THE JOURNAL FOR LIVE EVENT TECHNOLOGY PROFESSIONALS
SEPTEMBER 2019 | PROSOUNDWEB.COM

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INSIDE

FITTING IT TOGETHER SEAMLESSLY

Delivering audio impact, detail, and image for Jeff Lynne's ELO on tour

REDUCING THE COUNT: DO I REALLY NEED THIS INPUT?

A RANGE OF APPROACHES & VARIABLES WITH FRONT FILLS

ASSEMBLING A WELL-APPOINTED WORKBOX FOR EVERY GIG

FILLING THE GAP

A range of approaches and variables with front fills.

by Eric Ferguson

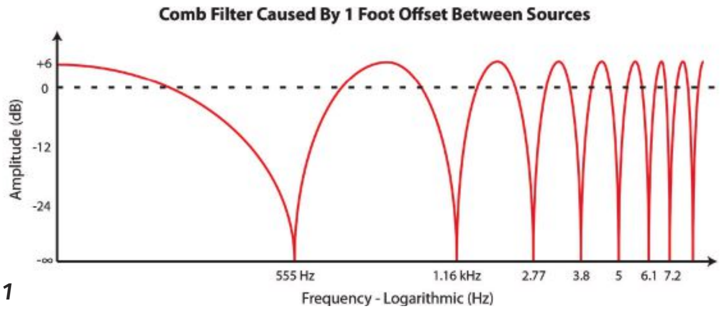


Figure 1

As a college educator to newbie live sound students, I'm always looking to simplify audio engineering techniques into easy to understand best practices. Whether it's mixing, system optimization, or stage set up, I try to research available literature, experiment, talk to working professionals, and then organize the information for my students.

The challenge in this effort is that the sound reinforcement industry is highly subjective, and there are many opinions regarding how to complete most any task. There's simply no correct way to do things when art is involved.

With this in mind, I often present students with what appears to be the most scientifically viable approach, but then offer alternative methods for evaluation. Through critical analysis of contrasting opinions, I encourage students to make their own conclusions.

One subject that I have found difficulty in finding a single best practice is the tuning of front fill loudspeakers. With main loudspeakers typically flown overhead, coverage and clarity in the first few rows of an audience are often less than ideal. Front fills thus become necessary, and a variety of calibration techniques have evolved to smooth the transition from fills to mains coverage. Let's look at three alternative front fill alignment approaches.

GETTING STARTED

Depending on venue size and target SPL of the event, a variety of different loudspeakers might be deployed as front fills. In touring applications, larger 2-way boxes and even line array elements might be used to cover the "pit." In smaller venues where sightlines are a concern, front fills are typically small in size, and may be mounted within the front of a stage or placed on the lip of a stage or orchestra pit.

Ideally, fills should be from the same manufacturer and product line as the mains. Although it's not mandatory, matching product lines can make the system optimization process go more smoothly, as mains and fills are more likely to share a similar magnitude and phase response. Regardless of the chosen model, front fills are typically EQ'd to match the tonal balance of the mains, and high passed to eliminate low frequencies that can interact with energy from the mains, subwoofers, and stage.

Another important consideration when selecting and optimizing front fills is to ensure they possess headroom similar to the mains system, and that fills do not clip at a lower input level than the mains. Front of house engineers often cannot hear front fills. If the fills are under powered, they may clip and fry while the mains are rocking, and the mixer may never know it. Not only might this sound bad for the front rows, but the issue may not be discovered until another day, when an expensive replacement of drivers is required.

IMPORTANT FACTORS

Time alignment and level setting are critical steps in front fill optimization. This is because fills do not work in isolation. Spill from the stage and mains can also be heard in the front rows, and "flamming" or comb filtering may be audible if the system is not time aligned.

Fills are usually closer to their target audience than mains and/or sound sources on stage, and as result, their drive lines are typically delayed so energy exits the fills in sync with the arrival of sound from these other more important sources. Without delay, sound from the fills would meet the audience first, with energy from the stage and/or mains arriving late. Depending on the difference in arrival times, various ugly-sounding issues can arise.

If the difference in arrival between fills and other sources is less than 20 milliseconds (ms), comb filtering can occur. Comb filtering, or combing, is a pattern of peaks and dips in frequency response caused when identical but time-offset signals are intermixed. Combing is typically heard as a hollow or nasal sound and a graphic example can be seen in **Figure 1**.

If the difference in arrival time between fills and other sound sources between 20 ms and about 150 ms, a flam is heard. Flam is a musical term referring to a grace note, or two notes slightly off in time. Flamming front fills can smear percussive transients and can make drum hits sound doubled.

