Understanding Loudspeaker Measurements

One of the most important parts (and sometimes the most confusing part) of buying a loudspeaker is, understanding the data sheet that accompanies it. The goal of this paper is to help you understand what some of the specifications mean, and how to differentiate between measurement methods.

Two of the specifications that people tend to look at first are *frequency response,* and *power handling*. Although these can be important things to look at, sometimes for certain applications, measurements such as *Q,* and *Directivity Index* (DI) are even more critical.

Power Handling

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The 2 most commonly used measurement systems for calculating the power handling of a loudspeaker, or loudspeaker system, is the *AES standard,* or the *EIA 426 Standard. AES* uses pink noise filtered with a 12dB/octave Butterworth filter, both high and low, 1 decade apart. (A decade is a 10:1 frequency ratio, for example 200 Hz to 2 kHz). The decade used will be specific to the device being tested. It is a 2-hour test with a crest factor of 6dB. (This means there will be peaks in the signal up to 4 times the continuous signal level). *EIA 426A* uses white noise filtered with a 6dB/octave high pass filter at 40 Hz, and a 6dB/octave low pass filter at 318 Hz. This is an 8-hour test with a 6dB crest factor. *EIA 426B* uses pink noise, and has a flat response from 50 Hz to 2 kHz, above 2 kHz, the response rolls of at 3dB/octave. There are also "brick wall" filters at 50 Hz, and 10 kHz. This is also an 8-hour test with a 6dB crest factor.

Other methods used in the audio industry are to list a *short term* power handling specification, which will typically be at least 25% higher than the *long term* power handling specification, or to list the *peak power*, which will be 4 times the long term power handling of the speaker**.** You might also see it listed as *continuous* and *program* power handling. *Continuous* power handling is the long-term rating, whereas *program* will be a short term listing, and twice as high as *continuous*.

Frequency Response

There are many things to consider when looking at a frequency response number, but the most important is the +/- tolerance at the end of the rating. Typically a frequency response would read: 70-15 kHz +/- 3dB. This is very useful, because it tells us that we should expect the speaker to have no more than a 3dB variation in level between 70 Hz, and 15 kHz. Many manufacturers will also list a –10dB down point, which is also useful, because 10dB down can be considered the usable frequency range of the speaker. Most manufacturers will recommend using a high pass filter on a speaker at, or very near, a speakers' low frequency –10dB point to protect the speaker from over excursion. Any frequency response data that does not include the +/- tolerance at the end should be considered useless because it does not specify what kind of level variation there is.

Another consideration to keep in mind when looking at a frequency response number is whether the tests where conducted in *full space* or *half space*. A full space measurement does not include any level gain from a room boundary, where a half space measurement is done with the speaker on one boundary, which will result in 3dB of gain in the lower frequency range.

