Interpreting Loudspeaker Specifications

This material was originally presented as part of a 4 hour class during the technical training courses at the 1998 NSCA (National Systems Contracting Association) trade show in Las Vegas on April 27/98. It has been expanded upon in some areas for the website to include material presented verbally. This is a large file, and has many support graphics, to avoid large surprise downloads, we've configured this page to allow the graphic support material to be popped up in separate small browser windows. You need a JavaScript capable browser to view these pop-ups, and you can close the pop-up windows as you finish with them, or leave them open if your computer has the resources.

Impedance

Impedance, a pretty basic loudspeaker parameter, how much interpretation can there be?

1. Remember that a conventional ohm-meter measures the DC resistance, not the AC impedance. It is rarely enough to measure AC impedance at two or three discrete frequencies, the variations can be more substantial than that. Look at the impedance charts below and consider the magnitude of variations.

2. Look for an indication of whether the rated impedance is the "nominal" rating or the minimum impedance rating. This will be very important where devices will be connected in parallel, the amplifier will see the minimum, not the nominal load impedance when it is called upon to deliver high output in that portion of the bandwidth.

3. For raw drivers look for variations in impedance out of the usable bandwidth, this will affect the system behavior when used with a passive crossover. A passive crossover works by raising the impedance out of the usable bandwidth. If the driver impedance also rises at the same rate, or even faster, then the driver is not being attenuated as much as is expected. This especially critical where HF drivers are used with a passive crossover.

4. When a speaker system incorporates a 70V transformer, the impedance measurement should include frequencies between 0Hz to 100Hz. Many transformers drop to very low impedance values below their operating bandwidth and this may adversely affect some amplifiers.

5. The impedance rating may also have an affect on the sensitivity rating as we will see shortly.

These three impedance plots are from large format high frequency drivers mounted on their companion high frequency horns. Note that the variations near the low frequency cutoff of the horn are significantly different for each other, which will affect their behaviour when used with passive crossovers. Also note that most of these drivers that are rated for 16 ohms nominal, reach a minimum impedance of between 10.5 and 12 ohms in the middle of their operating range. Note too that the low frequency impedance ripples will vary with the horn the driver is mounted on, which is an issue in 300Hz voice warning applications.

View Impedance Graphs

56kB GIF's JavaScript Needed

Power Handling

Power handling is one specification that has been widely interpreted by various manufacturers. A variety of measurement methods has led to some lack of clarity as to the relevance of each rating.

1. Consider what the use of the device will be when investigating power handling specs. Will the loudspeaker be used at relatively low levels, or will it be used to generate high sound levels? Where the system will be used at low power levels for its typical operating level, the selection criteria will be less critical. Where the devices are likely to be used at consistently high levels, the issue of thermal and mechanical stresses make power rating criteria more important.

2. Continuous program power ratings are intended to give an indication of the power handling of the system when used with musical program material driven by an amplifier with that power rating. For a small foreground music system this may be relevant, but there are significant variations in program material energy levels, so this is not a reliable indicator of power handling when the device is likely to be used at consistently high levels, with large amounts of equalization, such as in dance club systems, or music reinforcement systems.

3. AES power ratings are a good indicator of thermal and mechanical survivability where the program material is generally uniform in its spectrum content. Because this measurement is based on long term 24 hour power handling, it will also incorporate the effects of the change in impedance that occurs with heating of the voice coil (power compression). This power rating may not disclose the mechanical limits of the device when used with highly transient signals.

4. Continuous sine wave has always been a good indicator of mechanical limits when used with signals that are relatively free of transients. The hard part has always been trying to relate sine wave power handling to real world signals such as music. It may still be applicable for musical instrument loudspeakers that are often producing more steady state pure tone types of signals.

5. RMS power handling always seemed to be based on different bandwidth and signal type, depending upon the manufacturer. It is always important to scrutinize the data to see what the parameters were.

6. When comparing power handling ratings between competing devices always check the following parameters:
    1. Bandwidth
    2. Signal type (pink noise, swept tone)
    3. Test duration in hours

Sensitivity Ratings

This is a common enough specification: 98dB @ 1w @1m measured 400-3000Hz with bandlimited pink noise, what's it all mean?

1. When looking at sensitivity ratings of loudspeakers always look at the bandwidth used for this measurement. Is the measurement range the same as the operating bandwidth (i.e. subwoofers being measured between 100-500Hz - not that relevant in the real world).

2. While most devices are rated for sensitivity at 1 watt at 1 metre, it always pays to confirm that, since the level difference between a 1 metre and a 4 foot sensitivity rating is 1.8dB, the 1m distance being higher by that amount.

