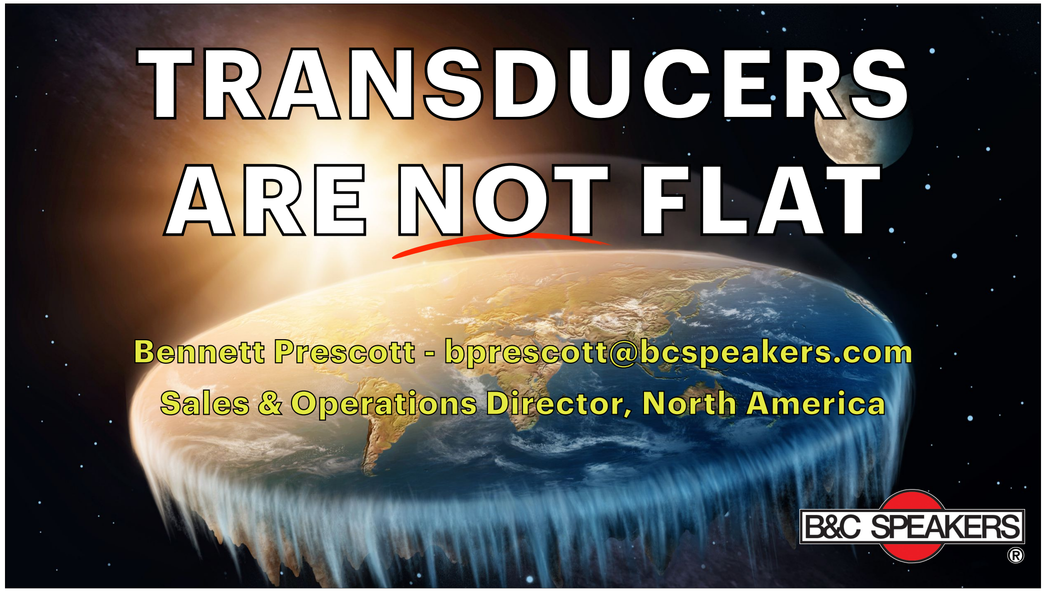
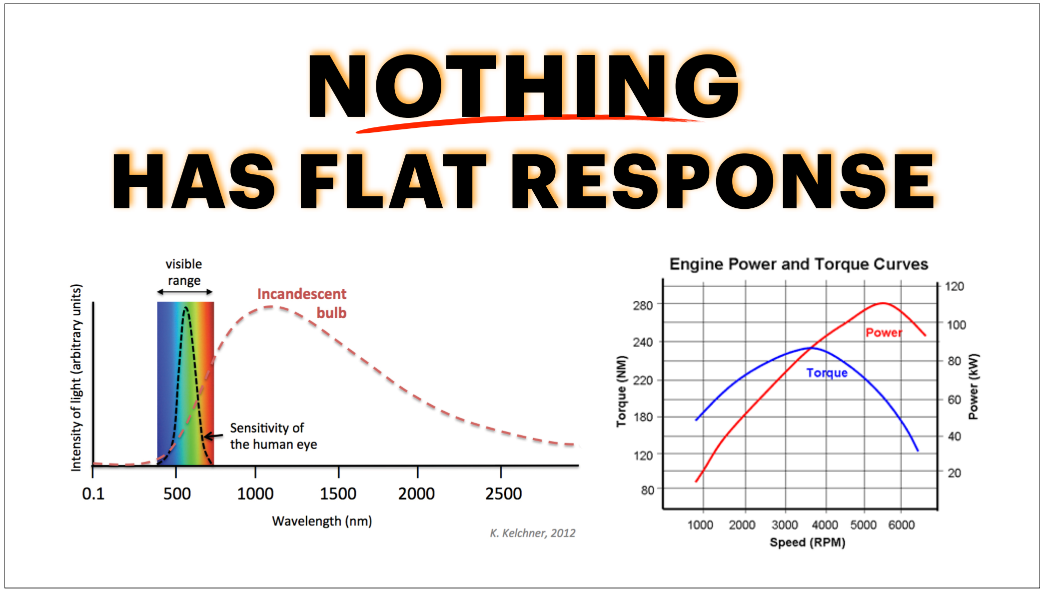


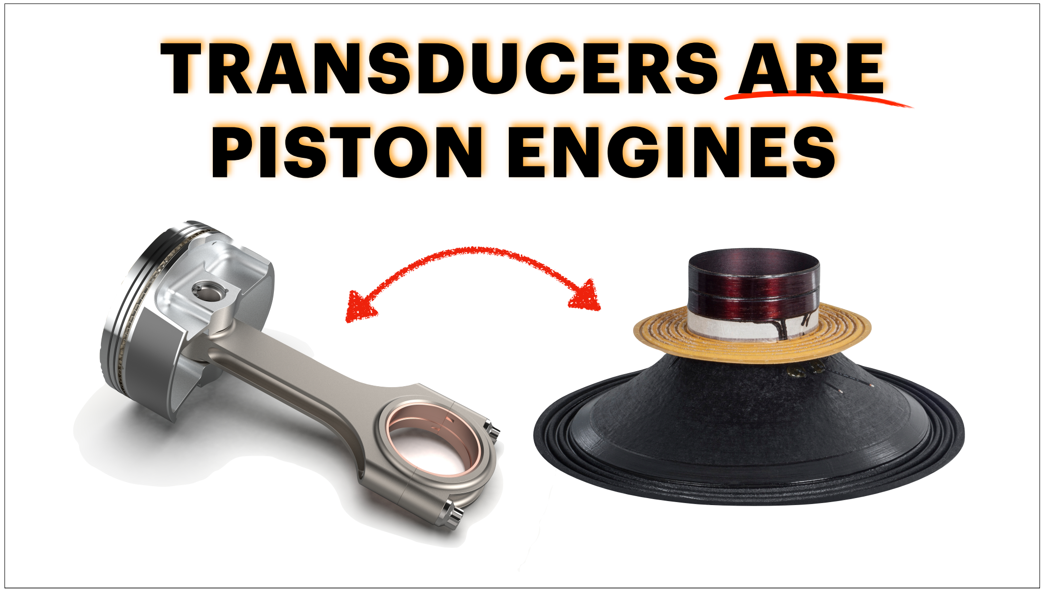
Introduce self, position, and topic: Transducer frequency response.

Transducers aren't flat, and you don't want them to be.

Appear that way because of a series of cosmic coincidences.



Note the shape of these curves, engine torque especially.
If you don't see this response, wonder why (or adjust your measurement axis).



