Live Sound for Small to Medium Size Venues

Video 2 – Sound Distribution – Speaker Systems

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Review/Introduction

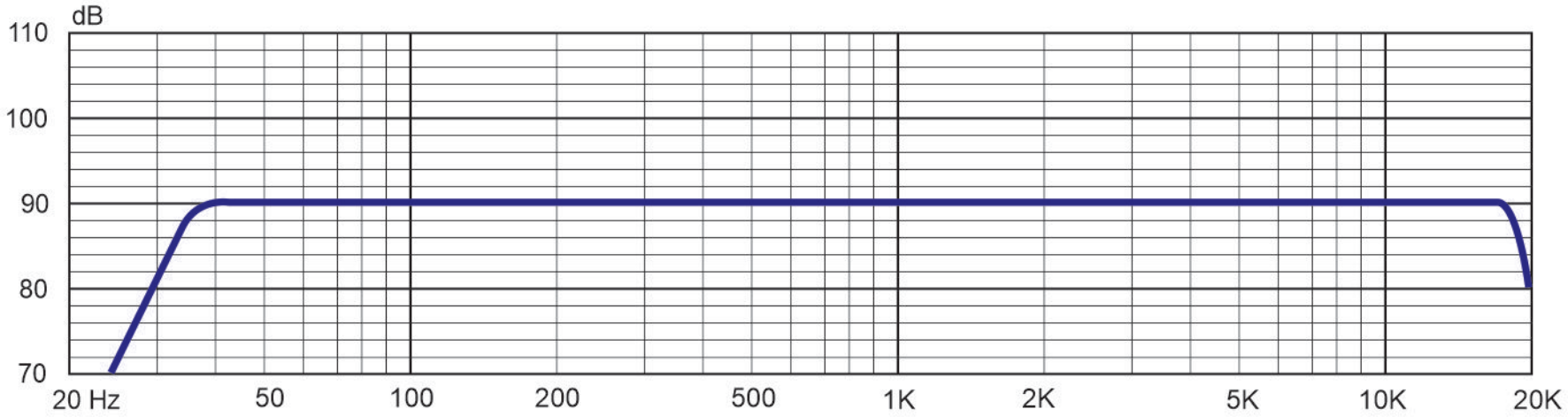
- In part one of this series, we stated that speakers are the most important component in determining the sound of a sound system.
- We further established that there is very little musical content below 40Hz.
- In this video we will discuss how to select, set up and run speakers to achieve “good” sound.

What is a Good Sounding Speaker

- Floyd Toole and Sean Olive are acoustic researchers who did research in Canada and are now part of Harmen International. They have done extensive testing of speakers to determine what measurable characteristics correlate with good sound.
- Speakers that sound “good” consistently correlated with:
  - Flat, smooth frequency response on-axis, well maintained off-axis.
  - Extended, flat bass response.
  - Absence of audible resonances (peaks and valleys).
- For more information there are several videos on YouTube of interviews with Floyd Toole or Sean Olive where they discuss their work.

Ideal Speaker Frequency Response Curve

- From the first video in this series, we know that for live sound a frequency range of 40Hz to 16kHz is desirable.
- An ideal speaker would have flat frequency response over this range when measured on axis (directly in front of the speaker).
- The speaker should maintain flat frequency response as you move off axis.
- The curve shown below is flat from 40Hz to 16kHz and is free of any resonance peaks or valleys.

