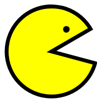
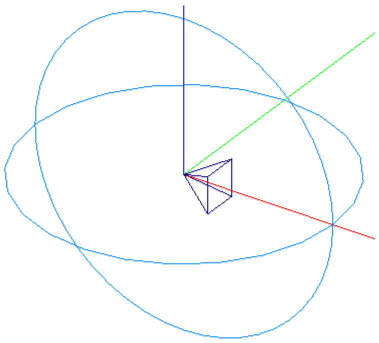
Measuring directivity ballons. Pac-Man is back

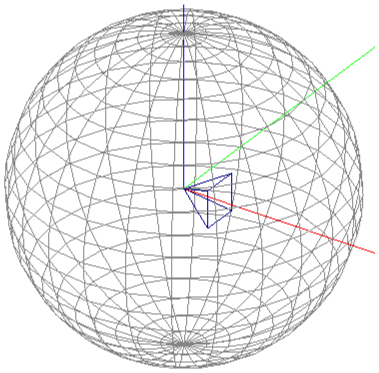


Can you remember Pac-Man (originally Pakkuman in Japan), the 80's video game? Pac-Man was a yellow ball that opened its mouth to eat dots through a maze while escaping from four ghosts. What's Pac-Man got to do with loudspeakers? Well, if you do not want your prediction coverage maps to look like Pac-Man you may need to measure the polars of your speaker in 3D.

The problem



In the old days, for product specifications one would run horizontal and vertical polar plots on a speaker. You would place a speaker upright on a turntable and measure horizontal polars, then turn it on its side and measure vertical polars. When modelling software came around, the need for 3D measurements (that is, measurements taken all around a sphere surrounding the device under test) became apparent. However, a system that was able to measure and store all that was complicated, slow and expensive, so most often **interpolation** was performed to fill in the data for the angles in between. For a typical horn, say a 90°x60°, the error would be up to 2-3 dB on the front hemisphere, and most people lived with that.



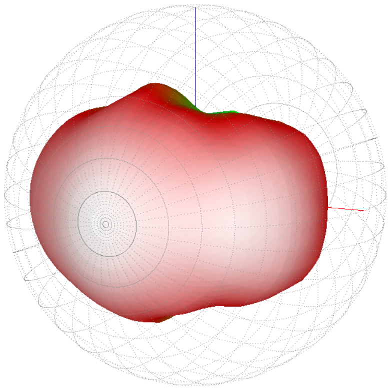
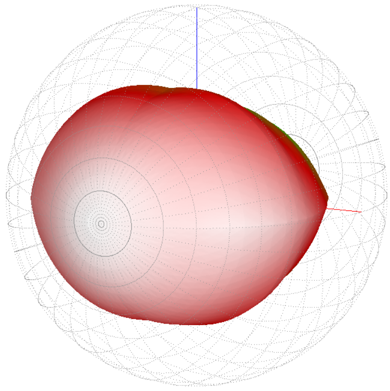
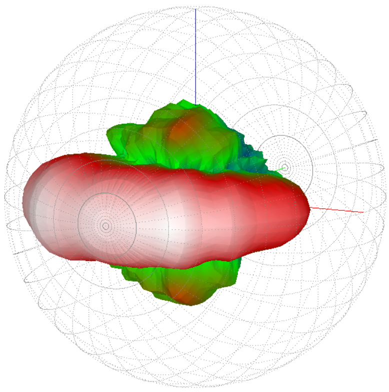
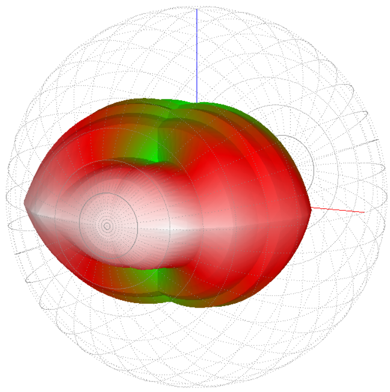
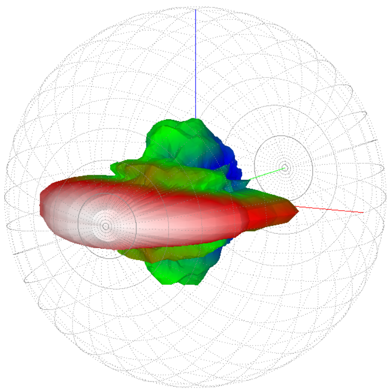
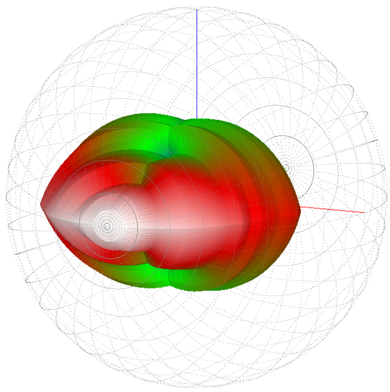
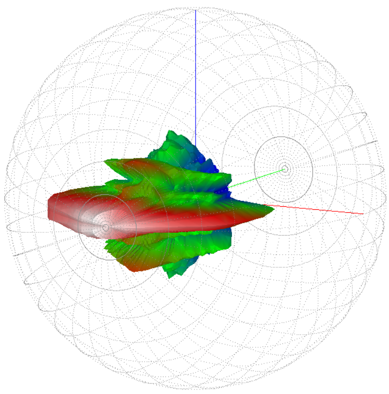
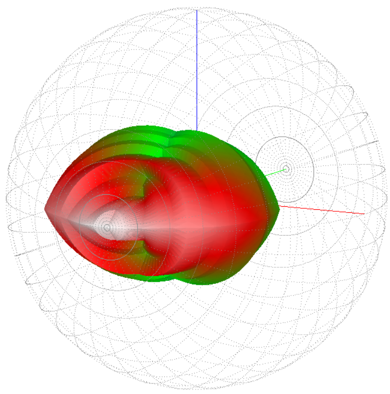
Fast forward to the early 2000's: line-arrays (call them line source arrays or anything else if you want) are a must-have for any manufacturer. Of course, these vertically articulated array modules use compression drivers that are invariably attached to a wave shaping guide or ribbon emulator of some sort, and this produces very narrow coverage angles at high frequencies. Now the directivity balloon was squashed vertically, but very wide horizontally. Unfortunately, this means now **elliptical interpolation fails miserably**. Most earlier line-array specific prediction software calculated only vertical coverage so the lack of good data for the missing oblique angles was not a problem, but with the advent of 3D modelling software that maps the results onto a listening plane (both line-array specific or generic), **the issue cannot be avoided anymore**.

