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Domestic line Array

Or:

How to make a whole (good) audio system with full-height line-source speakers for less than $2000?

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I have been tinkering with loudspeakers for many years, making all sorts of designs including closed, bass-reflex, full range quarter-wave, isobaric, even a 3-way Voice Of The Theatre. Some time ago I came across Jim Griffin's white paper on arrays. I also read about the work by Roger Russell, designer with McIntosh and their big arrays, and then his own IDS-25. Before that, I had never listened to line arrays except at live music events where, as big hanging contraptions and if properly set up, they can deliver an outstanding sound.

But this is what particularly attracted me in Jim's own description of the domestic arrays:
· *Recreates live event sound dynamics*
· *A wider sound stage*
· *Near-constant sound levels throughout the listening room*
· *An image 'sweet area' and not a 'sweet spot'*.

I have also read a lot of pros and cons, but noticed that:
1 – Many people who are against arrays have even not shown they have listened to any, yet complaining about the lack of lows, the comb filtering, and the cost among other things.
2 – Nearly all who have built full-height arrays have become enthusiastic supporters.

OK, then how about making a couple of these beasts, just to find out for myself?

Not having the money to spend $50k on a system, I decided to allocate my meagre budget to building something nevertheless acceptable. Even if it's rough: I am always keen to apply the Pareto principle: 20% effort for 80% return.
After some iterative trials on half-height designs with different combinations and sub woofers, that's how my tall babies look now:

There are 3 ways: main array, treble array and sub woofer placed in the corners of a (small) room.

The main array:

The main array is 2.3m high and, for ease of construction, is made of 2 identical sealed columns each 115cm high and joined together in the middle with a full opening between them.

I know you'll find my work ugly but I have respected all the main rules of line-source design. Function before looks!
Anyway, watch for the trick: the lines are placed behind a light curtain which hides the speakers...to better reveal the sound stage!

Since I don't have the tools to work on MDF, I went plywood. It's easier to use and safer health wise anyway. A thickness of 16mm is enough for this type of woodwork.

In order to minimise the vibrations, I used the welcome fact that in columns two of the three dimensions are very small, like here the internal base being only 188 x138mm. And here also, because of the internal bracing and walls, there is no theoretical fundamental resonances lower than 2.4kHz, either in the column void or in the walls. Being so high, they would then, with any harmonics, be killed instantly - no quarter.

As you can see, panels and partitions are glued and fastened by screws...this is 420 screws in total but my small cordless screwdriver survived. The partitions act not only as a strong bracing but also as a multiple chicane. This makes the sound path inside the column longer than the column itself, but not smooth like in a tube. That should help to make the F3 of the drivers as low as possible and mitigate the lengthwise standing waves which are then spread among a quasi-infinity of frequencies. The highest of these frequencies is 3100Hz (plus harmonics if any) which corresponds to the 11cm between 2 partitions. The possible "remaining" standing waves are easily absorbed by the internal

damping material: 5mm thick polyester felt glued on to the partitions, soft polyester fibre against the back of the drivers, and non-compacted rock wool elsewhere.

The main array has 18 GRS 4FR-8 full-range 4-1/2" (11.5cm), current rendition of the iconic Pioneer “69 cents wonder” of the 90’s, with Fs of 100Hz, and sensitivity of 91dB 1W/m each, in 6/3 series/parallel.
The internal net volume is 38dm3, or 2.1dm3 per driver. The (theoretical) Qtc is 0.7, just to make sure the lower frequencies are sharp.
The efficiency with 18 drivers comes to 103dB 1W/m, which is enormous for a full range speaker.

Half-wave for a height of 2.3m corresponds to a frequency of 75Hz, for the broadminded pragmatic ones who accept half-wave as a measure of the lowest theoretical frequency produced by an array, this being at -3dB.

And for the other ones who doubt the ability of an array of small drivers to reproduce low frequencies: imagine a membrane equivalent to these eighteen 11.5cm drivers. This is a total area of 950 cm2, like one 18" (46cm) woofer with the same efficiency of 103dB 1W/m, AND adding to it the good transient response and low distortion of very small membranes. The best of both worlds! Still, we may need something to enhance those frequencies below 75Hz, or even 100Hz which is the resonant frequency (Fs) of our drivers.

The treble array:

The treble array has 12 Pioneer horn-type drivers similar to the current GRS BT2-8 3-3/8" Horn Loaded Bullet Tweeter, in 3/4 series/parallel. This array is suspended from the top of the main array by ropes in order to uncouple the 2 arrays acoustically and make the higher frequencies cleaner (the difference is really noticeable). The suspension allows me also to move this line from front to rear to adjust the phase for any chosen cutoff frequency. It is really critical because a difference of only 2mm is quite audible with the pink noise at close range, at least on the median axis of the lines.

This array is 1.2m high and placed in a way that it covers the listening height when sitting as well as standing. I have tried to stagger the tweeters among 2 separate swivelling supports in order to splay them and to open the beam horizontally but in fact I haven't found any related improvement to the image. Moreover Jim Griffin advises against it. The efficiency with 12 tweeters is huge: 110dB 1W/m.

The sub woofer:

Behind each array I have placed a sub woofer I made from 2 recycled low-cost small tower speakers mounted on top of each other. Each box already had two ordinary 7" woofers, and I added 5 similar (and similarly cheap!) 7” woofers bought new for AUD 13.00 each from a “leading global wholesaler”. I braced each box internally before reinstalling all these 9 woofers. Therefore I ended up with 2 columns for the subs, each 1.6m high, one for the left and one for the right, with 18 woofers in total!
Please note these subs are not intended to act as a line sources because they are only 1.6m high and the very low frequencies they cover. Here I benefit only from the SPL increase caused by the number of drivers. I estimate it to be in the vicinity of 97dB 1W/m anyway. The membranes barely move, even at a good level, which is a sign of low distortion.