Figure 1 is a picture of a full space environment, with the speaker at the center. Notice that the coverage cone of the speaker is not reflecting off of any of the boundaries of the test environment. The test results from a full space measurement will be more meaningful for speakers that will be hung or arrayed, because it closely represents their real world environment.
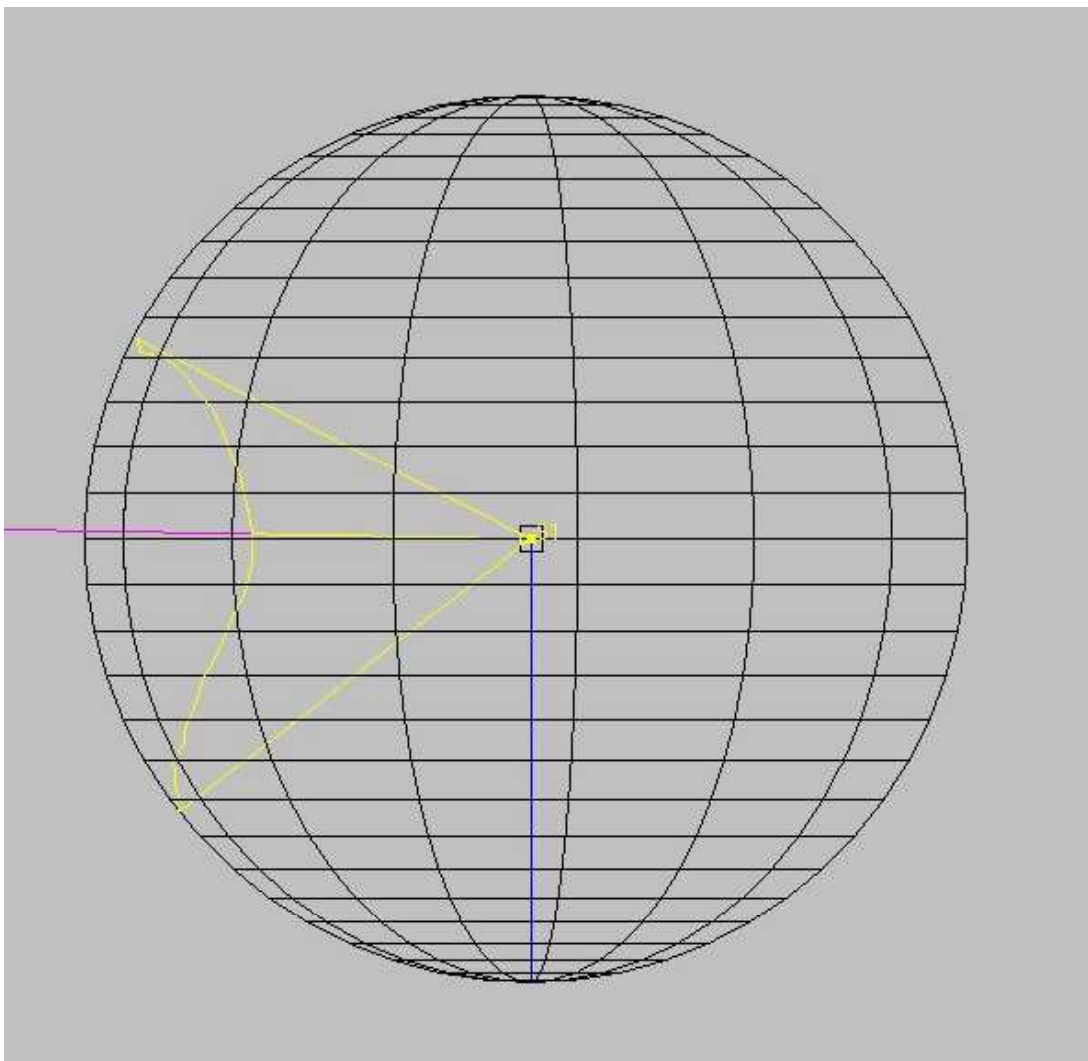

Figure 1

The other method used is the *half space* method, which is pictured in figure 2. Notice that the speaker is on a boundary and that the coverage cone is reflecting off of that