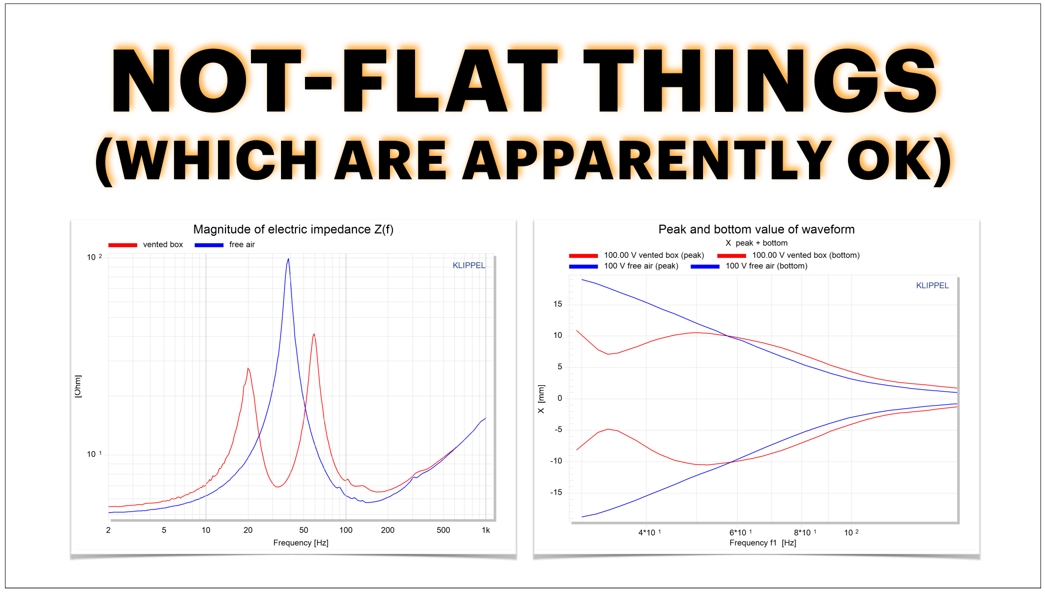
Mechanical systems (e.g. engines) don't have flat response.

As RPM increases, same torque is applied more times per second: More power!

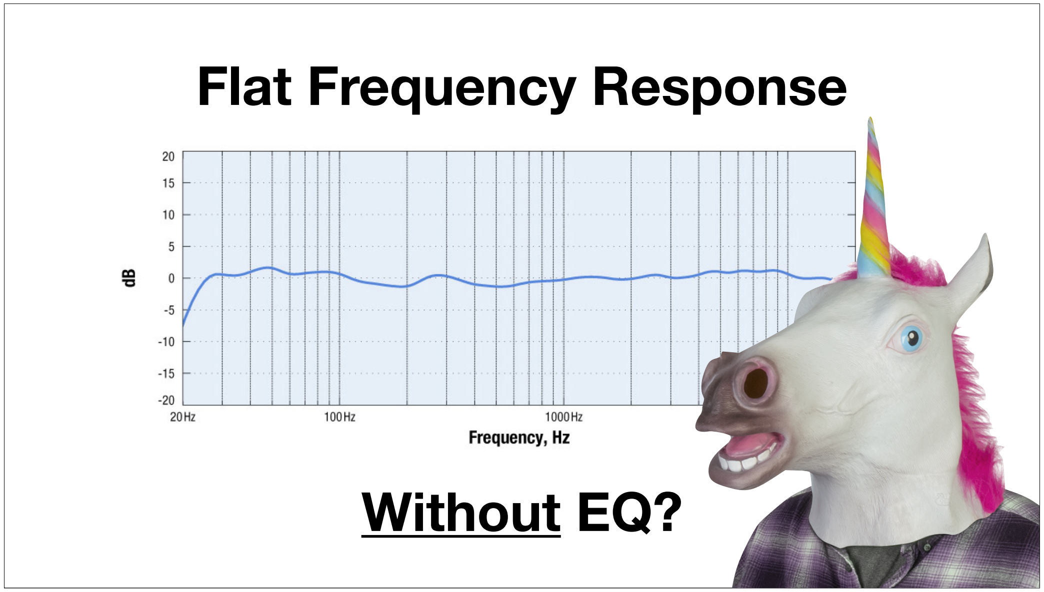
Can only go so fast, until moving parts mass / friction is too much.

This is why race cars have such high horsepower. Toyota RVX-06 F1 engine: 2.4L V8, makes 740 HP @ 18K RPM!

Exotic materials and costs to push higher output, usually only last one race.



Impedance, excursion, efficiency, inductance, acceleration, directivity: not flat.
Nobody asks me about flattening these parameters.
Managing these parameters is part of the <u>system</u> design process.



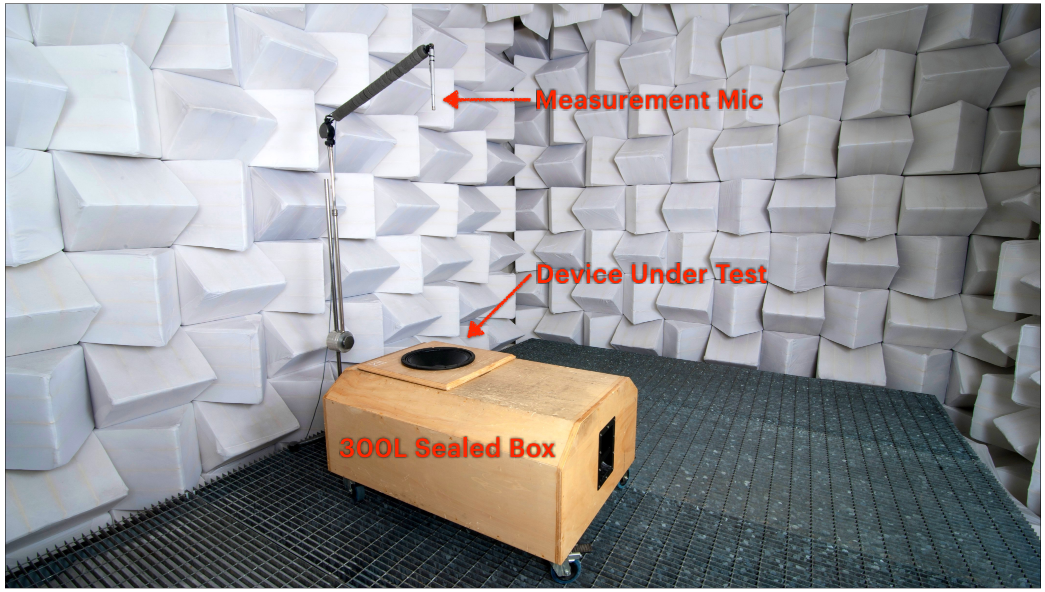
Do changes to make loudspeaker response flatter improve performance?

No. Effects which make raw response seem flat are mostly to be avoided, not encouraged.

This thinking treats transducer like its main job is to be an equalizer, when in fact it's to push a piston.

