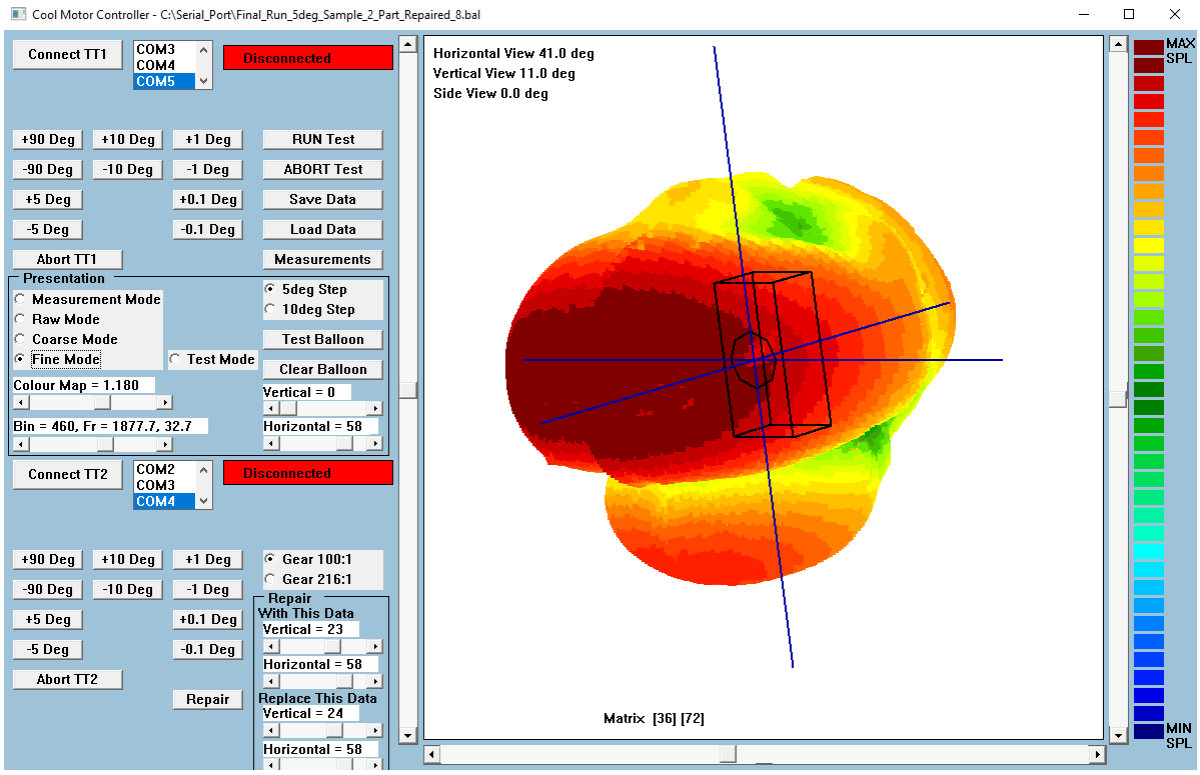


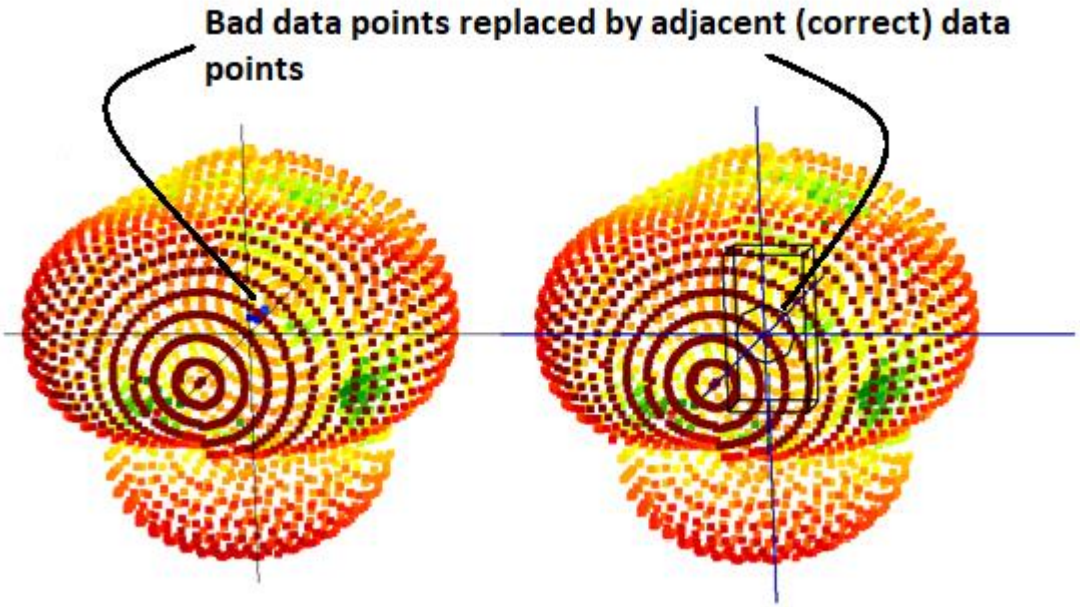
It is also clearly visible, that data point **V29 H24** now contains very similar SPL frequency response to it's neighbour **V28 H24**. These two SPL responses were measured 5deg apart, therefore, it is expected for them to be very close, but not identical.



Using the method described above, one can identify and correct all suspected data points (measured SPL frequency responses) on the balloon sphere.