The evidence. Balloons

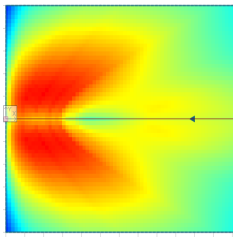
To illustrate this, Brusi Acoustics run automated 3D directivity fully anechoic measurements on a commercial line-array module with a resolution of 5 degrees (that means a whopping 2664 measurements). We read the full data set and produced directivity balloons. We then read just the horizontal and vertical parts (that's just 144 points, i.e. around 5% of the data) of the very same data and generated the missing data via interpolation. The captures below show the balloons obtained from full spherical measurements on the left, while the ones with interpolation are shown on the right. For the 1000 Hz one-third octave band, the results are different but the balloons are reasonably close; directivity is only a bit different in the vertical plane and the interpolation works smoothly. However, at **2k, 4k and 8k Hz, the result gets increasingly disastrous**.

Brusi Acoustics

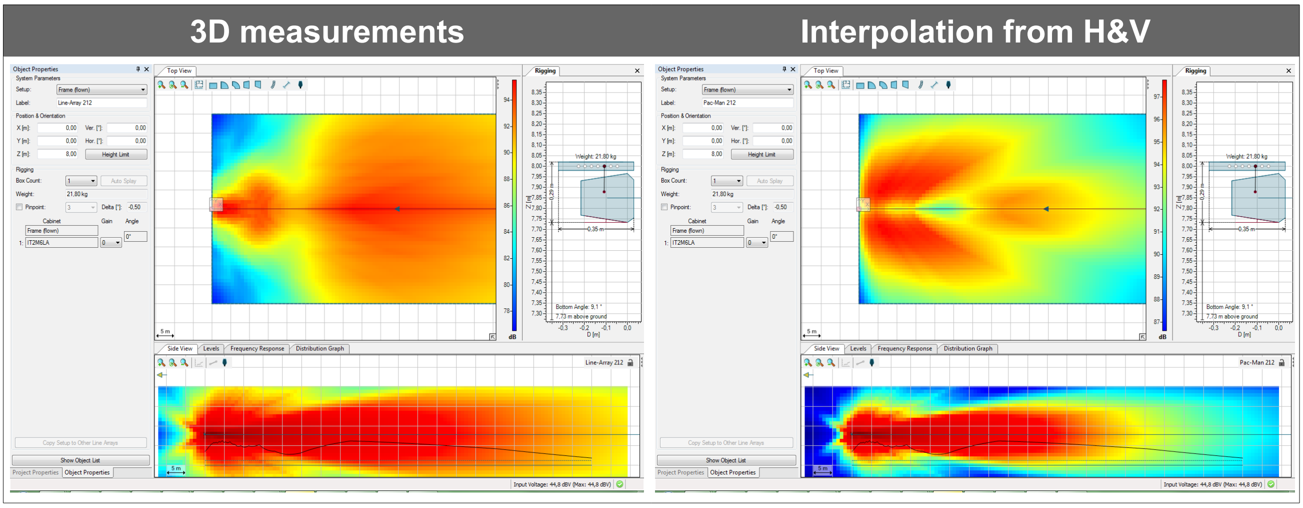
This is why you need 3D polar measurements