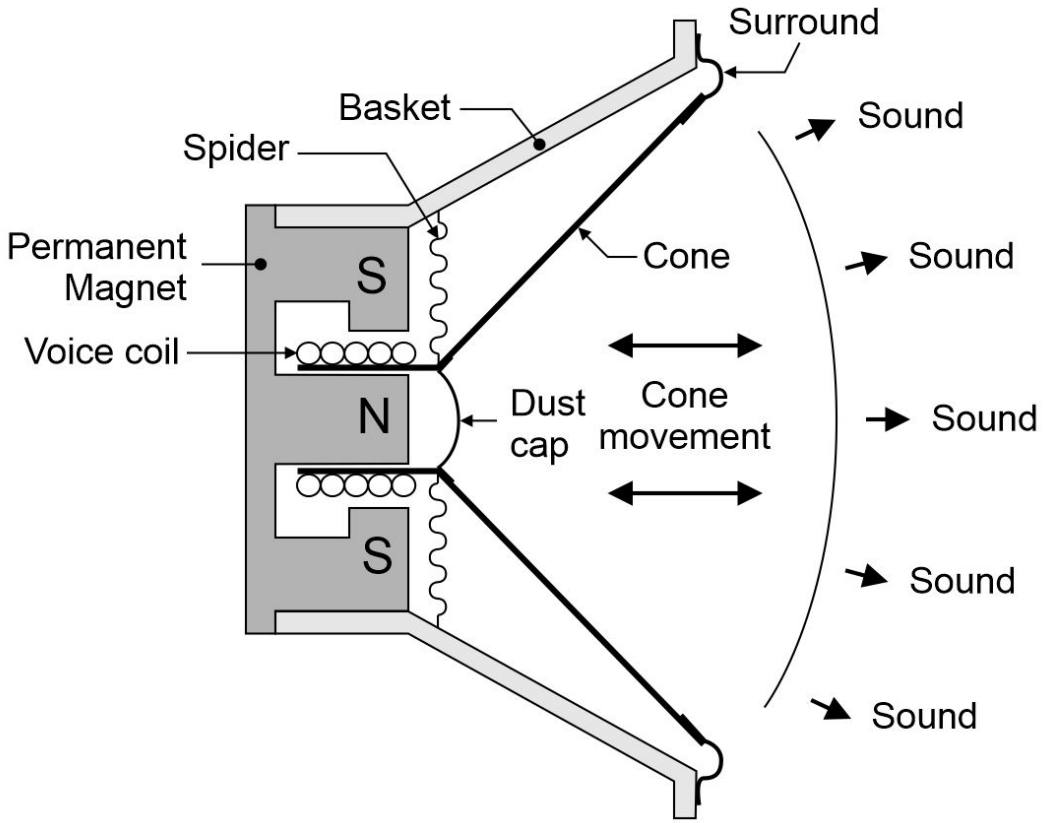


Speakers for Live Sound

- Flat frequency response from 40Hz to 16KHz.
- Sensitive, produce a loud output without requiring a lot of amplifier power.
- High power handling, capable of producing loud output without distortion.
- Directionality, you want a speaker that covers the area with sound but is directional enough to not send out sound where it isn’t wanted.

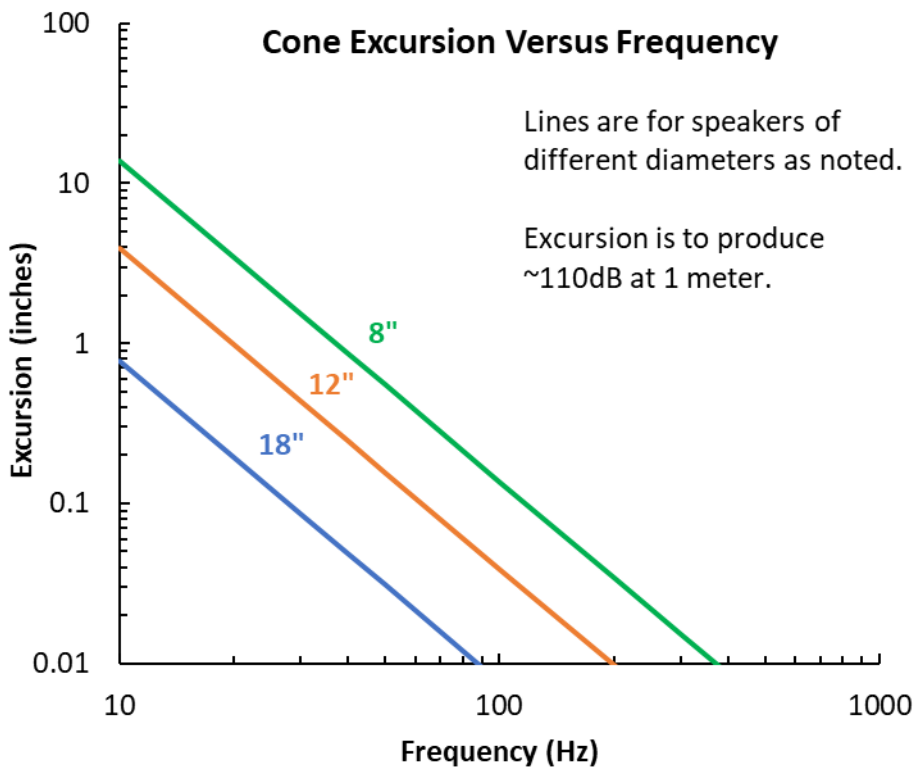
Speaker Driver

- When we refer to a speaker it is a cabinet with one or more drivers mounted in it (may also have a cross over).
- As described in part one of the video series, speakers are electromechanical components.
- An electrical signal is fed in, the signal travels through the voice coil creating a magnetic field.
- A rigid speaker cone is suspended with a flexible spider and surround holding it in a basket.
- The voice coil is attached to the base of the cone and the magnetic field causes the speaker cone to move creating sound waves.