Example balloon sphere with corrected SPL data is shown below in "Fine Mode". A symbolic loudspeaker is also superimposed onto the picture to show the actual location of the sound source, and most importantly – the front baffle. Please note, that at 1877Hz, quite strong radiation is coming from the tweeter.



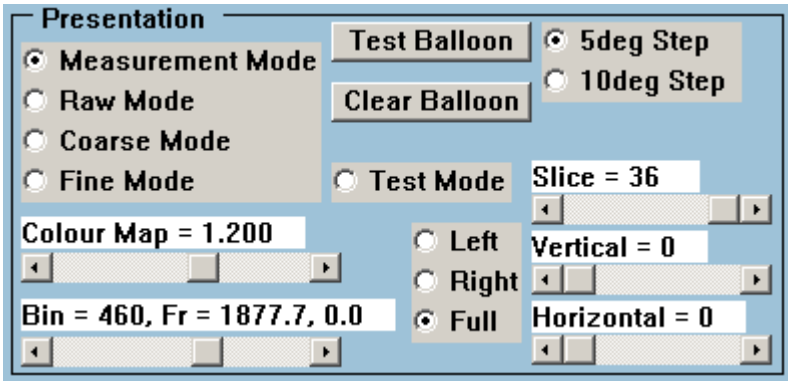


The above picture shows an example of balloon spheres in “Raw Mode”. This mode was selected to highlight the presentation improvements by using the SPL corrections technique.

Presentation Of The Balloon Properties

Loudspeaker mounting /starting loudspeaker position for the dual turntable rig measurements.