A speaker which is durable *and* high efficiency *and* has flat un-processed response is a unicorn.

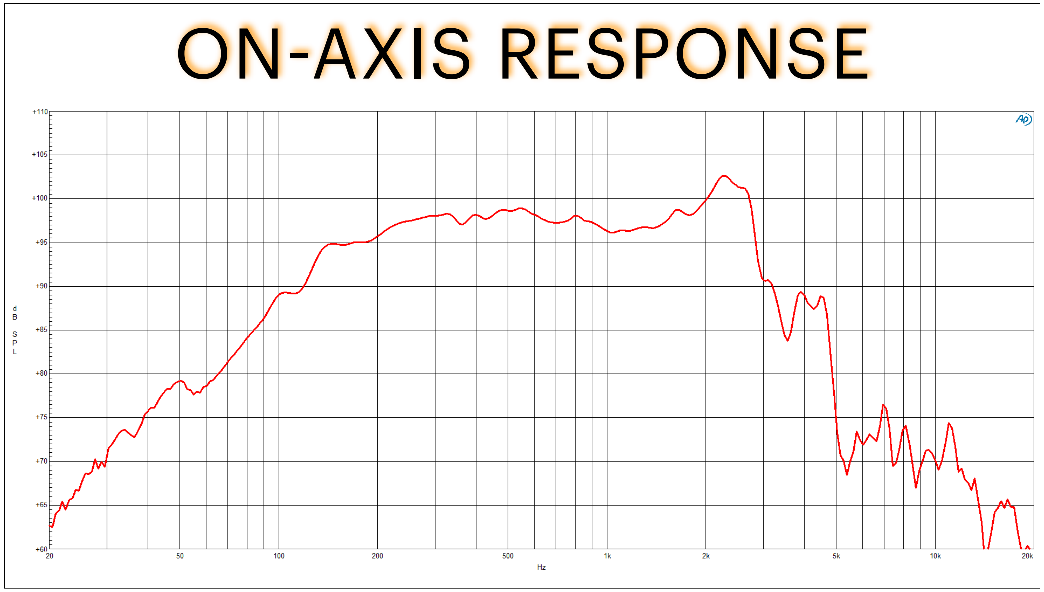
ACOUSTIC MEASUREMENT



How are spec sheet measurements taken at B&C?

Anechoic response on axis at ≈1M.

300L sealed box with beveled edges per Olsen's "Acoustical Engineering" ca. 1951.



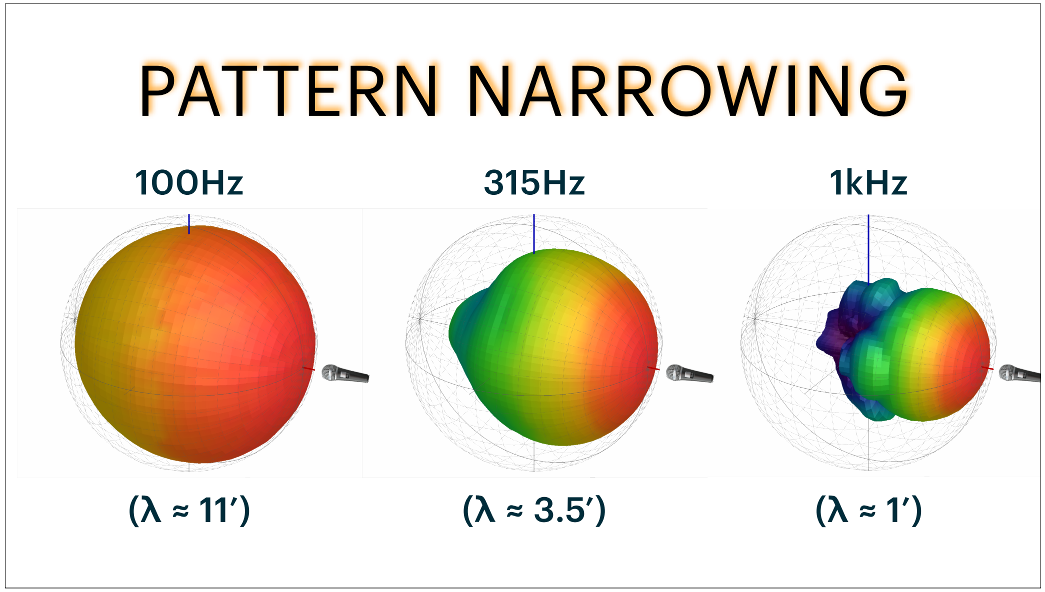
Result looks something like this (12FW76).

Looks relatively flat, but why isn't it *more* flat?

- What's with the peak at ≈2.5kHz? Why so rolled off <100Hz?
- Is this good? What results should we expect?

EFFECTS TO CONSIDER:

- Measurement is in Sealed Box
- Pattern Narrowing
- Soft Part Modes
- Cone Mass (sets HF limit)



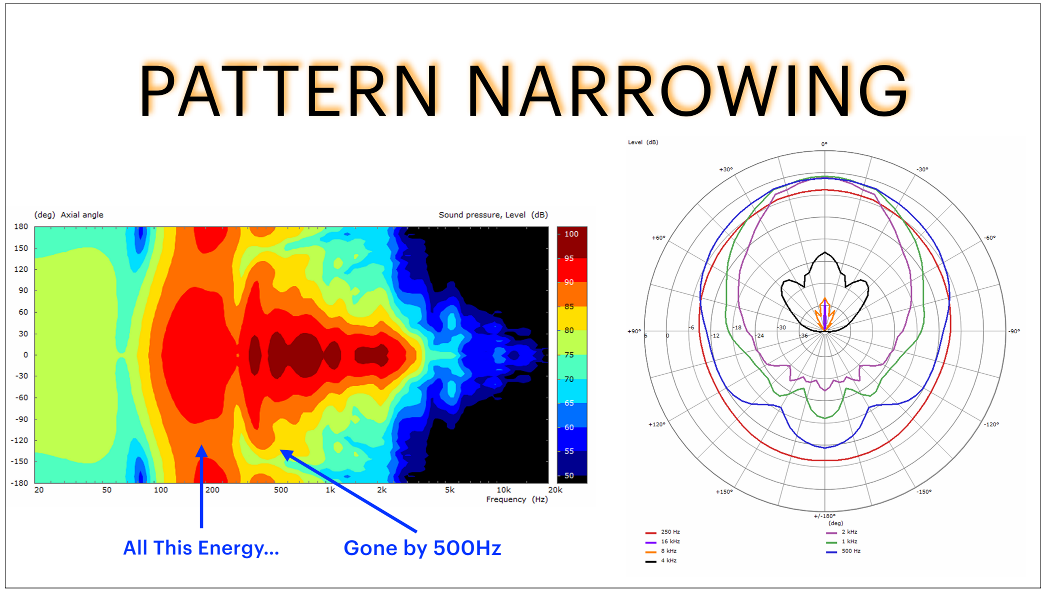
Transducer becoming large relative to wavelength.