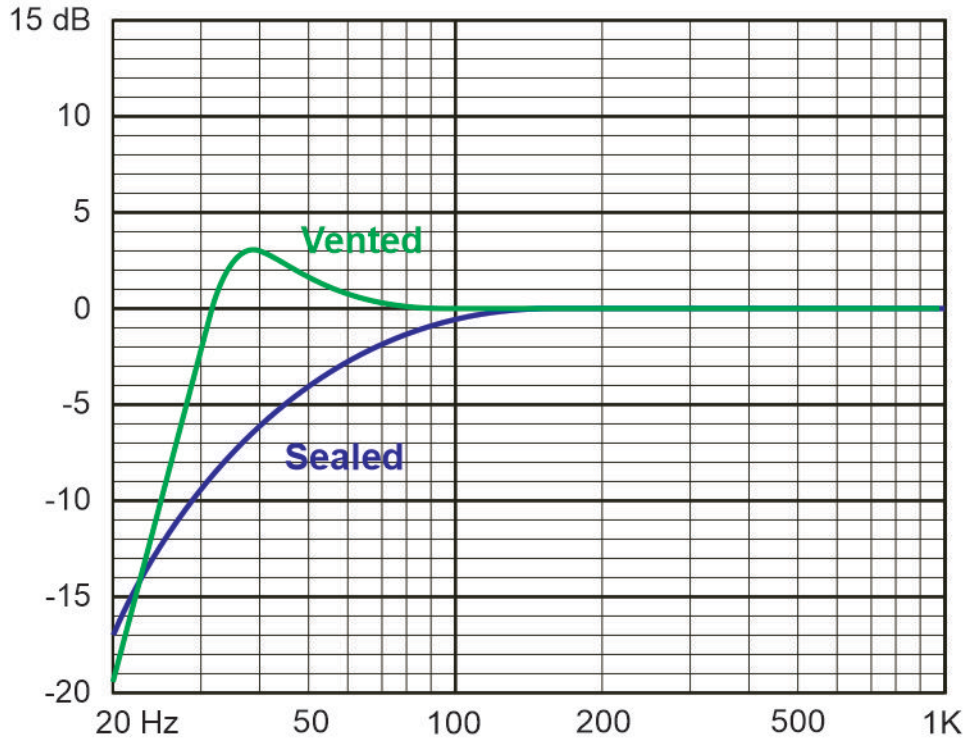
Excursion and the Bass Problem

- In order to produce low frequency, you must move a lot of air, ~4x the air every time you cut the frequency in half.
- At low frequencies you need large diameter drivers, or long driver excursion distance or a combination of both.
- It takes a lot of amplifier power to move a lot of air.
- For 20Hz an 8” woofer needs ~3.4” of excursion to produce 110dB, whereas at 40Hz the excursion required is reduced to ~0.9”.
- Long excursion is difficult to achieve in drivers.



Speaker Cabinets

- Speaker cones moving in a driver produce sound from both the front and the rear.
- The sound from the rear is out of phase from the sound from the front and can interfere with it.
- Speaker cabinets either contain the sound from the back of the cone (sealed), or if properly vented as a bass reflex can use the sound from the back of the cone to reinforce the bass making the speaker more efficient.
- Most speakers designed for live sound are vented to improve bass response.



Wavelength

- The wavelength of a sound wave is inversely proportional to frequency.
- Low frequency notes are very long, a 40Hz frequency (our minimum target) is 8.3 meters or 27.2 feet long (this varies with atmospheric conditions).

Frequency (Hz)	Wavelength (m)	Wavelength (ft)
20	16.550	54.30
40	8.275	27.15
80	4.138	13.57
160	2.069	6.79
320	1.034	3.39
640	0.517	1.70
1,280	0.259	0.85
2,560	0.129	0.42
5,120	0.065	0.21
10,240	0.032	0.11
20,480	0.016	0.05

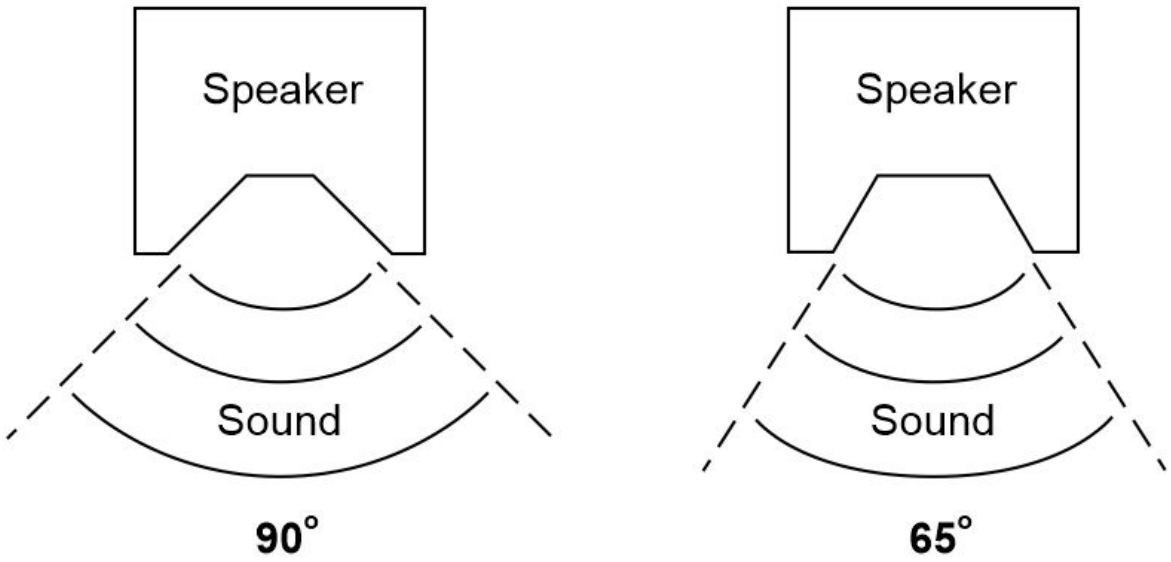
Directivity and Efficiency

A speaker driver designed for good low frequency performance has two problems at higher frequency:

1. When the wavelength of a frequency becomes comparable to the size of the driver the driver becomes directional with directivity increasing with frequency. As we will discuss later sound system speakers are typically designed for a specific coverage pattern. In order to have flat frequency response off axis the speaker directivity must match the desired coverage angle at all frequencies.
2. Large heavy diaphragms do not vibrate efficiently at high frequencies.