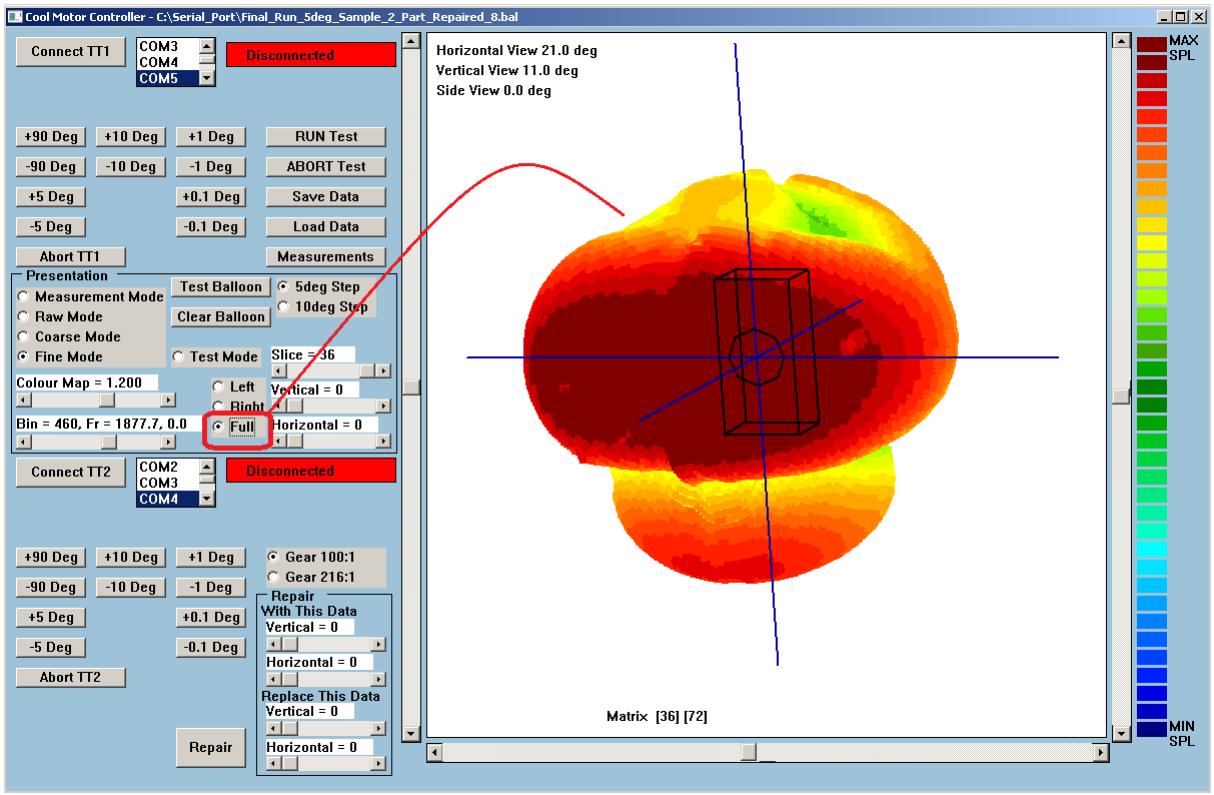
The development of high quality loudspeaker systems greatly benefits from the ability to visualize the sound-field generated by the loudspeaker system under development. This measurement rig allows the user to do just that – **to actually see the SPL coming from the loudspeaker for all frequencies from 10-50000Hz**. This is accomplished by taking 2592 SPL measurements in 5deg resolution mode, and 648 SPL measurements in 10deg resolution mode. All performed automatically. It is a significant, and perhaps the final step in loudspeaker development and evaluation.



Controls for the presentation of the balloon.