3. Check to see how the 1 watt signal input was determined. If the measurement was based on the voltage needed to produce 1 watt at the rated (or nominal) impedance (i.e. 2.83 volts at 8 ohms), then the actual power delivered to the device may be higher through the measurement bandwidth if the minimum impedance is lower. A typical commercial LF driver may have a minimum impedance as low as 5.0 - 7.0 ohms through the 250-500Hz bandwidth, which would mean up to a 2dB advantage in the sensitivity specification. At higher power, the minimum impedance may rise closer to the nominal rating due to voice coil heating, but not in low power sensitivity measurements.

4. Compare the sensitivity specification bandwidth to the coverage in the same bandwidth. Is there any area of the spectrum where the coverage narrows drastically. If a high sensitivity rating is achieved because the device is

"beaming" because it becomes highly directional through a narrow segment of the spectrum, then the equalized sensitivity may be considerably lower.

5. The same consideration applies for sensitivity measurements in free space versus half space for low frequency devices. A LF device measured in free space will have a different sensitivity than one measured in a plane or baffle (half space). The variation will depend upon how large the device is, and how directional it is in the sensitivity measurement bandwidth.

6. When comparing competing devices, check to make sure that there is a common basis to the sensitivity rating in bandwidth, signal type and measurement conditions.

Power = $(\text{Voltage})^2$/ Impedance

Determine if the sensitivity rating is based on a specified signal voltage at either the rated or nominal impedance, it makes a difference. Where minimum impedance is lower than nominal, and the test signal bandwidth includes the minimum impedance point, it can skew the sensitivity rating.

$P = (2.83V)^2 / 8$ ohms = 1 watt

$P = (2.83V)^2 / 6.8$ ohms = 1.17 watts (+0.7 dB)

$P = (2.83V)^2 / 5.5$ ohms = 1.45 watts (+1.6 dB)

Quick check of ratio of impedance

10log (8 ohms / 6.8 ohms) = 0.7dB

10log (8 ohms / 5.5 ohms) = 1.6dB

Sensitivity, Power Handling and Output

Remember that sensitivity is only part of picture. Sensitivity combined with power handling will tell you what the maximum output level capability is. A high efficiency device with low power handling may not be able to produce as high an output level as a low efficiency device with higher power handling, and vice versa.

1. There are other factors that tend to change in the sensitivity/power handling tradeoff. Distortion will vary, and will tend to increase as output level and cone excursion increases. In general, a high efficiency device has the voice coil entirely within the voice coil gap at rest, which means that it has the maximum motor force

available through small excursions, but at longer excursions the voice coil starts to leave the gap which results in a non-linear drop in motor force, and non-linear distortion. A high linearity / low efficiency device has a long voice coil to maintain linear travel through long excursion, but only a fraction of the wire is in the gap at any time, so only a small amount of the total motor force is available. You need to match the device to your requirements for low distortion or high output, and integrate those requirements into the overall system design.

2. Bandwidth - Efficiency Product is something that generally applies to loudspeakers. Typically higher efficiency is available at the cost of extended bandwidth, and extended bandwidth is available at the cost of high efficiency. Basically what this saying is that there is no such thing as a free lunch, and a moving system has to balance the need for efficiency with the need for linearity. Even systems that seem to cheat by using dynamic or motional feedback to deliver linearity at higher excursions, if analyzed, will show that the extra negative feedback drops the true efficiency of the overall system. In the world of loudspeakers this means that very efficient all horn loaded speaker systems, require multiple devices operating over narrow bands. Wide bandwidth systems like studio monitors are seldom as efficient as a horn loaded speaker system.

Speaker 1

Sensitivity: 95dB @ 1 watt @ 1 metre

Power handling: 300 watts AES

300 watts is 24.8 dB above 1 watt

Max output: 95dB + 24.8dB = 119.8dB @ 1

Speaker 2

Sensitivity: 99dB @ 1 watt @ 1 metre

Power handling: 150 watts AES

150 watts is 21.8dB above 1 watt

Max output: 99dB + 21.8dB = 120.8dB @ 1

Speaker 3

Sensitivity: 90dB @ 1 watt @ 1 metre

Power handling: 1000 watts AES

1000 watts is 30dB above 1 watt

Max output: 90dB + 30dB = 120dB @ 1 metre

On-Axis Frequency Response (where the lucky few sit)

As strange as it may seem to think about, more people will sit off-axis than on -axis, so as important as it is to have smooth and extended on-axis response, it is only part of the picture, we'll cover the off-axis performance shortly. On-axis response is a common and important specification, and seems to enjoy a wide range of latitude in its interpretation by marketing departments.