Coverage

- The figure on the right illustrates a 90º and a 65º horizontal coverage pattern.
- 90º covers a wider area and doesn't project sound as far, 65º covers a narrower area and projects sound farther.
- 90º is good for smaller rooms and covers close to the stage well, 65º is better for bigger rooms, particularly long narrow rooms or sending sound a long way outdoors.



Drivers for Mid and High Frequency

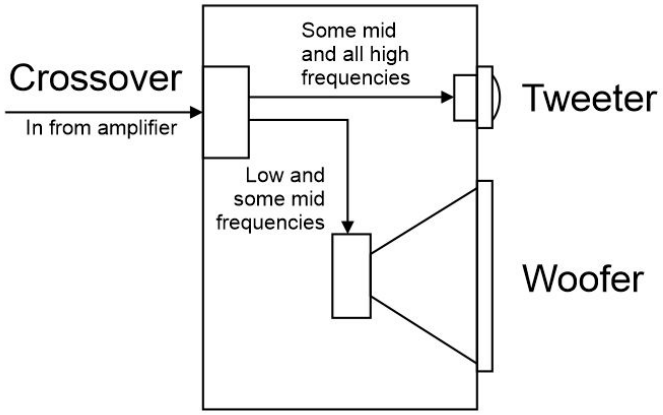
- As we just saw, drivers designed for low frequency are inefficient and too directional at high frequencies.
- The solution to this problem is the utilize different driver designs for different frequency ranges.
  - Large, heavy diaphragm speakers for low frequency, these drivers are referred to as woofers, 8”, 10”, 12”, 15”, 18”.
  - Small, light diaphragm speakers for high frequency, these drivers are referred to as tweeters. Tweeters maintain high efficiency and wide coverage at high frequencies. Tweeters may be coupled to horns to limit directivity to a specific value over a wide range of frequencies.
  - Intermediate size and weight speaker drivers may be added for mid frequencies, these drivers are referred to as mid ranges.

Crossovers

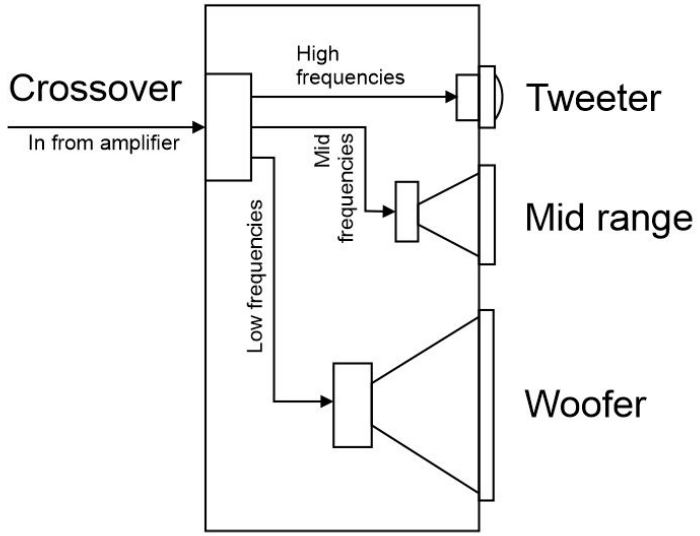
- In order to split up sound frequencies into bands to feed different types of drivers, crossovers are used. There are two main type of crossovers:
  - Passive – passive crossover is built into the speaker cabinet. A high-level signal is fed to the speaker from a power amplifier, inside the speaker at a certain frequency (crossover frequency), the frequencies lower than the crossover frequency are sent to the woofer, and frequencies above the crossover frequency are sent to the tweeter (two-way crossover). If there is a mid range in the cabinet, the frequencies and spilt into low, mid and high frequency (three-way crossover).
  - Active – active crossovers split the frequencies before the power amplifier. Active crossovers offer more options for how the crossover works including digital crossovers. The downside is that each frequency band requires it own dedicated amplifier although this can allow the amplifiers to run more efficiently.

Two and Three Way Speakers

- For small to mid size sound systems, most “main” speakers you encounter will be two-way or three-way speakers.
- Either type can also be paired with a sub woofer creating a three-way system (2-way + sub), or a four-way system (3-way + sub).
- 3-way speakers are in general, bigger, heavier, and more expensive than two-way systems but may offer superior sound quality.



2 Way Speaker



3 Way Speaker

Note: if you want to use an active crossover to split the sound between the drivers in a speaker cabinet you need to make sure you can bypass the crossover and directly connect to the drivers.

Sensitivity

- Live sound requires higher speaker output than home speakers because you are covering large areas.
- Speaker efficiency is defined as the volume produced at 1 meter from the speaker in dB when it is fed 1 watt of power.
- Home speaker efficiency is often in the 80 to 90 dB range, professional live sound speakers will be 95 dB and higher with some large speakers over 100 dB.
- The speakers listed in the table on the right are Electrovoice speakers that will be used as examples throughout this presentation.