boundary. This method will provide 3dB of gain due to boundary loading. The gain is frequency dependant, typically reinforcing longer wavelengths. This method is more accurate for loudspeakers that are either ground stacked, like subwoofers, or mounted on a wall, like theater surround speakers or commercial background speakers.
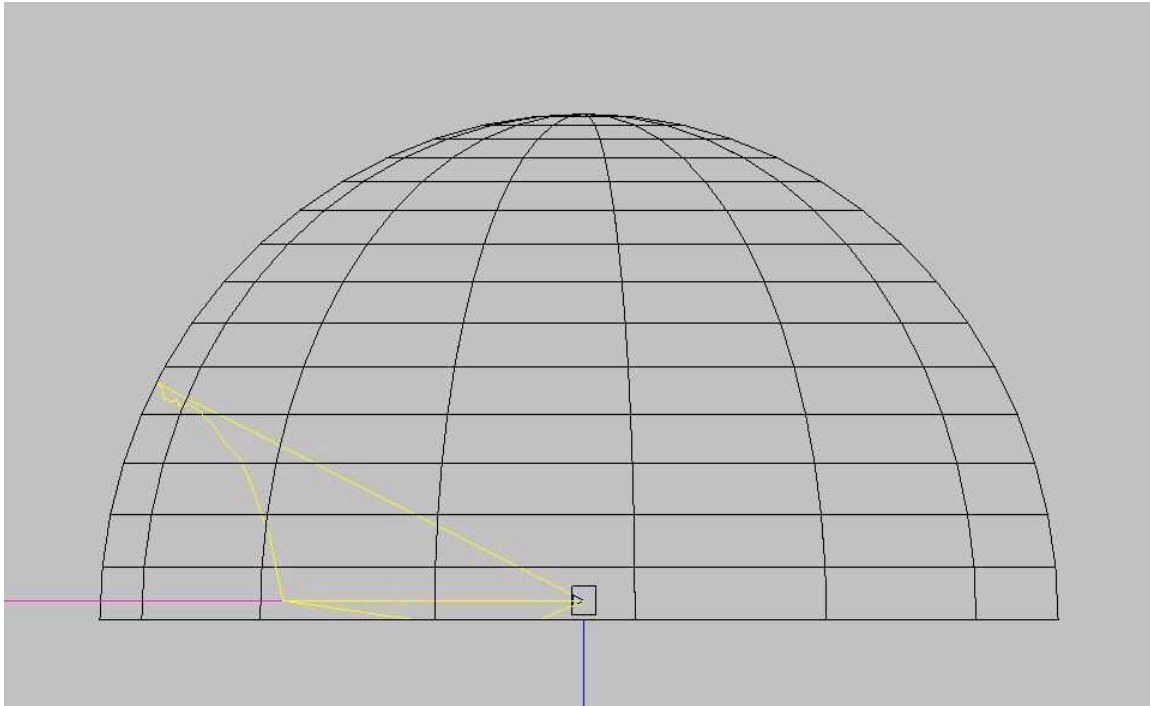

Figure 2

Q

Q for a loudspeaker is defined as: *the ratio of sound pressure at one axis to the mean sound pressure at all axes around the device.* What this tells us is that a low Q device will have a wide coverage area, and a high Q device will have a narrow coverage area. A 90 by 40 horn would be considered a lower Q device, whereas a 40 by 20 horn would be considered a higher Q device. Higher Q devices are often used for long throw applications, loudspeaker arrays where you want to minimize the pattern overlap between cabinets, and in highly reverberant venues where you want to keep sound focused on the listening area, and off of the reflective surfaces of the room.

Directivity Index (DI)

The term directivity index is defined as: *the gain of a loudspeaker at any stated angle. It is Q converted into dB. It represents the "gain" of the loudspeaker due to directivity.* This tells us that as the DI gets lower, the pattern radiation becomes more omni-directional. A loudspeakers' ability to control sound directivity is a function of frequency wavelength versus driver loading. This means that a large stadium horn will be able to control sound directivity at a lower frequency than a standard front loaded cabinet, because of its physical size, and because of the way that the drivers are loaded in the

enclosure. A front loaded woofer will start to exhibit a higher Q as the frequency wavelength approaches, and becomes smaller than, the diameter of the woofer cone. This effect is sometimes referred to as *beaming*. In Figure 3 is a DI chart for an Electro-Voice Fri 122/64, which is a 12" 2 way speaker with a 60 by 40 horn pattern. The crossover point between the LF and the HF is at 1.6 kHz. You will notice that at the crossover point and higher the DI increases because the horn is controlling the sound directivity. Below the crossover point, the DI starts to drop because the woofer does not have the ability to control the sound directivity.
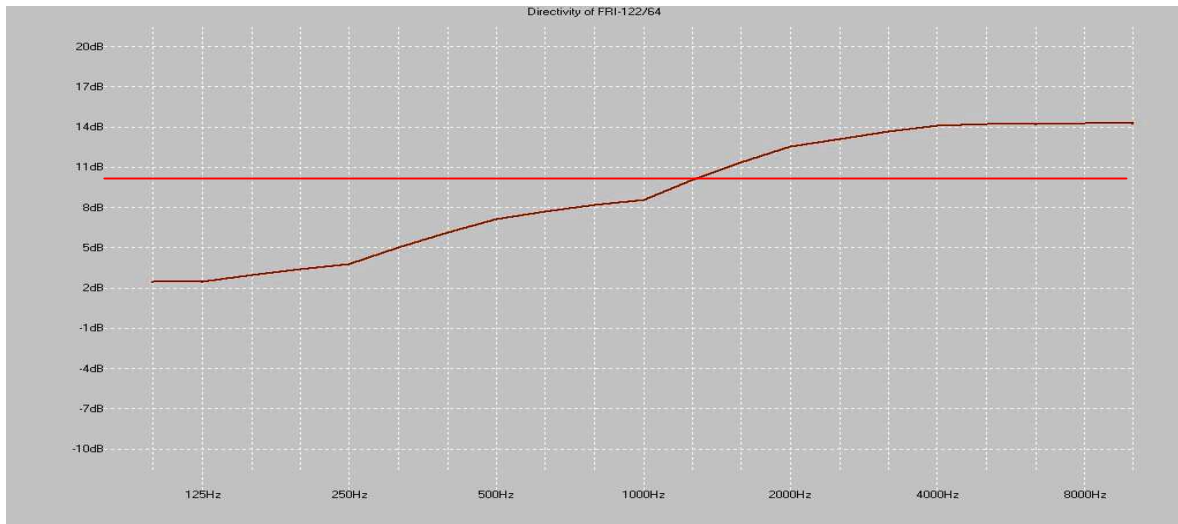