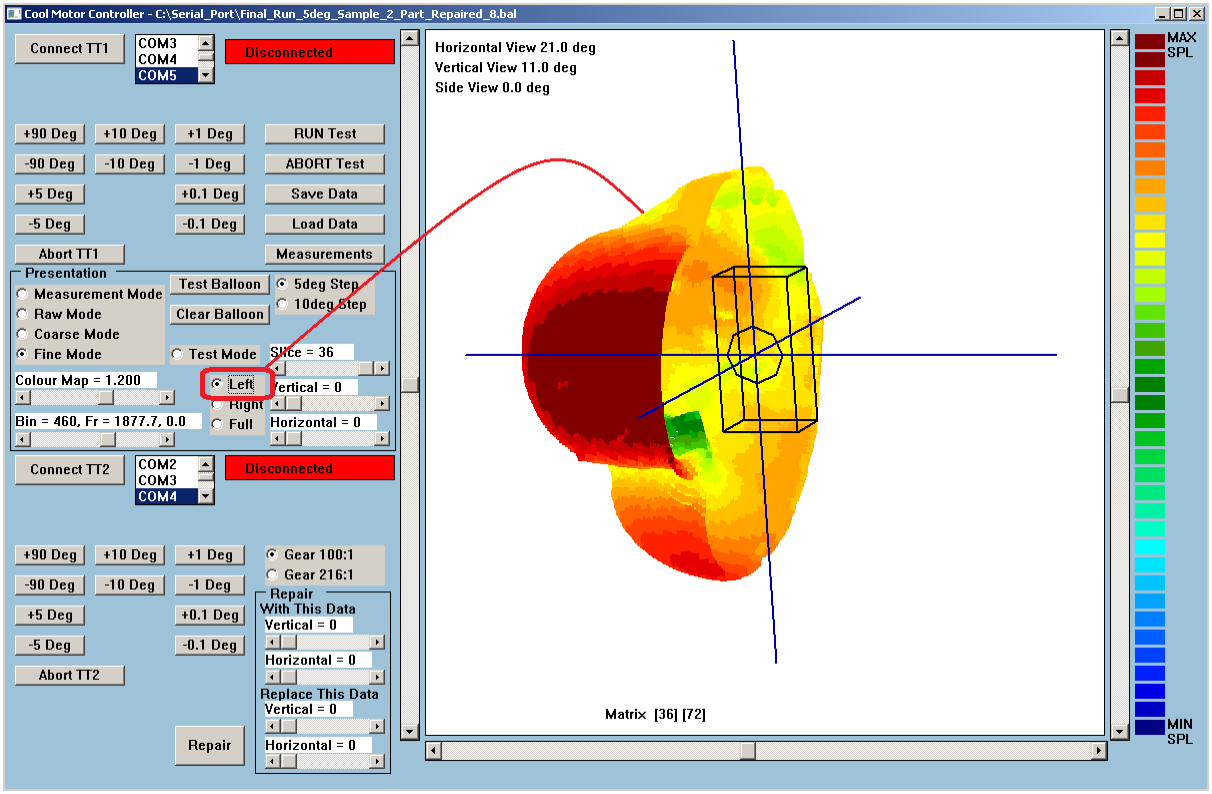
Balloon Presentation Modes, Colour Map adjustments and Frequency Selection were described previously in this Manual. The reader may also recall, that the balloon can be rotated in all directions, by using sliders provided.

In the remainder of this Manual we will concentrate on the finer ways, that the balloon can be presented: Slicing and splitting the balloon in halves.