Speaker	Type	Sensitivity (dB for 1W/1m)
SB122	Sub woofer	99
Sx300	Mid size 2-way main	99
Zx1-90	Small 2-way main	94

Passive Versus Active Speakers

- Passive – a speaker that does not have an amplifier built in, must be driven by an external amplifier.
- Active – a speaker that includes one or more amplifiers. Typically, a low-level signal is input to the speaker crossover, the signal is split by frequency and then built-in amplifiers power the drivers with one amplifier for each driver.

Active Speaker Pros and Cons

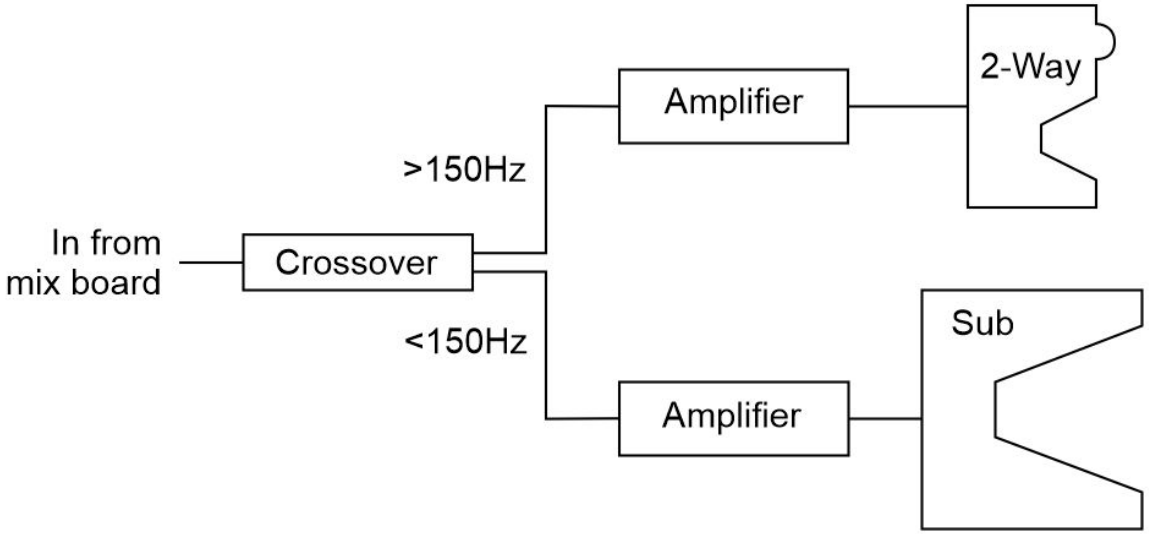
- Pros
  - Crossover operates at low signal level enables more sophisticated crossovers including digital.
  - Amplifiers are designed/selected for each driver.
  - Fewer pieces of equipment to bring with you.
- Cons
  - Generally heavier than passive speakers.
  - Each speaker needs a cord providing the signal and a power cord.
  - If you own a lot of speakers of different sizes and types, you are paying for an amplifier(s) built-in to each speaker as opposed to having a few amplifiers you mix and match with the speakers. For example, at one time I owned 14 passive speakers and 4 amplifiers.

Brands

- My opinion on some of the major speaker brands:
  - Electrovoice – huge speaker manufacturer, makes a lot of drivers for others. My favorite brand for small to medium size speakers. I don't have experience with their larger systems.
  - JBL – another huge manufacture, makes some great speakers but I haven't liked some of their "budget" speakers.
  - Yamaha – Club Passim uses Yamaha speakers and they sound good.
  - QSC – powered speakers, I know several people with these, and a lot of people love them, I have never been blown away by them, but I haven't heard the new versions.
  - Mackie – don't have experience with their PA speakers but I have HR824Mk2 monitor speakers and they are excellent, ruler flat from 20Hz to 20kHz.
  - Behringer – I am generally not a fan of Behringer gear, I don't think it is well made, I have heard Behringer 15" speakers with a horn driver that sounded pretty good in a venue in Boston one night.

Speaker Systems

- The diagram on the right shows a 2-way speaker with a sub woofer.
- An active crossover splits the signal at 150Hz (this would vary depending on the 2-way speaker and sub woofer capabilities).
- The signal below 150Hz is routed to a large power amplifier that drives the sub woofer.
- The signal above 150Hz is routed to a smaller power amplifier that drives the 2-way speaker. The 2-way speaker has an internal cross over.
- One interesting consequence of having a subwoofer is the 2-way speaker doesn't have to produce any sound under 150Hz and can therefore be relatively small.



System Example 1

- Me & Thee coffeehouse.
- Small venue known for good sound.
- The sanctuary is a live room that seats ~100 people.
- 2 – Electrovoice Zx1-90 speakers mounted up high pointing in and down.
- The Zx1-90 has a 90^{o} horizontal by 50^{o} vertical coverage horn, and an 8” woofer.
- Typical performers are acoustic guitar and vocals.
- In a live room these small speakers provide good sound.
- The high placement and type of music are key!

Cheryl Wheeler and John Gorka

System Example 2

- Dance in a high school gym.
- Loud dance music.
- 4 – Electrovoice Zx1-90 with 2 on each side, on each side 1 points across the room and 1 down the length of the room. The pair on each side is connected in parallel to a channel of a Crown XTi2000 amplifier.
- 4 – Electrovoice SB122 with 2 on each side. The pair on each side is connected in parallel to a channel of a Crown XTi4000 amplifier.