These woofers have a high compliance and are good enough to bring out a decent 30-100Hz, especially when I kick their magnetised behind with 250W of brute power. At the first listen these subs were a bit too boomy, so I plugged the ports and now they are pretty clean. I have tried one good B&W powered sub but was not happy with the result (home cinema sound, not linear and impossible to equalise properly).
I have also tried 2 sub woofers I made with one JBL GTO1214 (12”) each. They are drivers for car sub woofers, so I ran a WinIsd to work out a decent domestic sub. The result is better than the B&W, but not as good as my 7” columns alone.
I ran also these JBLs in series with the 7” columns in case that would add something, which it does somehow, but only when the recording needs it, like for dance music, but not for jazz or any kind of unplugged music, and especially not classical. In fact my 7” sub columns are very good: deep enough and sharp, nothing to add really.

The electronics:

To drive the arrays I went primal again, preferring a high quantity of cheap good watts to uber-sophistication and snake oil:

Pioneer DVD DV-344 player as transport (recycled)
Standalone DAC based on ageing but still acceptable Asahi AK4396VF
Volume control: Behringer Monitor 1 (simple potentiometer)
Equalizer Behringer FBQ6200 (as an option, see below)
3-Way active crossover Behringer CX3400, Linkwitz-Riley circuits 24dB/Oct
Amp for subwoofer: Behringer EPQ 1200, 2x250W
Amp for main: Behringer EPQ 2000, 2x500W
Amp for highs: Behringer EPQ 304, 2x60W in bridged mode

The internal fans of the amps are replaced by 3 temperature controlled fans connected in series for slow rotation and placed on the side of the rack...does not go on very often and nearly silent when on, but can be improved.
All line junctions are balanced with XLR connectors, to keep the S/N ratio as high as possible. In fact, without any program, no noise can be heard even in placing the ear on the drivers.
Loudspeaker cable 3.5mm2, length to speakers 4 to 7m.

Using pink noise from a CD or from the EQ, and the versatile controls of the CX3400, the adjustments are quick and very easy: frequencies, levels, phases etc.
The cutoff frequencies are currently: 90Hz and 5000Hz, giving ranges of (approx) 2, 5.5 and 2 octaves.

Now, how about testing for the alleged drawbacks of arrays:

Comb filtering with pink noise:
- Main array: faintly audible from the listening area 3-4m away, from 1000Hz and up .
- Tweeter array: fairly audible at 1m, not audible from the listening area.

Comb filtering with music program from listening spot: not perceivable, at least by me.

Horizontal Interferences between main array and tweeter array with pink noise:
Slightly audible at 1m when moving +/- 30deg, not relevant/audible from the whole listening area which is about 3m wide.
Then Roger Russell was right when he said not to worry about the interferences in domestic listening!

Lack of lows:
- No lack above 90Hz, which is where the individual drivers AND the main array start their nominal efficiency.
- Use of a sub woofer needed below this frequency, otherwise the lows are a bit light. With the sub woofers my arrays have never been defaulted, even with the most outrageous bass from any source, including huge organs.

Test as full range:
Now, test with the main arrays as full range speakers (no sub woofer, no tweeters)! Maybe I should have started with that?
I just had to bypass the crossover and go directly from the pot to the main amp.
Well, it's not bad, not bad at all. Obviously there is a lack at the extremities, but who needs a full 20Hz-20kHz when you listen to a Chopin nocturne or John Lee Hooker improvising live on his guitar? Anyway it seems even that there is a slight gain in 'natural', and some more precision in the sound stage.
Using a bit of EQ, like maximum 3dB on the lows and slightly ramping up the highs, it's getting closer to what I have with 3-way, although the lows are slightly light and muddled, and the highs not that sharp. It lacks a bit of the grandeur of the 3-way. And as I increase the level I can notice a small reduction in dynamics and precision, I suppose because the speakers are driven below their resonance, leading to some cone break-up plus some Doppler distortion etc.
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Below is an attempt at adjusting the EQ for the main line used as full range:

In conclusion:

I am extremely pleased with the result, particularly considering I have not spent a lot, less than AUD 2k in fact (as of 2018), including materials and accessories, as I got the original drivers from a buyout of Parts Express, and all the Behringers from a kind local retailer who offered me a deal impossible to refuse.

Apart (only maybe, it was years ago!) from the 3-way Voice Of The Theatre I made with modern drivers and which were in a much bigger room in another location, this is surely the system which brings the most outstanding presence. Plus these arrays give a huge, detailed and deep sound stage and a very natural sound. The potential seems unlimited. They manage to really make you feel that you are on the stage among the musicians! Not many domestic systems can do that, and not many people can afford the ones which can.

Some recordings, for example older solo pianos, seem a bit aggressive on the attacks or even “ring”, but then you realise the recording was not very good, and/or the post-production is to blame.

I have rediscovered many of my good recordings, but some others can't hide their shortcomings anymore and have gone down one or two levels in my selection.

I am very happy with this project, except that my 25m2 room is definitely too small for these arrays which deserve at least double that size.

Verdict: put me in category 2 (see above, 1st page)!

And if you are reading this, Jim, thanks for your good work and advice!

As off Dec 2022 you can find Jim Griffin's white paper here:
https://audioroundtable.com/misc/nflawp.pdf