1. What is the bandwidth, and most importantly what is the rated deviation in response in dB? It is important to qualify the difference between a device capable of producing the bandwidth with +/- 3dB of variation versus +/- 10dB of variation. It seems every loudspeaker produced in the past fifty years has been able to reproduce a bandwidth of 20Hz to 20kHz, but may in fact have variations of +/- 40dB. The bandwidth spec is of no value without the deviation stated.

2. Some manufacturers list "rated bandwidth" and "usable bandwidth". Usable bandwidth may indicate that the speaker can be used to reproduce that spectrum, but that it may not meet all the other specifications while doing so. Rated bandwidth should indicate that the loudspeaker can meet both power handling, distortion and coverage specifications through that bandwidth. The use of the term rated bandwidth is still open to interpretation by marketing departments, so you have to take that into consideration when reviewing specifications.

3. Look for smoothness in the overall response. Smoothness can come from two places, the engineering department or the marketing department, and sometimes it is hard to tell what the source is. You want to see smoothness from the engineering department. A smooth on-axis response means that the device is relatively free of coverage and mechanical anomalies. Make sure that the graph you are looking at has not been equalized or normalized as part of a family of off-axis response curves.

4. Look for large variations around the crossover points that may indicate a signal delay based problem between the LF and HF device, or may indicate less than adequate "knitting" together of the coverage between the LF and HF devices. The signal delay problems are not equalizable and

neither are problems with variations in directivity (more about that in a moment).

Off-axis response (where most people sit)

This is the area of speaker performance that affects the largest number of people, and also governs how well speakers behave when used together. As important as on-axis performance is, the off-axis areas within the rated coverage pattern, and beyond the rated coverage pattern have a huge impact on the system performance.

1. Look for the behavior of the frequency response off-axis. Check the performance out to the rated coverage angles and beyond the rated coverage. See the following pages of examples of off-axis response measurements of medium format and large format high frequency horns. In these graphs, the on-axis response has been equalized to near flat so that the off axis response just shows the variations in off axis performance. Note how the off-axis frequency response is different for the horns of different manufacturers. Are there large variations in the response off the center axis? Is the off-axis response much less uniform than the on-axis response, indicating beaming or coverage variations in the horn?

2. Check the polar response graphs to get an indication of how consistent and uniform the coverage pattern is with varying frequency. It is hard to get a clear idea of what is going on in the coverage without looking at both the polar graphs and the off-axis response curves. The polar charts will show some of the major coverage anomalies in the device. This is very important because you can't equalize for variations in directivity. This issue is covered in more detail in this article on **Loudspeaker Directivity as a Design Issue.**

3. Some of the computer modeling programs have the 3D coverage "potato" or balloons showing what happens between the horizontal and vertical planes. There can be some surprising variations in speaker behavior that are only visible with this type of view.

The button below will launch a browser window that will allow you to step through the horizontal and vertical off-axis response of three medium format and three large format horns. You can see the variations in response, and the differences between manufacturers as well. The GIFs range from 15kB to 54kB each so this may require some patience.

View Off-Axis Coverage

JavaScript Needed

2kHz Coverage Balloons and Isobars

Have a look at these two animated gifs showing the 2kHz coverage of a variety of loudspeakers. Pressing the buttons below will launch a new wiondow with the animated GIF in each. When you view the shape of isobars, have a look at the wild variations in shape of the red, yellow and green isobars which are the -3dB, -6dB and -9dB isobars. Note that the green isobar is significantly different in shape than the -3dB and -6dB patterns. Keep in mind that -9dB would be subjectively perceived as half as loud, so even though you're pointing the speaker based on the -6dB coverage, the -9dB coverage of each speaker is influencing the performance and behaviour of your sound system.

View 2kHz Balloons

108kB animated GIF

View 2kHz Isobars

54kB animated GIF
JavaScript Needed

Coverage Angle (is that Fahrenheit or Celsius degrees?)

Coverage angle is typically defined as the -6dB points in the coverage of the speaker system. The only problem is that there can sometimes be more than one set of -6dB points, especially if there are multiple lobes in the coverage. Coverage angles are often specified with a huge latitude of variation, you can find ratings like: horizontal coverage 100° (+/- 60°). What does this mean to the speaker user?

1. Look for consistency in the polar response plots through the rated bandwidth. If it is a HF horn, the loss of directivity should be smooth and progressive as the test frequency approaches the low frequency cutoff of the horn. At high frequencies, the coverage should maintain the horizontal and vertical coverage angles up to the highest usable frequency.