Figure 3

Figure 4 is a DI chart for an Electro-Voice MH4020C, which is a large stadium horn. It is a high Q device because of its dispersion pattern and its physical size, which gives it the ability to control directivity even at lower frequencies.
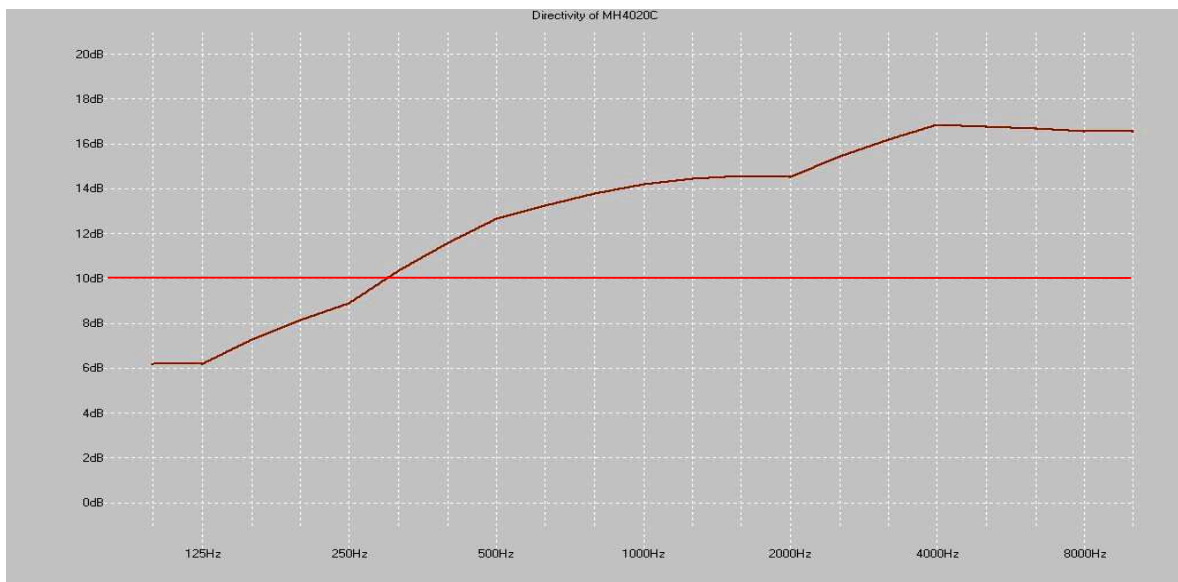