This system easily filled a gym full of screaming kids with loud music and pounding bass.

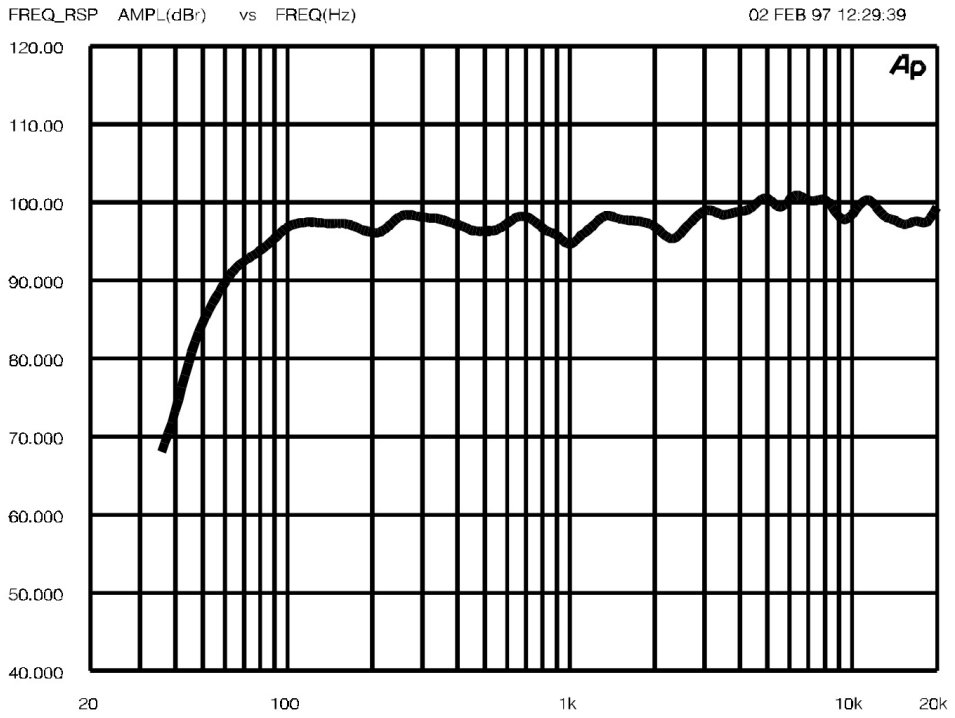
System Example 3

- The Lounge Stage at Falcon Ridge.
- 50’ x 150’ open sided tent with over 400 people in it.
- 4 – Electrovoice Sx300 with 2 on each side. The pair on each side is connected in parallel to a channel of a Crown XTi2000 amplifier.
- Mostly acoustic guitars and vocal but some bass guitar and small drum kits.

Many people commented on how good the sound was over the years including musicians and people who run recording studios.

Speaker Example

- Electrovoice Sx300 is a passive speaker with a 12” woofer and a 65º x 65º high frequency horn.
- It produces 99dB at 1 meter, 1 watt and can handle ~500 watts of music.
- Frequency response is 60Hz to 20kHz -3db and 50Hz to 20kHz -10db.
- It is an excellent sounding speaker, can be used alone for acoustic music and with a sub woofer for any music.
- At 32 pounds in a molded enclosure, they are sturdy and easy to carry.



Sx300 Frequency Response Curve per Electrovoice.

System Example 4

- The Workshop Stage at Falcon Ridge.
- 60’ x 200’ metal building (very live with reflective ceiling beams).
- 4 – Electrovoice Sx300 with 2 on each side. The pair on each side is connected in parallel to a channel of a Crown XTi2000 amplifier.
- 4 – Electrovoice SB122 with 2 on each side. The pair on each side is connected in parallel to a channel of a Crown XTi4000 amplifier.
- Full bands, at one point we had three bass players on stage, at another we had 2 full drums kits and a percussionist.

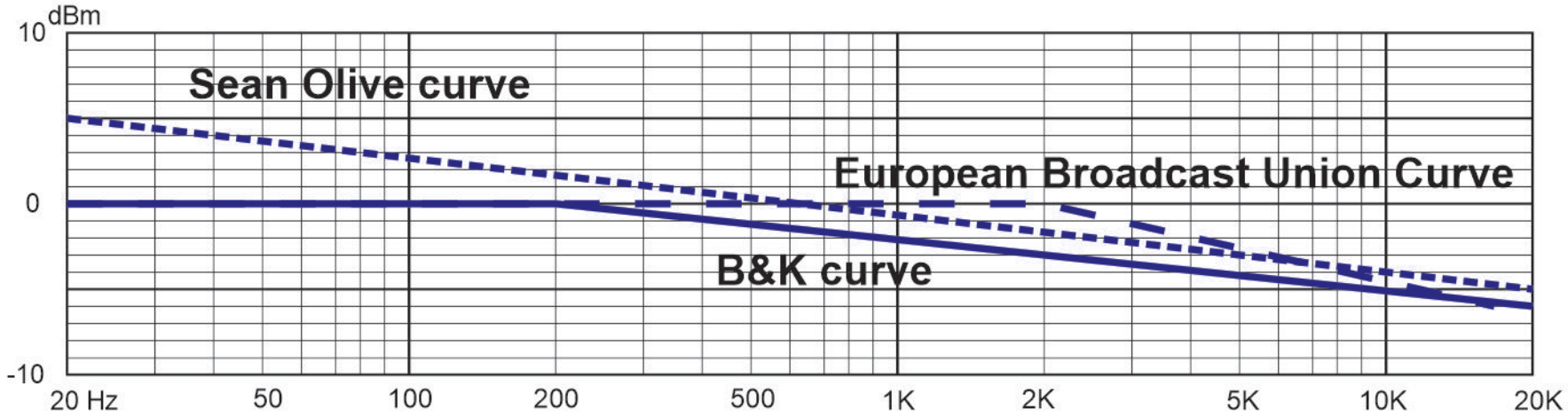
The 3x300 has a 65° x 65° horn that does a great job of sending sound out down the long room and minimizing reflections.