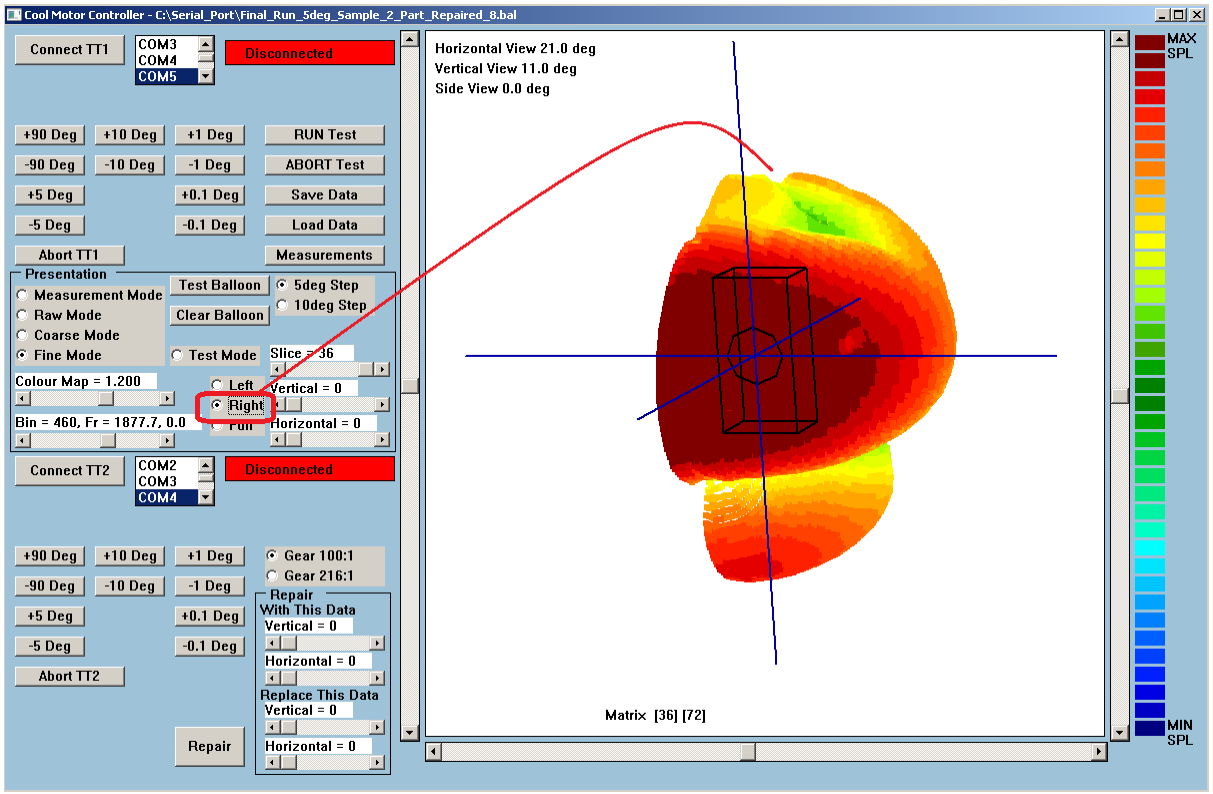


Balloon presented in Full Mode

Splitting the balloon in halves, can reveal features hidden from the view by the front section of the balloon sphere.

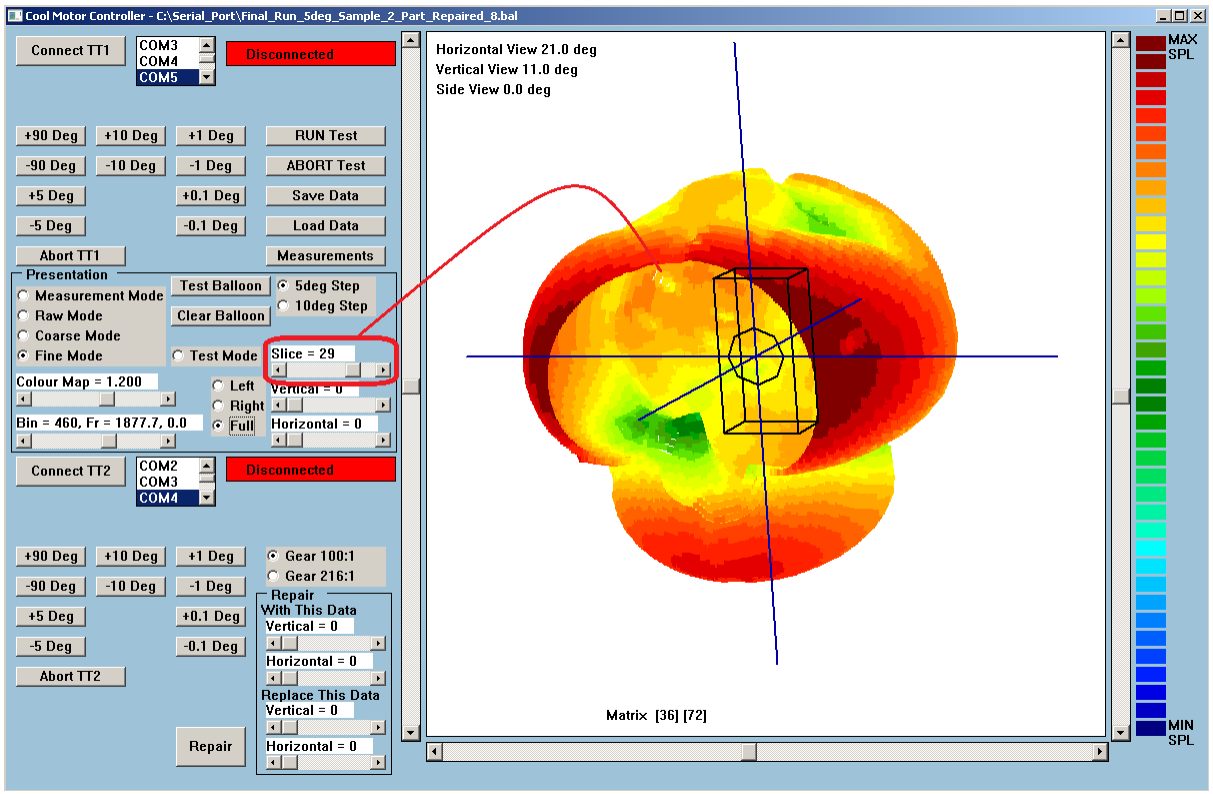


Balloon presented in Left Mode.