Figure 4

Figure 5 is a 3D rendering, done in EASE 4.0, of an Electro-Voice Fri 122/64 placed in the center of an 80' diameter sphere. The surface material is an absorber, so there will be little or no reflections to take into account. This picture is at 200 Hz. Notice that the directivity is virtually omni-directional.
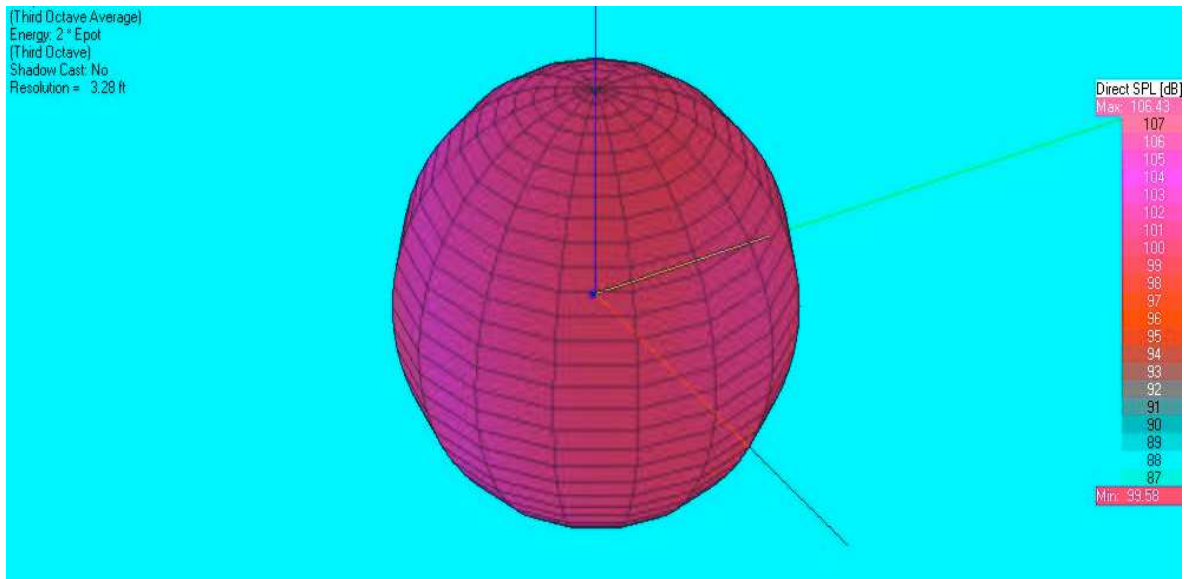

Figure 5

Figure 6 is the same speaker in the same sphere only this time at 4 kHz. Notice the difference in SPL from the area in front of the speaker versus the area behind it.
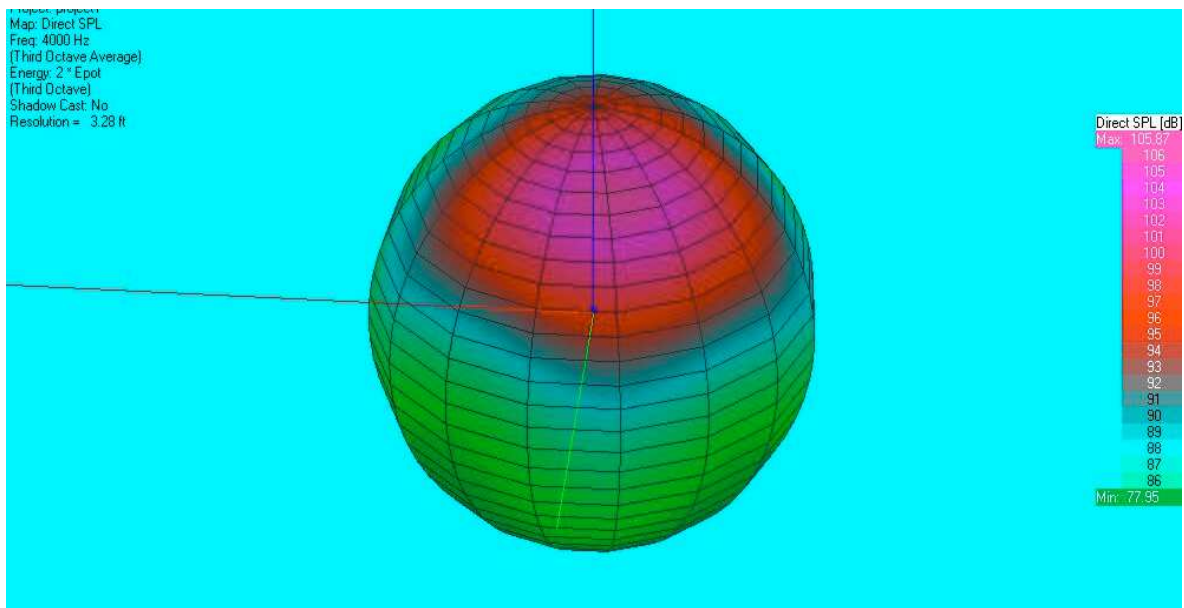