<u>On-axis</u> energy stays similar as pattern narrows.

<u>Off-axis</u> there's a lot of "pie" missing for the same power going in.

Flashlight analogy: Spot on the wall gets the same illumination from a floodlight, a flashlight, or a laser.

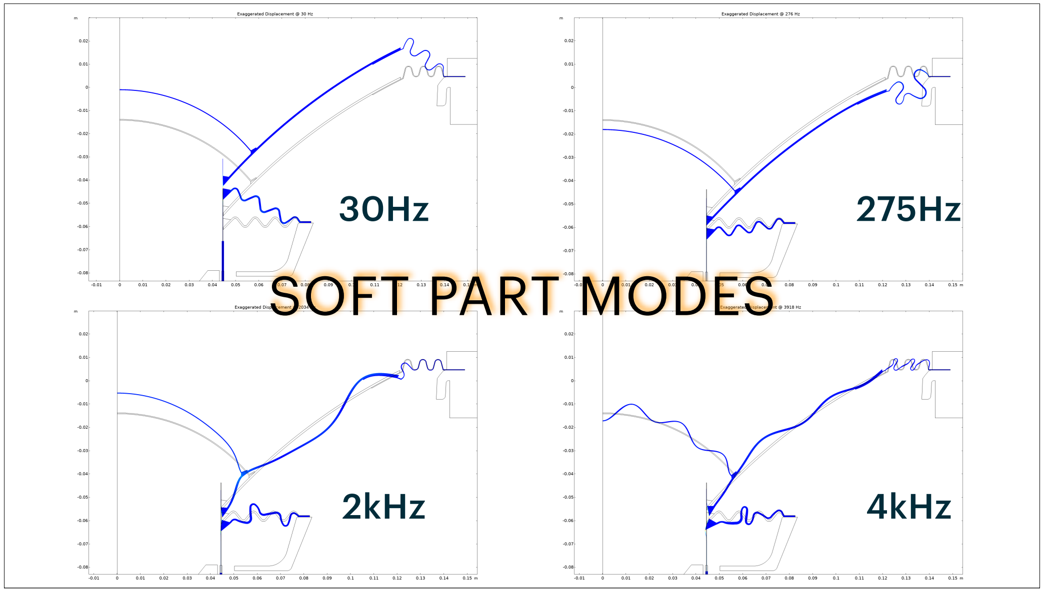
Floodlight illuminating a lot more of the room, putting out a lot more power.



Other ways to look at the same effect.

±60° at 1kHz, ±30° at 2kHz, ±10° at 4kHz

All that energy is gone, the woofer is getting <u>very inefficient</u>!

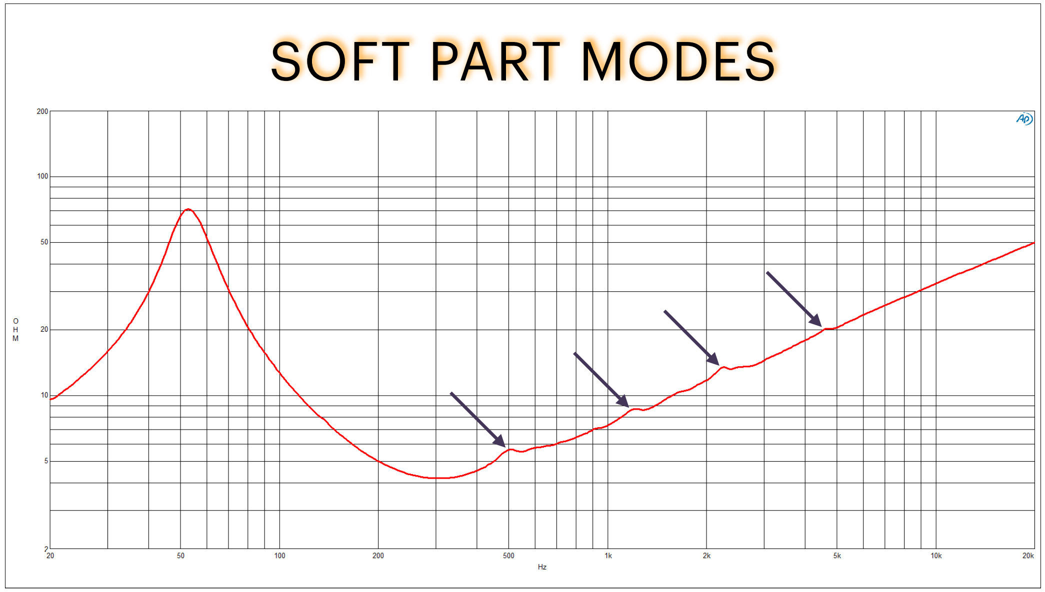


<u>Highly</u> exaggerated simulation of 12” woofer displacement (not to scale!)

Frequencies chosen to highlight problems - worst cases.

Can be improved with damping / ribbing / materials… for a while.

More problematic in larger woofers.



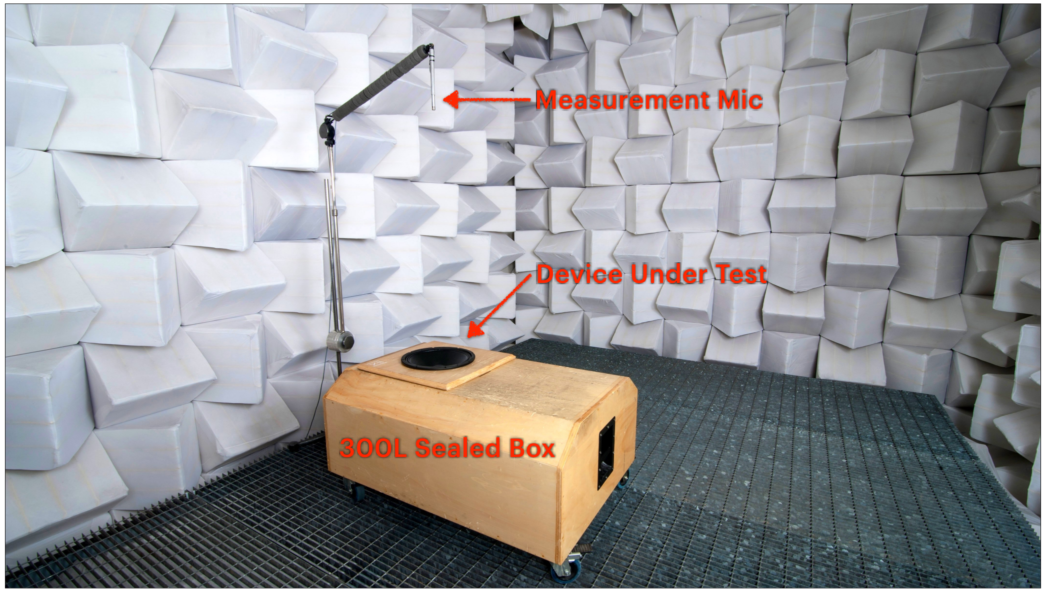
Modes from simulations on previous slide can be seen in impedance response.