3D measurements	Interpolation from H&V
 1000 Hz	 1000 Hz
 2000 Hz	 2000 Hz
 4000 Hz	 4000 Hz
 8000 Hz	 8000 Hz

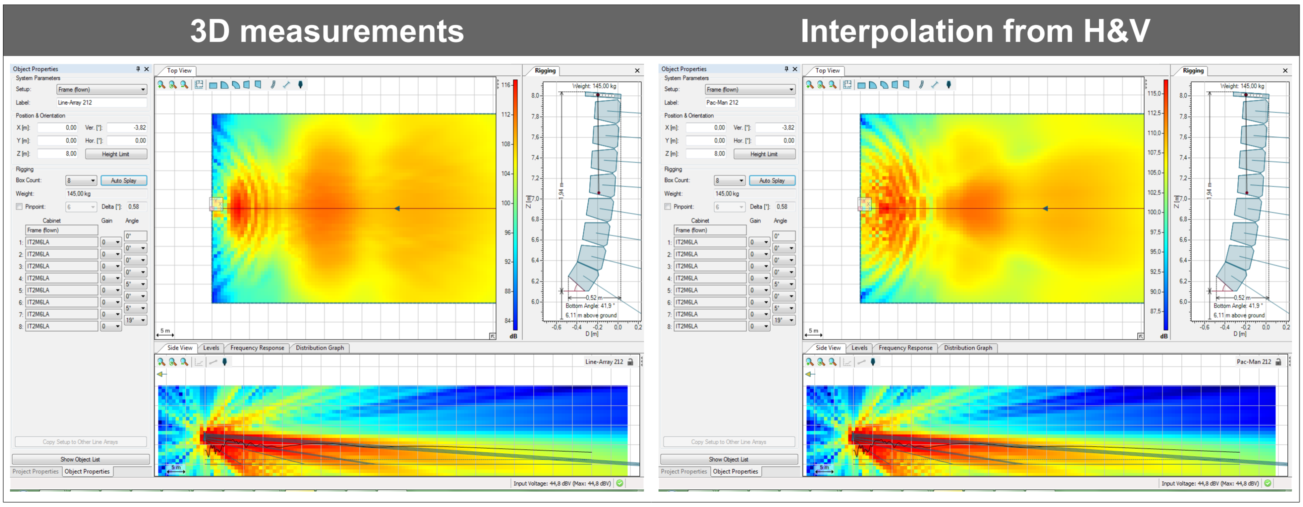
The evidence 2. Pac-Man returns



Now that we have shown how terrible directivity balloons look when only horizontal and vertical polars are measured, let's now see what happens when we model the speakers on prediction software. Here we used a 1 octave band centered at 4k Hz. On the captures below you can see the result of modelling a single box pointing forward. On the left, using 3D measurements. On the right, using interpolation from H+V measurements. All settings are exactly the same except for the model. As you can see, the predictions differ widely. ¡¡¡ Pac-Man returns !!!



Since these speakers most often come in multiples (hey, that's why they are called arrays), let's now run some coverage predictions for an 8-piece arced array. Again all settings are the same. Now the differences are not as massive as for the single box, but they are still very significant.



Conclusion

For line-array boxes or any other speaker **where the vertical directivity is significantly different to the horizontal** (such as column speakers), **3D polar measurements are a must** as interpolation from vertical and horizontal polars provide unacceptable error.