Figure 6

Figure 7 is a MH4020C in the same sphere at 200 Hz. Notice how much more focused the directivity is compared to the Fri 122/64.
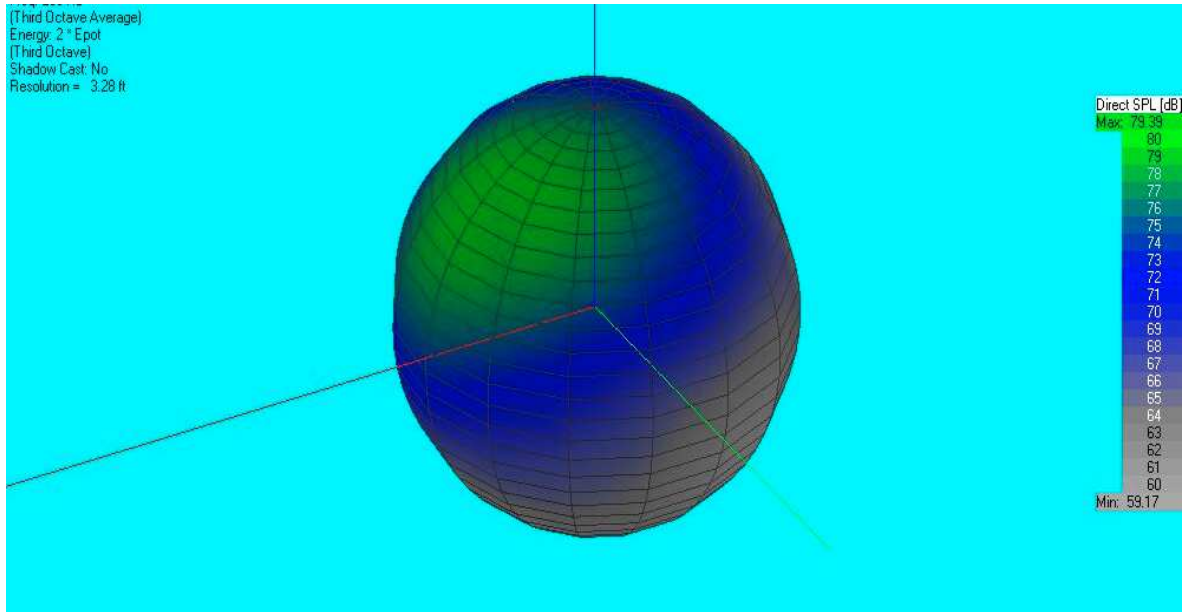