This is a 12” and problems begin to show up at 500Hz!

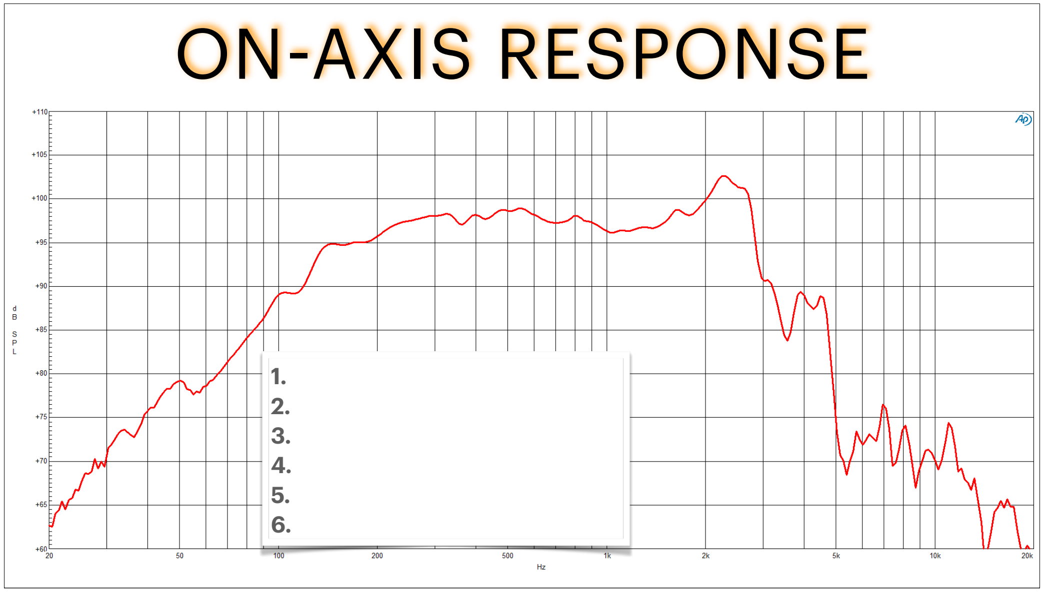
Notice they’re spaced an octave apart. Good indicator of 2D+ problem.

Note 10x impedance bump @ Fs, and steady rise from inductance.

FREQUENCY RESPONSE

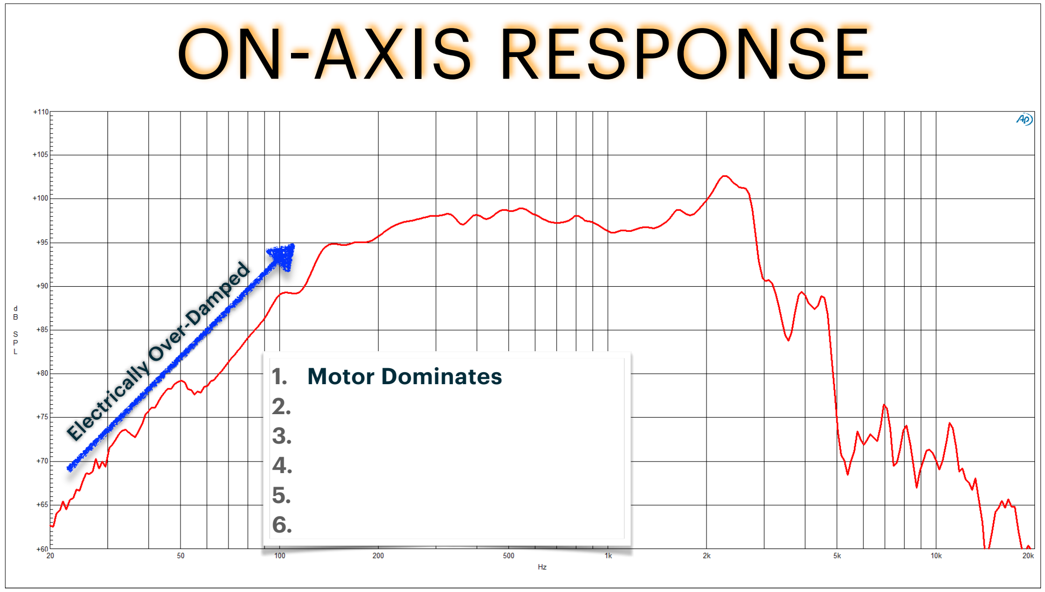


Response is only considered on-axis, rest of sphere not measured.



Go through frequency response measurement one step at a time.

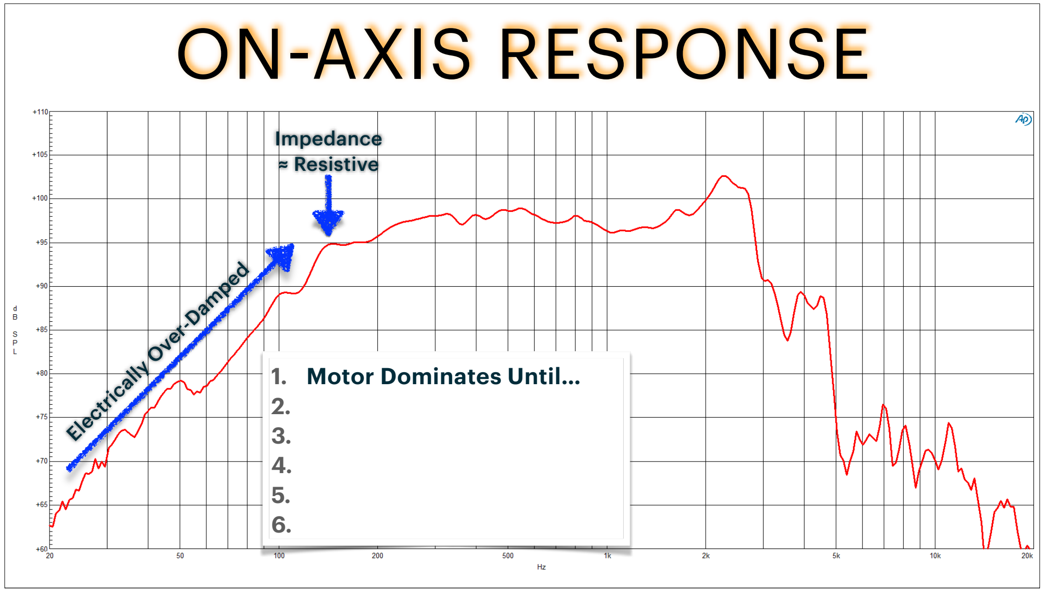
Why is the response shaped this way?