Making things more complex, the audibility of combing and flamming depends on the relative level of the fills and other sound sources. Up close to the fills, where they're about 10 dB (or more) louder than the mains or stage, combing and flamming is difficult to detect, as the fills drown out the other sound sources. Vice versa also applies. Further into the audience, at a location where the mains are approximately 10 dB louder than the fills, it's hard to hear the fill speakers and any combing or flamming.

The location of greatest concern is where the fills and mains are at equal level. Called the *acoustic crossover*, the location of equal level sees the most significant interaction between spaced sound sources. This is where flamming or combing is most severe. Because of this, it is at the acoustic crossover that delay time of the front fills is often determined. Get the fills synced at the acoustic crossover, and flamming will disappear while combing will be minimized as much as possible.

Front fill level determines the location of the acoustic crossover. Ideally, front fills are not loud, covering only a small area. As a listener walks away from the fills, coverage should smoothly fade into the mains, with no discernable difference in level or frequency response between the two systems. Key to achieving this goal is placing the acoustic crossover at a location at which the mains level has diminished compared to its on-axis response.

Next, fill level is tweaked to make it equal at this location, making an acoustic crossover. If the fills are too hot, the acoustic crossover will be pushed further into the audience and have greater overlap with the mains. This can make the front rows too loud. If the fills are too soft, the acoustic crossover moves toward the stage, and clarity in the front rows might suffer.

OPTIMIZATION APPROACH #1

The first method to front fill tuning is that recommended by Bob McCarthy, Merlijn van Veen, and other respected leaders in the system optimization world. Called "Level Time Combine" by Jamie Anderson of Rational Acoustics, the approach makes seams between the fills and mains that are first set to be equal level, and then time aligned to be equal in phase.

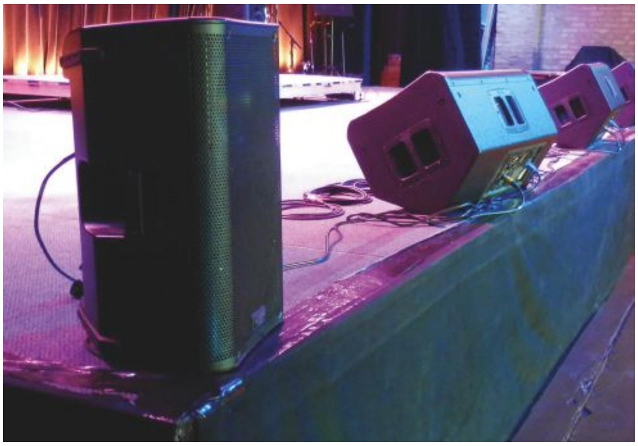
This method ensures that combing is nonexistent at the acoustic crossover. In other locations combing will exist, as it is impossible for more than one position to see perfect time alignment between spaced sound sources. The severity of combing is minimized elsewhere, however, as locations other than the acoustic crossover see less than equal level between the mains and fills. The farther you move from acoustic crossover, the greater the time is misaligned, but less similar the relative levels.

Key to this approach is picking an effective location for the acoustic crossover. A position mid-way into the target area is typical. To be more precise, the ideal spot is where mains response has diminished -6 dB compared to their on-axis level.

This is the classic array construction technique in which neighboring loudspeakers are placed so the -6 dB coverage limits of their high-frequency (HF) horns are aligned to make an equal level seam. Since -6 dB + -6 dB = 0 dB, the seam creates an even-level transition between the two loudspeakers. Finding

the -6 dB location of the mains HF coverage and setting the front fills for equal level at this position can create a smooth shift from system to system.

In reality, due to horn design and acoustic reflections, it can be difficult to find the location at which mains HF has attenuated by -6 dB. This is especially true with line arrays, as their proportional Q horns narrow in vertical coverage as frequency increases. With line arrays, the -6 dB location varies with frequency, and the system engineer must pick a frequency at which to align the acoustic crossover. A vocal intelligibility frequency, perhaps 4 kHz, is recommended.