Figure 7

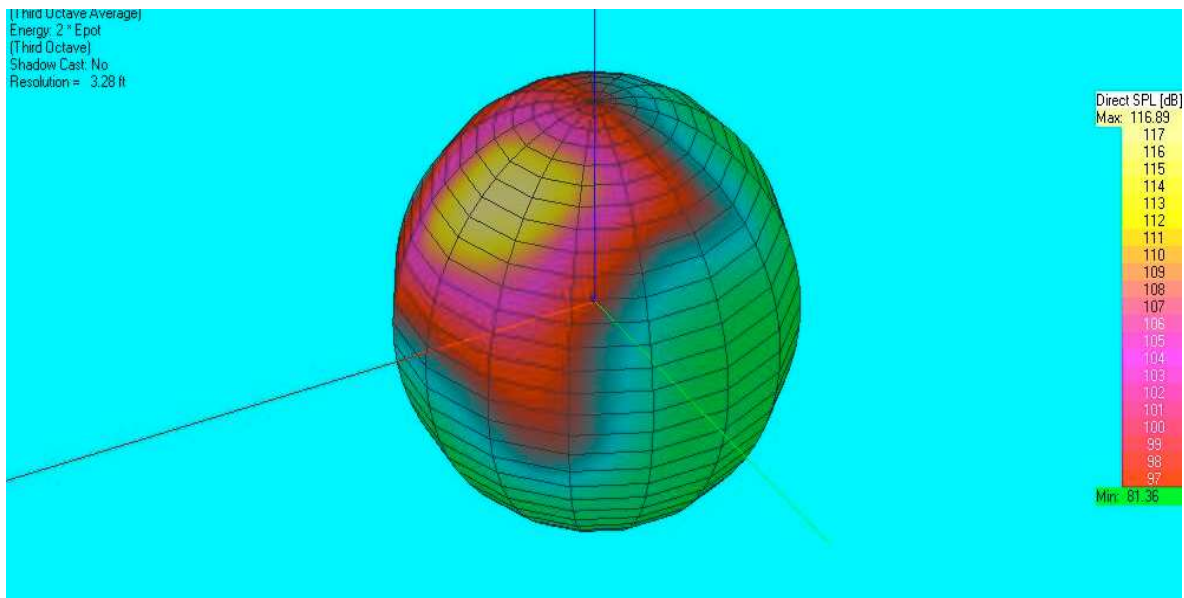Figure 8 is the same as figure 7, only this time at 4khz.

Figure 8

Sensitivity

Sensitivity is arguably the most difficult specification to understand and decipher from a specification sheet. Generally it will be stated as 1watt/1meter, measured directly on axis

with the speaker. The 1-watt of power comes from 2.83 volts applied to an 8-ohm load. If you see a specification that says 2.83volts/1meter, make sure that the speaker is 8 ohms. If it is 4 ohms with 2.83 volts applied, the reading will be 3dB higher, because that will actually deliver 2 watts of power. Being a higher sensitivity rating means that you get more output with less amplifier power, some of the other methods used in the audio industry have creatively altered this rating. Ideally, the rating would cover the speakers' entire bandwidth from the low frequency –3dB point to the high frequency –3dB point. This would give you an accurate rating. Some of the other methods will list a sensitivity rating at the speakers' highest SPL point in the frequency spectrum. This is not completely accurate, because that frequency band will probably be attenuated to smooth its response, effectively lowering the sensitivity.

By using the speakers' sensitivity rating, you can calculate the speakers' maximum output. There will be a gain of 3dB for every doubling of power. If we take a speaker with a sensitivity of 97dB at 1W/1M with a continuous power handling of 300 watts, we know that the maximum output at one meter will be 122dB. We can also determine what the peak output will be by multiplying the continuous handling of 300 watts by 4 to get 1200 watts peak power handling. The shortcut is to add 6dB to the maximum output at 300 watts. We now know that the peak SPL at 1 meter will be 128dB.

Inverse Square Law states that there is a 6dB of loss for every doubling of distance from a sound source. Using that information, we can calculate the on axis level of the speaker. Using the maximum output of 122dB at 1 meter, we can determine that at 2 meters we will measure 116dB, at 4 meters 110dB, etc.

Impedance

By definition, impedance is: *the opposition to current flow presented to the amplifier by a loudspeaker. Impedance is frequency dependent.* What this tells us is that impedance is more than just the electrical resistance that you would read by putting an ohm meter across the input terminals of the loudspeaker, this will only give you the DC resistance of the speaker. Impedance for an individual driver is the culmination of DC resistance, voice coil inductance, and the motional impedance (resistance, inductance, and capacitance from the driver in motion). Driver loading also affects the impedance. A compression driver mounted to a 40 by 20 horn will have a different impedance measurement than the same driver on a 90 by 40 horn. The same applies to woofers. A front loaded woofer will have a different impedance measurement than the same woofer that is horn loaded.

A loudspeakers' impedance rating is its *nominal* or average impedance. This means that there will be points in the impedance curve where the impedance is higher, and points where it is lower. Because of the impedance dip at certain frequencies, care must be taken when hooking multiple speakers to a single amp channel. Most pro audio amplifiers available on the market today are capable of driving a 2-ohm load. Connecting 4-8 ohm loads in parallel would be 2 ohms, but most 8-ohm loudspeakers will dip down to at least 6 ohms somewhere in their response. This will present an

amplifier with a 1.5-ohm load, which will either put it into protection, or cause amplifier failure.