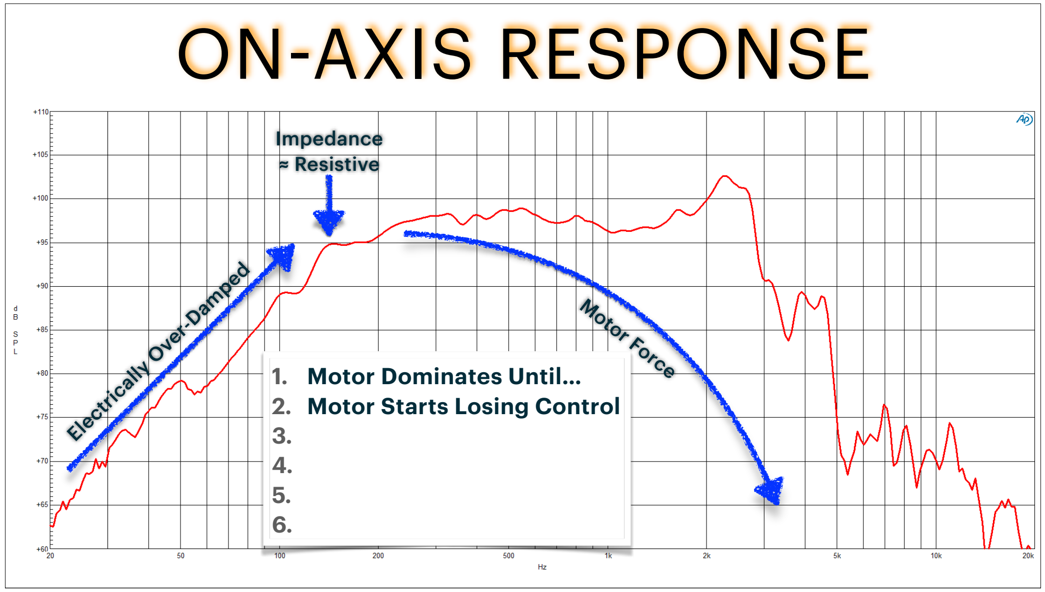
Electrical system is in complete control within an octave or two of resonance.
Response driven by radiation impedance, which rises at 12dB / octave.

Wavelength gets smaller with respect to cone, so coupling increases.

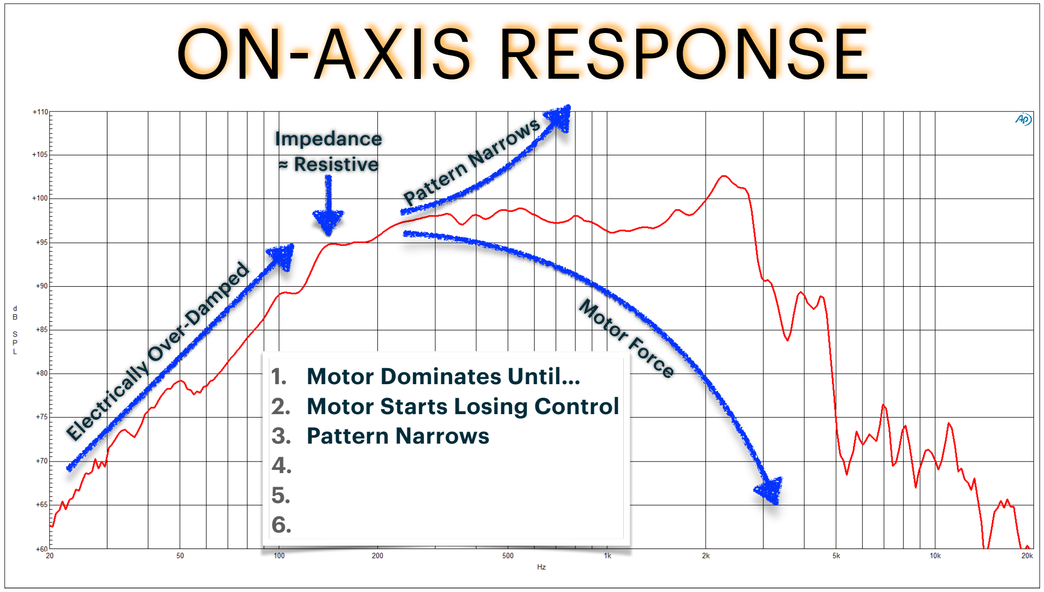
Like the air is steadily getting easier to push against.



Impedance close to resistive - around Zmin.
Response no longer affected by primary resonance and its damping.
Loudspeaker behaves like simple models.



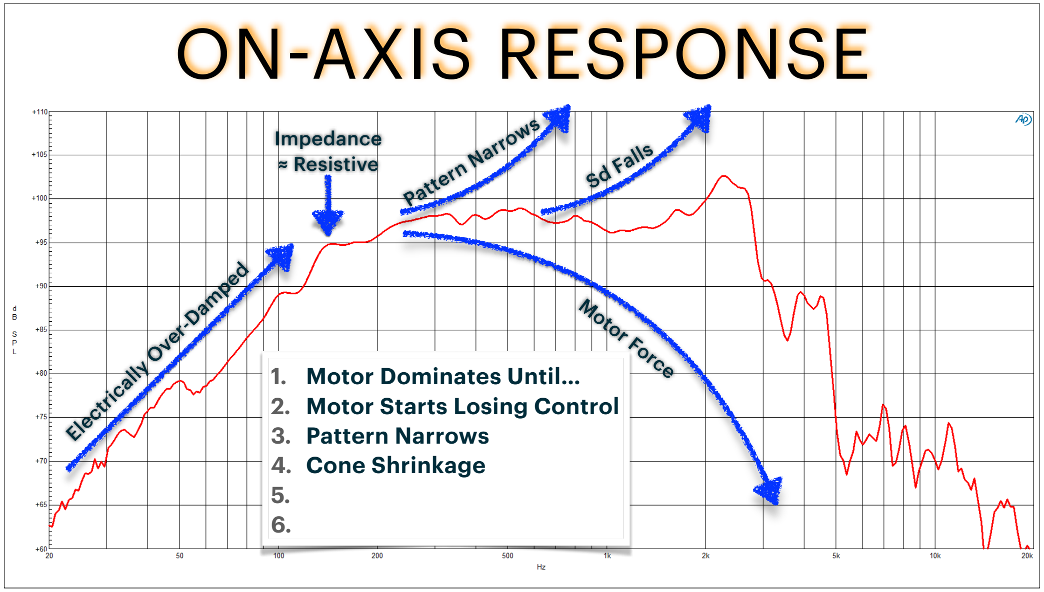
Motor force declines as it can’t keep up with required acceleration at constant input voltage (e.g. 2.83v).
Exacerbated by impedance rise.
Curve would look different with constant current, but that’s not how we measure transducers.