Objectivity is the mantra to the Level Time Combine approach, as fills are aligned in a measurable and repeatable manner. Use of FFT measurement software, such as Rational Acoustics Smaart, is preferred by many to avoid the subjectivity inherent in tuning by ear. Here's a suggested workflow:

1. Using FFT software, capture a trace of the mains system frequency response. If working with a line array, this may require averaging multiple microphones spaced across the coverage area, as response can vary with location.
2. Place a measurement mic on-axis with the front fill and EQ it to match the trace of the mains system frequency response. A typical goal is to have the entire system sound similar everywhere. Reducing highs in the fills might be necessary to match the mains, which are farther from the audience plane and have experienced HF air loss.
3. High pass the front fills to reduce low-frequency (LF) combing with mains, subs, and stage wash. Since low frequencies are omni directional and audible in the front rows from other sources, they can be removed from the fills.
4. Choose a location midway into the target area to be the acoustic crossover. The ideal position is where HF from the mains attenuates -6 dB compared to the on-axis mains level.
5. Capture a trace of the mains system at the acoustic crossover. Adjust fill level to be equal to the trace in the vocal intelligibility frequencies (around 4 kHz).
6. Using the FFT software for guidance, delay the fill to match the mains system arrival time. Note relative phase between the mains and fill and reverse polarity of the fill if necessary.

OPTIMIZATION APPROACH #2

An alternative approach to front fill alignment is popular in theatrical settings. On Broadway, many sound designers prefer to keep the illusion that sound is emanating from the actors on stage, not from the loudspeakers.

To accomplish this goal, mains and fills are delayed together or differently to be slightly late, to produce sound after the arrival of direct energy from the stage. This pushes audience attention forward, as due of the *Hass Effect*, humans localize sound based on the direction of first arrival. Manipulating fill delay and level can also steer the image upwards and downwards. Increasing stage-mounted fill level or shortening delay time can pull the sonic focus down from the mains flown far above.

While these techniques are effective for a small area, precise time and level alignment is only possible at one location. Other areas remain uncalibrated and do not benefit from the steering.

An argument against this approach is that the acoustic crossover is not time aligned. Because of this, the position of equal level might see significant combing. Opponents of this technique argue that since there is an acoustic crossover, it might as well be in phase.

Proponents, however, cite that the pros of localization outweigh the cons of a less-than-smooth transition between systems. Some designers even calibrate for ideal sound at one specific one seat. This seat is then given to powerful critics whose published evaluations can make or break a show.

Another potential issue with localization approach is that it is subjective. Objective tools might still be used match some parameters of the sound, but the role of personal preference in the process inherently makes the alignment less repeatable. Here's an example of how a system engineer might tune fills to achieve image localization:

1. Match (with ears or software measurement) the fills and mains in frequency response.
2. High pass (with ears or measurement) the front fills to reduce low frequency combing with mains, subs, and stage wash.
3. At the target location, use ears to subjectively adjust fill level to steer image toward the stage, not toward the mains or fills.
4. Use ears to subjectively adjust fill delay time slightly late to ensure localization to the stage, not the fills or mains.

OPTIMIZATION APPROACH #3

The equal level, equal time technique excels at minimizing combing in the seams between fills and mains. In my experience, this works well at shows where the majority of sound originates from the PA system. For concert events in smaller venues with significant stage volume, the Level Time Combine system may not provide the clarity necessary for patrons in the front rows.

This is because stage wash, a combination of unbalanced backline instruments and LF energy bending around monitor wedges, can make for an uneven and muddy mix for those close to the band. To counter this issue, front fills might be turned up during sound check or showtime, and even a special matrix might need to be created to feed the fills with greater vocal or other important but quiet instruments.

This creates what I call the Stage Wash Alignment. The fills might be optimized before sound check for smooth seams, but once the band hits the stage, tweaks may be made to ensure the front rows can clearly hear the vocals.

As with the Image Localization approach, tweaking overall fill level by ear moves the acoustic crossover to a location without time alignment, potentially intensifying comb filtering. If the overall front fill level is left untouched, but greater vocal is added, the acoustic crossover is moved for the vocal only, which can make for a difficult-to-predict comb filter. Of course, these issues might be worth overlooking for the sake of vocal clarity in the all-important front rows.

Similar to the image localization method, the Stage Wash Technique can be accomplished with subjective listening, objective FFT software measurement, or a combination of the two. While measurement software is the most reliable and precise, trained ears can achieve excellent results. The following steps can be accomplished with tools of your preference:

1. Match the fills and mains in frequency response.
2. High pass front fills to reduce low frequency combing with mains, subs, and stage wash.
3. Adjust fills for equal level with mains.
4. Delay fills to match mains system arrival time.
5. At sound check, if necessary, adjust fill level by ear or use a matrix to add additional vocal or other weak mix elements.

IN SUMMARY

In my role as an educator, I searched for a simple solution to front fill alignment that my students could understand, remember, and practice. What I discovered is that there is no one-size-fits all approach. Depending on venue size, event type, and personal preference, different techniques may be appropriate.

The workflows presented here represent my current understanding of the subject, and other engineers will most likely have differing opinions and practices. This is what makes our field so interesting. There's more than one way to make great sound, and there's always more to learn. LSI

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