Subject: Re: Basshorn Size
Posted by Wayne Parham on Thu, 23 Aug 2007 19:43:18 GMT
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Hoffman's Iron Law states that the efficiency of a woofer system is directly proportional to its cabinet volume and the cube of its cutoff frequency. What this means is the most powerful subwoofer systems are necessarily large.What this formula says is you can reduce bass bin size only if you are willing to sacrifice efficiency or low frequency cutoff, or a compromise of the two. If you want deep bass from a small subwoofer system, you have to sacrifice efficiency. If you want high efficiency from a small package, you have to sacrifice deep bass and live with a higher cutoff point.Don't dismiss Hoffman's Iron Law as some sort of generality or "rule of thumb". The formula was written by physicist Anthony Hoffman of KLH loudspeakers. It was later adapted by A.N. Thiele and Richard Small to create the now standard Thiele-Small parameters that describe loudspeaker properties.Since there is a relationship between size, efficiency and cutoff, it doesn't make sense to say any one implementation is "better" or "worse" than another. If you need deep bass in a small package, it makes sense to use a loudspeaker of reduced efficiency and use more power to drive it. Or if you need a lot of acoustic power for an outdoor concert, maybe a loudspeaker that offers high efficiency in a larger package makes more sense.What doesn't make sense is sales rhetoric that promotes a small subwoofer product as being a "magic bullet", smashing a competitor's larger product offerings in SPL and low frequency cutoff.Assuming two subwoofers are of the same basic type and neither is grossly mis-configured, you can expect comparisons between them to track Hoffman's formula very closely. If one subwoofer is larger than the other, then the larger one will have higher efficiency or deeper cutoff, or some proportion of the two.If one subwoofer is exactly half the size of another, you can compare two of the smaller sized systems with one of the larger. In this case, Hoffman's formula predicts similar performance either way. Efficiency and low frequency cutoff should be about the same, assuming similar configurations. If one is tuned for higher cutoff, it will have slightly higher efficiency but if both are tuned for the same cutoff, efficiency will be the same and vice versa. Again, this assumes that neither one is grossly misconfigured or has a lot of wasted space.An intuitive reaction is to think that multiple woofer drivers can be employed or other techniques that would give one system an edge. The thing is, a box that's perfect size for one woofer is probably too small for a group of them. Just adding drivers to a cabinet (direct radiating or horn) won't necessarily make a positive change. This can actually cause a misconfiguration that tips the scale and reduces subwoofer efficiency. Likewise, you can't narrow horn passages in an effort to "make more horn" in the same space. This can give bad results too.There is a sort of continuum of configurations, from narrow-band resonant systems to wide-band systems. Most tend to think of bass-reflex and transmission lines as resonant systems, with horns being more like wide-band resonators. But there really is a continuum of alignments, with lots of good configurations in between horns and reflex boxes or transmission lines.Basshorn or Transmission LineBass reflex cabinets are usually small to medium sized because they simply use a Helmholtz resonator to tune the cabinet. The woofer operates as a direct radiator over most of its operating band. The Helmholtz resonator is employed at the lowest frequencies and it serves to increase system efficiency over a very narrow band at the bottom end of system response. The resonator decreases excursion at the tuned frequency and increases efficiency, but its effects are felt only over less than half an octave.Likewise, transmission lines or tuned pipes are usually moderate in size because they

woofer in a transmission line operates as a direct radiator except at the narrow band where the pipe resonates. The pipe has no effect at frequencies other than odd wavelengths, and the next

mouth area large enough to operate over a wide bandwidth. If the expansion from throat to mouth isn't big enough, the device acts like a tuned pipe and resonates at odd wavelengths. Only a horn with enough mouth area is able to provide loading through the band without developing peaks at harmonic multiples, like a pipe.Bandpass boxes and pipe/horn hybrids make up a middle ground between resonating cabinets and wideband horn cabinets. Bandpass boxes use multiple tuned Helmholtz chambers which provide more efficiency than a reflex box does. Pipe/horn hybrids also use multiple resonators to increase efficiency greater than that of a traditional tuned pipe. Both techniques use multiple resonators. The bandpass design is pretty straightforward with Helmholtz resonators that are easy to see. The pipe/horn hybrid employs multiple standing wave resonances usually defined by driver position or by internal passageways within the pipe aligned to standing wave nodes.Back to basshorns, one has a dilemma with regard to size. If a basshorn is small, you have one of two choices. You can either make its cutoff rather high, in which case you have enough room inside the box to develop enough mouth size to support the horn. In this case, response is good and the horn is efficient. The other possible choice is to try and support a low cutoff frequency, in which case you cannot provide enough mouth size to support the horn. Efficiency suffers and response is peaky.In my way of looking at things, the too-small-basshorn tuned low is a non-viable device. I would never design such a thing. However, in fairness, if several such devices are used together in a group, the horn system may have enough total mouth area to support the deep frequency of each individual horn's path length. This is a workable solution. It should be noted, however, that this is in no way a superior solution in terms of efficiency or size. Hoffman's Iron Law shows us that efficiency is directly proportional to cabinet volume. If the two systems are the same total size and have the same cutoff frequency, then you can expect efficiency to be the same too.The downside to the undersized basshorn is it cannot be used individually in small venues. This is a huge deficit, in my opinion, because the whole reason people want small basshorns is they want a package that's easy to carry and setup in smaller environments. In larger venues, if you're carrying a truckload of these things, you would expect to have truck ramps and load out is probably easier rolling down a few large basshorns than carrying a whole bunch of small ones. So if you have to use a large number of small basshorns to get good response, I'd say it was a non-viable design.On the other hand, a small basshorn with a higher cutoff frequency is definitely worthwhile. Or a small horn/pipe hybrid, something that offers deeper cutoff at the expense of reduced efficiency. These are both preferable, in my opinion, to an undersized basshorn with peaky response. Both can be used individually or in small groups in small venues, or they can be used in greater numbers to increase efficiency by increasing size.One last thing. This kind of goes without saying, but I've found that even though audio isn't rocket science, it's sometimes better to make mention of things that seem to "go without saying."There comes a point of diminishing returns with respect to efficiency. You can't ever exceed 100%. In fact, you can't even reach 100%, only approach it.Don Keele showed that the maximum nominal efficiency of a loudspeaker is 50% and the maximum true efficiency is 100%. Maximum efficiency occurs at resonance. In the absence of mechanical losses, the maximum nominal efficiency of a horn occurs when the reflected acoustic load resistance equals the driver’s voice-coil resistance. The maximum true efficiency occurs when the reflected acoustic load resistance is much higher than the driver’s voice-coil resistance. To maximize the driver’s broad-band true efficiency, the Bl force factor must be increased as much as possible, while jointly reducing moving mass, voice-coil inductance, mechanical losses, and front air chamber volume. Higher compression ratios will raise high-frequency efficiency but may decrease mid-band efficiency. Not really something you want to do in a basshorn, which "lives" mostly in the area where reflected acoustic load is still reactive.The careful designer juggles these parameters to optimize his design, but the bottom line is that maximum efficiency is somewhere between 50% and 100%. You can optimize the system as much as you want, and stack as many basshorns together as possible, and you'll never exceed this limit. So when discussing basshorn systems, you can't really say one type is leaps and bounds better than another, assuming neither is grossly misconfigured. You can't increase efficiency above 100% and there is no magic bullet that defeats Hoffman's Iron Law.