Pattern narrowing as woofer becomes (acoustically) large.

Remember that flood light? It's becoming a laser.

"Visible" effect of increasing radiation impedance.



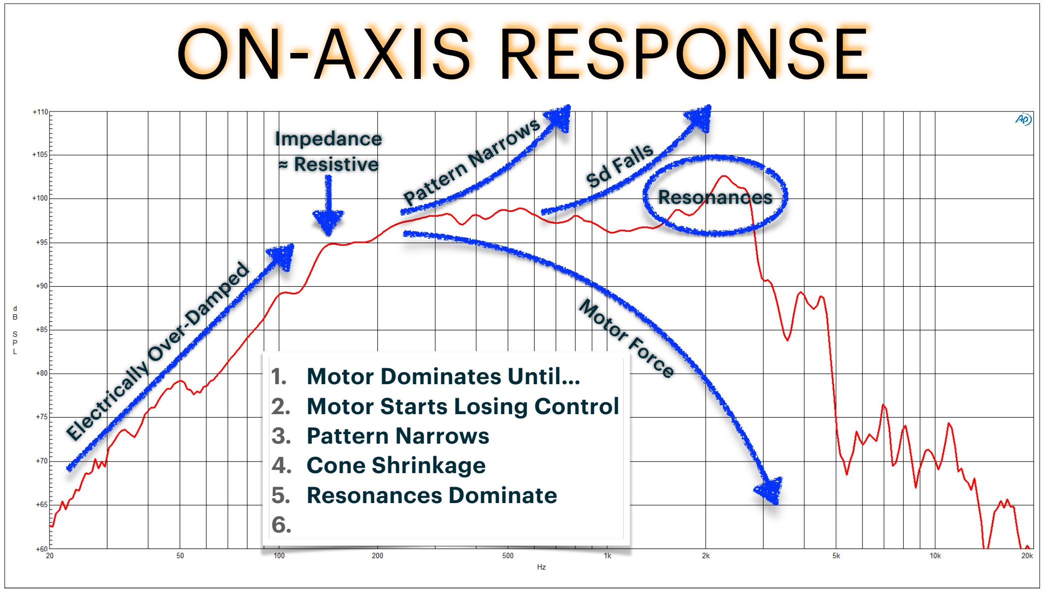
Soft parts not working completely together any more, synchronous area reduced.

Pattern collapses faster as modes out of phase off axis.

Still looks OK on-axis as modes mostly cancel each other out - like in a ribbon.

Cone working better near coil & dust cap (where it is strongest) that at perimeter.

Non-linearities begin to have sonic consequences.

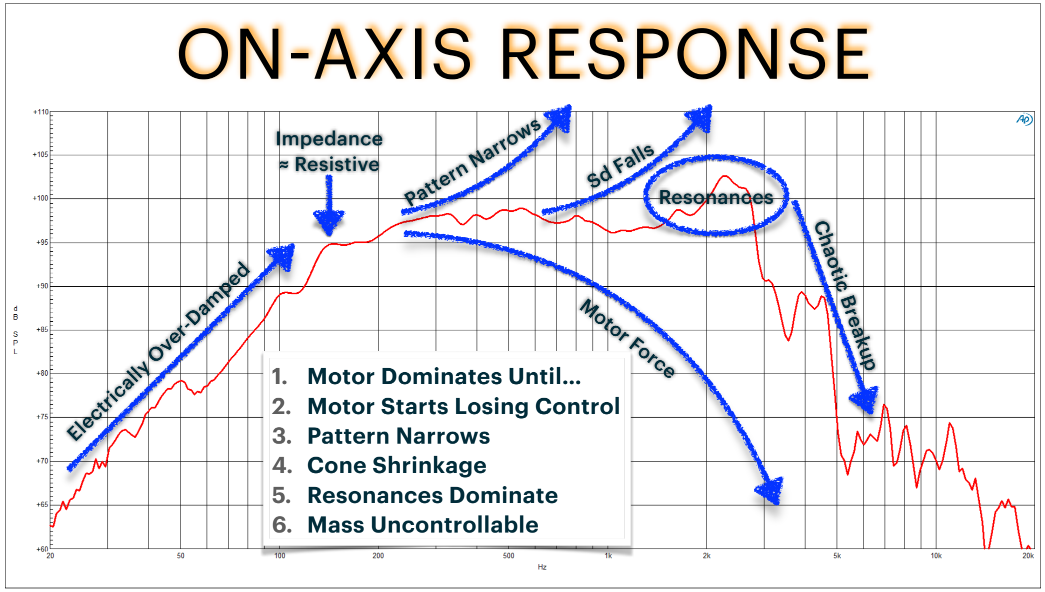


Last octave of response dominated by resonances in cone, surround, spider, even voice coil.

Very notchy response as time domain effects dominate.

Sounds bad. Waterfall plot a disaster. Avoid this region.

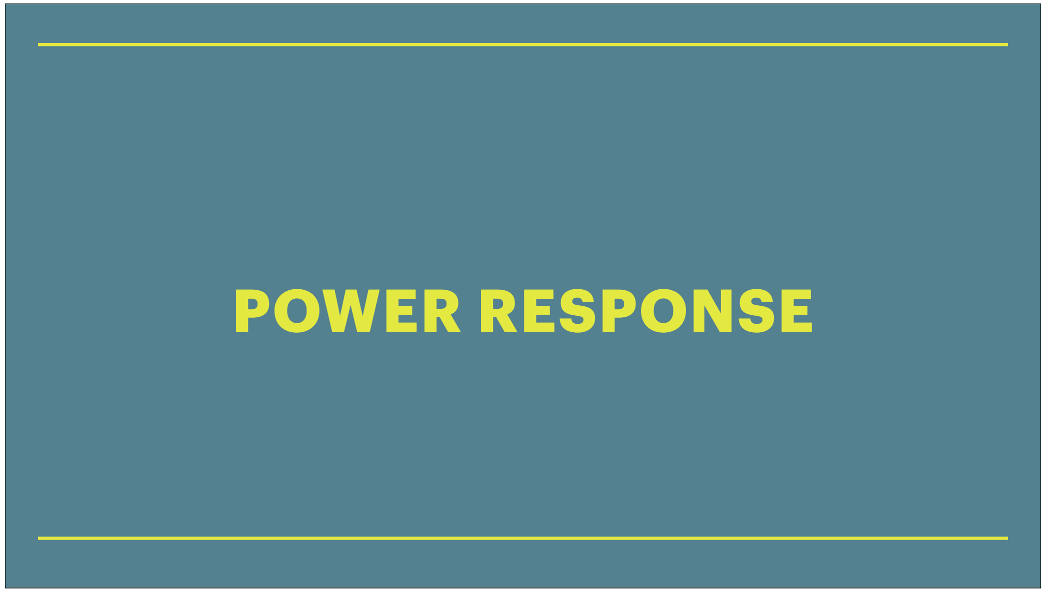
Not always so clear: Cone mass rolloff can mask. In small woofers, can be quite spread out.