Balancing Speakers

- Checking the balance:
  - Pink noise with analyzer (Studio Six Digital, Audio Tools).
    - Preferred listening curve.
  - Listening to music, with/without headphones.
    - Pick the right music and “good” headphones if used.
    - Must be at the same volume as the performance.
- Adjusting the balance:
  - Start with speaker location.
  - If you can’t get good balance with location, then use equalization to get a good balance.
- If you get your speakers to sound good in an empty room the balance will likely change when people come in, be prepared to make some adjustments.

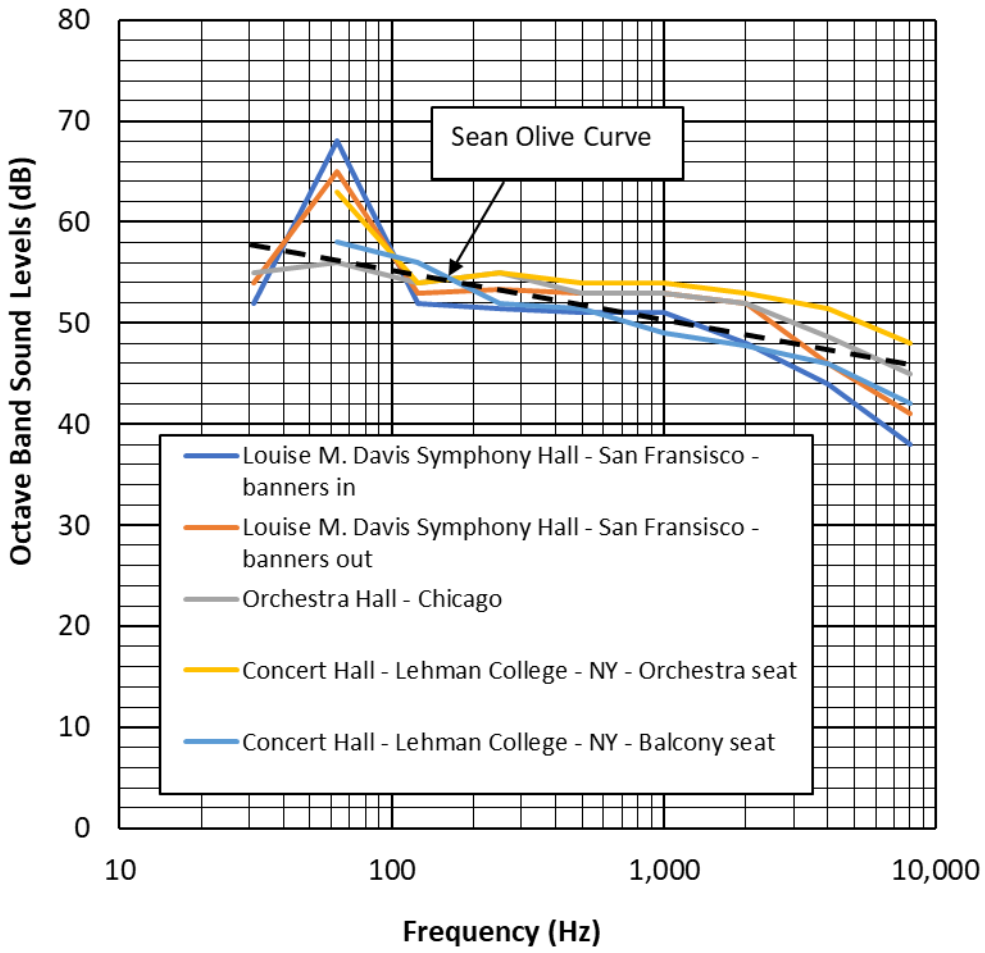
The Preferred Listening Curve

- Speakers should not be set up to deliver flat frequency response to the listener.
- In a concert hall you are hearing the orchestra at a distance with sound that is influenced by the room, you don't have your ear right in the instrument which is what flat sound to the listener would represent.



Concert Hall Measured Frequency Response

- Measured performance for 3 concert halls, summarized from “Halls for Music Performance: Two Decades of Experience: 1962-1982,” American Institute of Physic for the Acoustical Society of America.
- In general, a pink noise source is placed on the stage and the resulting frequency response is measured in the seating area.
- All the curves follow the same general trend and most closely match the Sean Olive curve.