2. In full range or multi-way systems, look for smooth coverage pattern transitions through the crossover regions. In three/four way systems check that all the devices actually can deliver the same coverage. Remember you can't equalize for variations in directivity or coverage. Just because you aren't "using" the sound that isn't pointed at your target doesn't mean that the "spillover" isn't going somewhere.

3. The off-axis response and polar patterns are the key to

grouping loudspeakers in a cluster. The interference between devices will have a huge impact on the cluster performance.

Coverage Angle vs. Frequency Graphs

Another way to look at the even-ness of coverage angle is to view the Coverage Angle vs. Frequency graphs. These graphs show two things at a glance:

1. They quickly show how close the device meets its own rated coverage angles over its rated bandwidth. If the horizontal and vertical angles only approximate or average the rated coverage, then you know the off-axis response will be all over the map.

2. This graph will also give you a good idea of how the device achieves it's rated Q or Directivity Factor. If the device only meets its rated coverage in one plane (say the horizontal plane), and then perhaps drastically narrowing its vertical coverage at higher freqiencies, but losing vertical coverage control at lower frequencies (like old radial or sectoral horns), then you know that it won't be suitable for environments that demand tightly controlled Q or highly directive devices to avoid exciting the reverberant field.

View Coverage vs. Frequency

70kB GIF's JavaScript Needed

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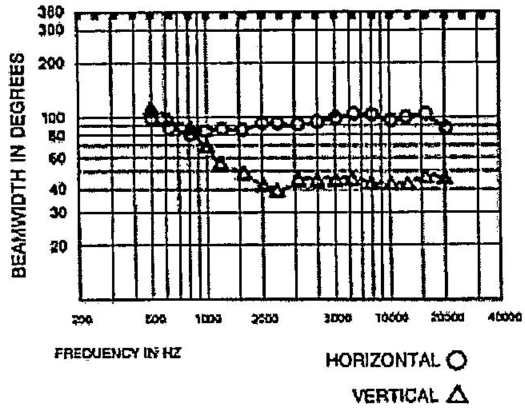
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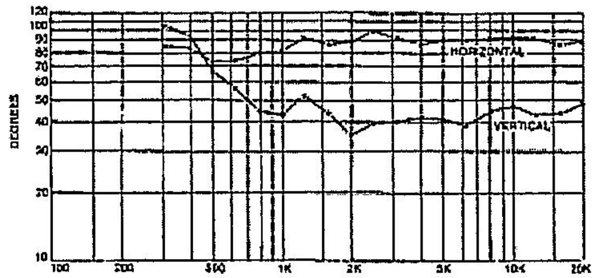
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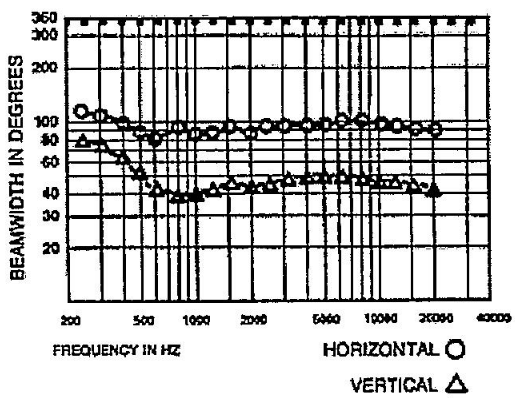
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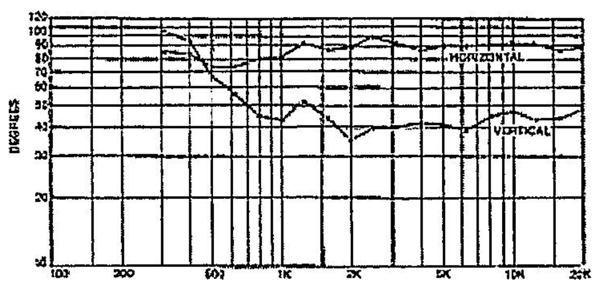
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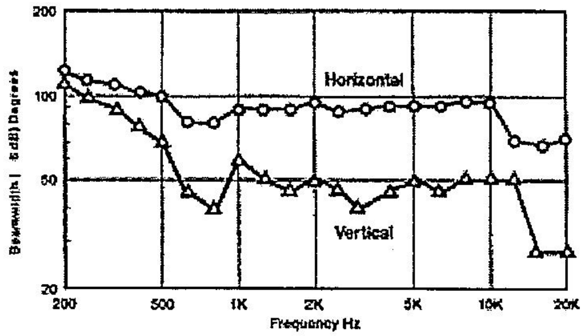
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