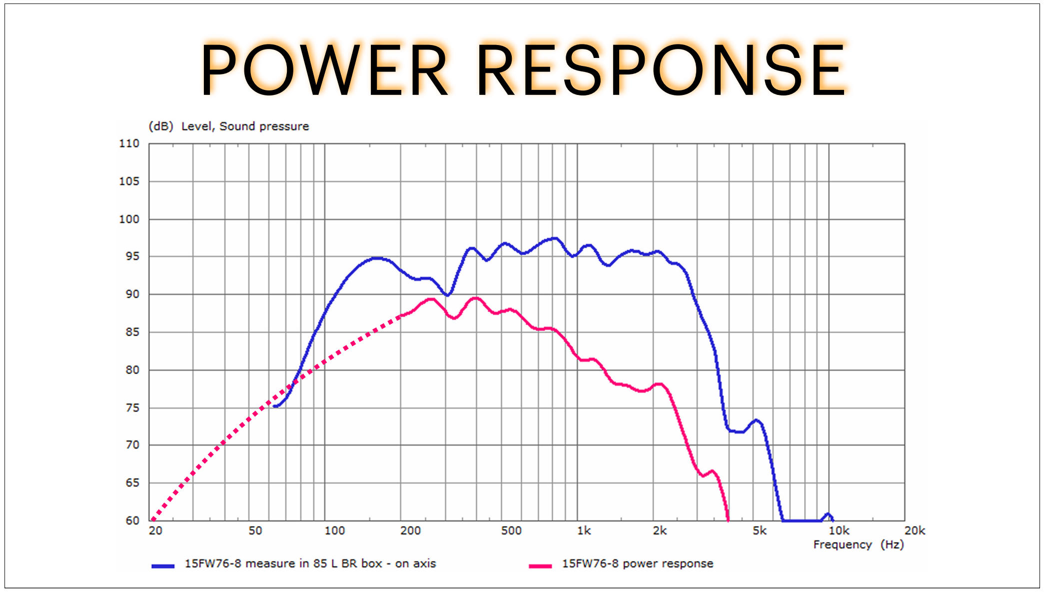
Finally soft part mass is too much for motor to overcome and response collapses.

Very inefficient, and impedance quite high: inductance unmanaged.

Half of cone moving in while half is moving out, heavy response cancellation due to modes.



Deep breath.
If the on-axis response is leading us to ignore what's going on off-axis…
What if we took measurements at all points around the speaker and averaged?



Power response reflects what you'd expect to find from physics.

Rolls off ≈12dB/octave on both sides of minimum impedance, where transducer close to resistive.

Still a constant <u>voltage</u> measurement, so impedance rise makes HF rolloff look worse than it is.

This 15" is efficient and predictable below 500Hz, resonances and modes not problem yet.

Possible to flatten on-axis frequency response by making compromises unacceptable in pro audio.

- Use multiple, smaller devices (weight & size, limited excursion)
- Add modes near HF limit (time domain yuck)
- Add lossy elements (durability, poor stability with aging and signal level)
- Use exotic materials (expense, manufacturability, durability)

Trying to accomplish without EQ something that EQ is the ideal tool for, and not improving power response.

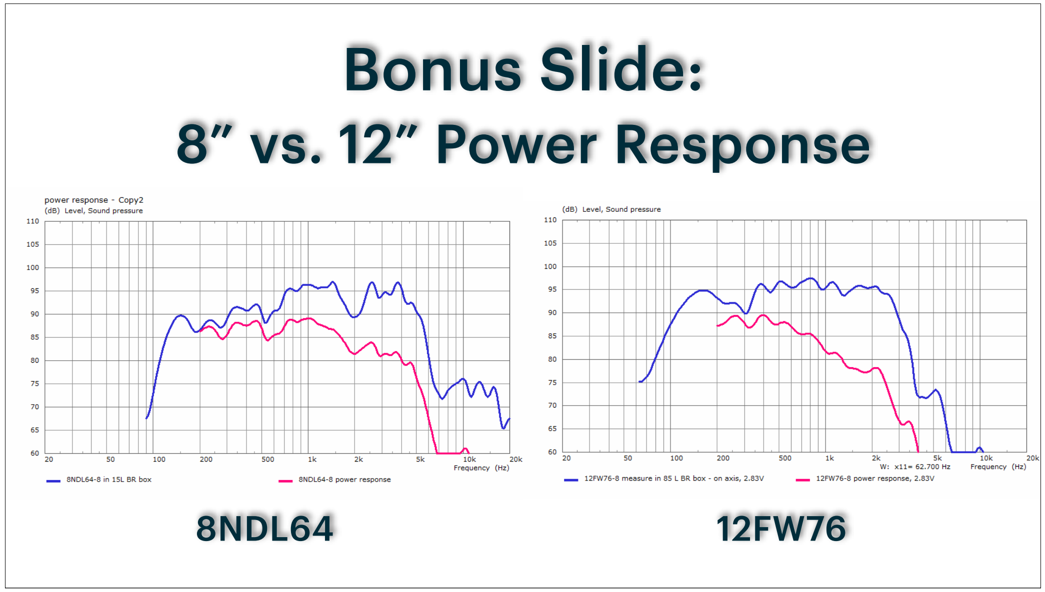
PRESENTATION TAKEAWAYS

- **Efficiency falls *octaves* before on-axis response limit.**
- **Higher efficiency woofers even less flat in first & last octaves.**
  - **You want the strongest mechanical system**
  - **It's 2020. Correct response with DSP**
- **Multi-way systems a necessity for high efficiency.**

Strong motors make LF roll off more, but increase efficiency everywhere.
Stiff cones make HF response roll off more, needed for durability and sound quality.
B&C design philosophy is to make the best motor, frequency response is what it is!

Stronger mechanical systems sound better, have more output!


Q&A
production site



Blue line is in a very small reference box.
Red line is power response calculated after polar measurements.
Smaller transducer power response is much closer to power response.
    Surface area so much less compared to the rest of the mechanicals.
    Sensitivity actually rises above 700Hz in 8” woofer - how to flatten?