There are a couple of simple formulas that will tell us what the impedance of multiple loudspeakers wired in parallel will be. The symbol for impedance used in formulas is **Z**, so this is what will be used in the following equations.

For 2 speakers there is a very simple formula that is easy to remember. It is the product over sum method:

$$Z= \frac{Z\,1 \text{ times } Z\,2}{Z\,1 \text{ plus } Z\,2}$$

So if we had an 8-ohm speaker wired in parallel with a 4-ohm speaker and wanted to know what the impedance (Z) was, it would look like this:

$$Z= \frac{8 \text{ times } 4 = 32}{8 \text{ plus } 4 = 12} = 2.66 \text{ ohms}$$

For 3 or more speakers the formula looks like this:

$$Z= \frac{1}{\frac{1}{Z} + \frac{1}{Z} + \frac{1}{Z} + \frac{1}{Z} + \frac{1}{Z}}$$

So if we had 2-8 ohm speakers, a 16-ohm speaker, and a 4-ohm speaker wired in parallel and we wanted to calculate the impedance presented to the amplifier, it would look like this:

$$Z= \frac{1}{\frac{1}{8} + \frac{1}{8} + \frac{1}{16} + \frac{1}{4}}$$

$$Z= \frac{1}{.125+.125+.0625+.25}$$

$$Z= \frac{1}{.5625}$$

$$Z= 1.77 \text{ ohms}$$

This last formula can be used to calculate any number of paralleled speakers. If you were going to remember one formula, this would be the one.

Pictured below is an impedance curve from an Electro-Voice FRX 640. Notice that there are a few impedance peaks, one reaching 70 ohms at about 3.2 kHz, and a dip centering at 125 Hz that is 5 ohms. The red line indicates 8 ohms.

FREQ_RSP   AMPL(V)   vs   FREQ(Hz)   31 JUL 91 11:54:04
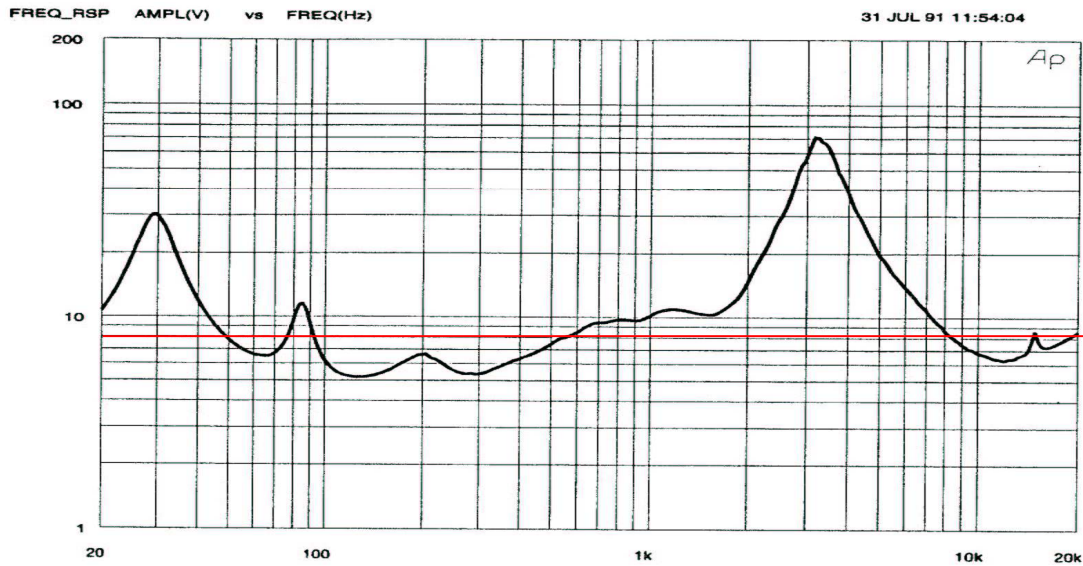
Hopefully this paper has helped inform you to make better decisions, and better understand a loudspeaker data sheet.

Stu Schatz
Electro-Voice Tech Support