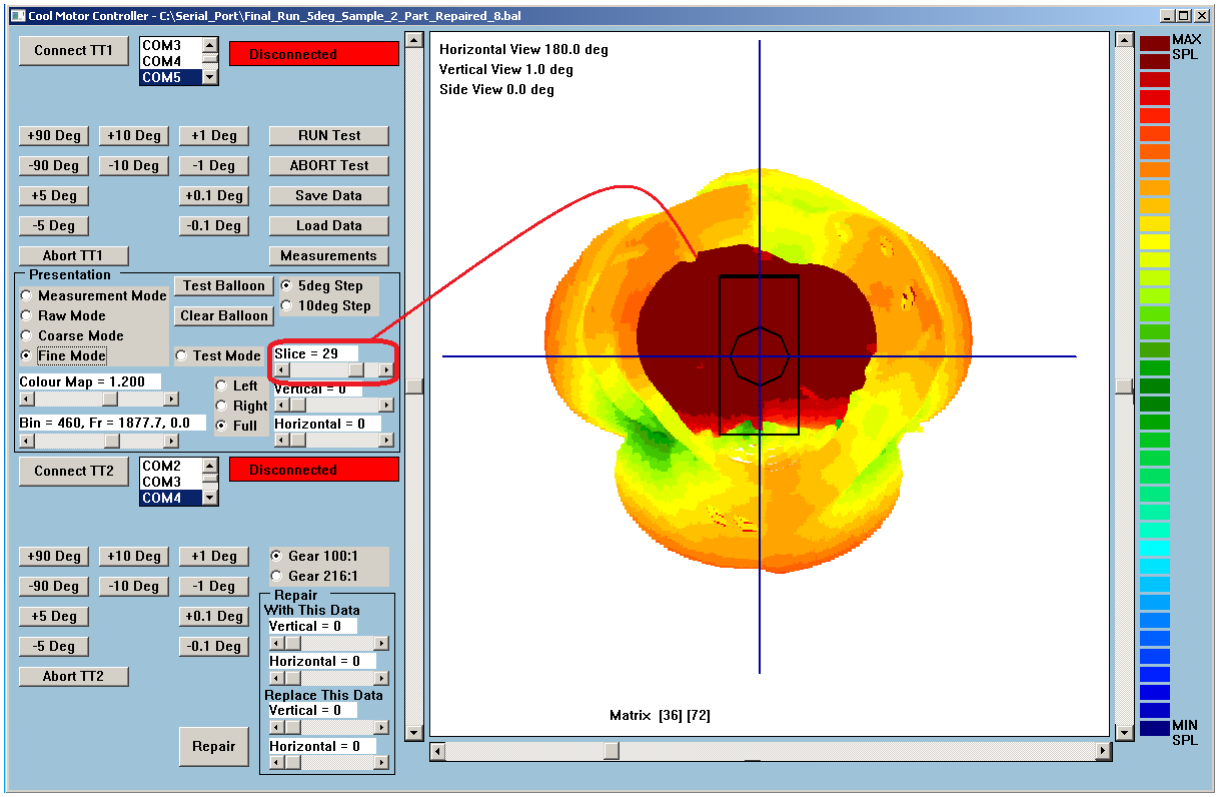


Balloon presented in Right Mode

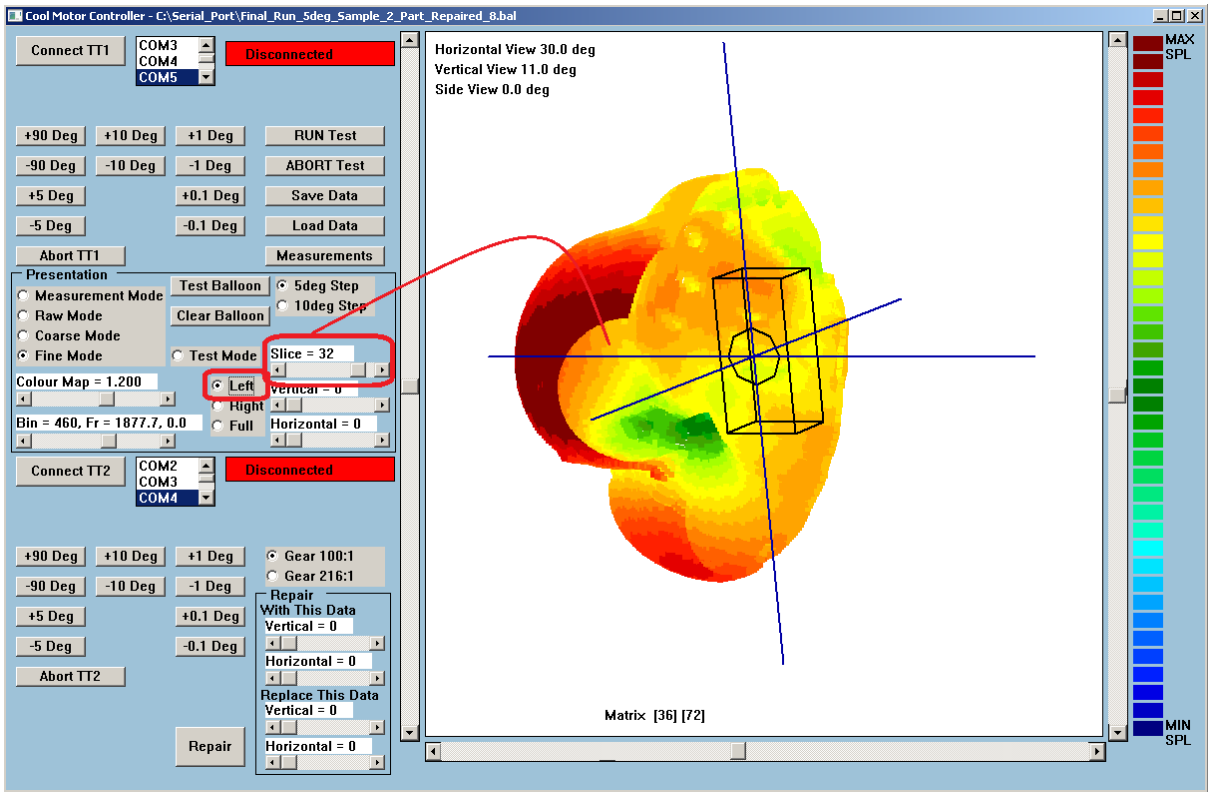
The balloon can be sliced in 36 vertical cuts, in 5deg resolution. Or 18 cuts in 10deg resolution. On the picture shown below, the balloon is sliced with Cut 29 from the front.



Next, the balloon is rotated 180deg to the left, and sliced with Cut 29.



Finally, the balloon can be cut and sliced at the same time, as presented on the picture below.



The measurement results presented in this manual. were taken in quite bad acoustical environment, with significant reflections coming from all surrounding surfaces. Indeed, there was some debate if the measurements should proceed. At the same time, it was a good opportunity to put the whole measurement rig (hardware and software) to the test and see how it would cope with really adverse conditions. As it turned out, with the help of the FFT Windowing and particularly, the Matching Filter Technique, the room reflections were supressed to negligible levels. This allowed balloon presentation to be of a good, usable quality.

All frequency-dependant radiation patterns predicted by theory are clearly captured by the dual-turntable measurement rig and displayed in a variety of positions and angles. These include for example, individual drivers' sound field radiation patterns at crossover frequencies, waveguide contribution to tweeter radiation, various diffraction options, front baffle padding at high frequencies, and much more.

There can be several factors negatively affecting the measurements. It may even happen, that the frequency response taken at any measurement point is damaged beyond repair. In this case, the program implements a simple "substitution" method allowing the user to identify and discard the bad SPL measurement and replace it with carefully selected adjacent measurement sample.

The dual-turntable measurement rig was powered by Windows 7 PC with Delta1010LT soundcard. Loudspeaker under test was JBL LSR305, 2-way active system with port at the rear.