Recommended Music for Speaker Tuning

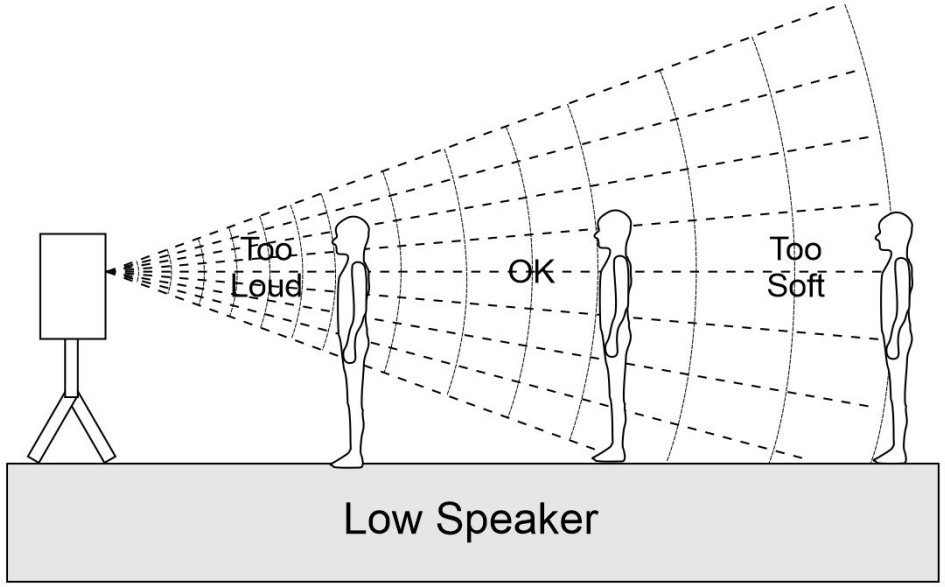
- Bob Katz is one of the best mastering engineers in the world. These CDs are from his honor roll of well recorded and mastered CDs (comments are from Bob Katz):
  - Brand New Day - Sting Mastered by Chris Blair. Engineered by Simon Osborne. Superb sound quality, one of the best sounding modern CDs.
  - You're the One - Paul Simon Mastered by Bob Ludwig. Engineered by Andy Smith. Solid and beating bass drum goes down to the center of the earth, but cleanly.
  - Sergent Pepper - Beatles Produced by George Martin. Engineered by Geoff Emmerick . This is an example of a great 33-year-old mix transferred almost flat.
  - Dark Side of the Moon - Pink Floyd Mastered by Doug Sax. Engineered by Alan Parsons. I think the original LP sounds more open, but this is still a good transfer to CD.
  - Citizen - Steely Dan Mastered by Glenn Meadows. Engineered by Roger Nichols, Elliot Scheiner, and Al Schmitt. Produced by Gary Katz.

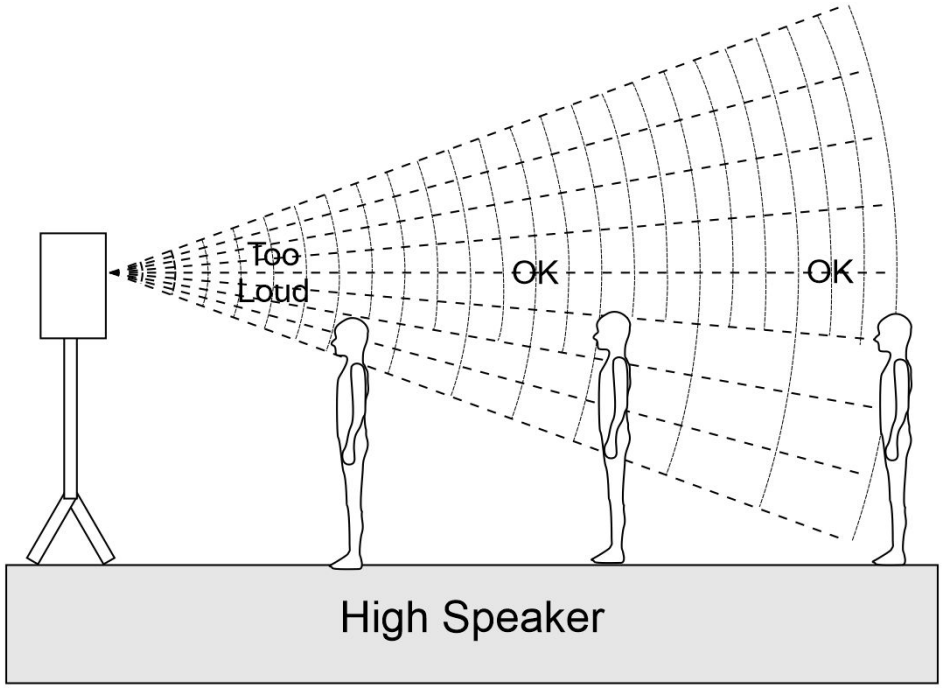
Speaker Set Up

- Placement
  - Boundaries increase low frequencies.
    - Sub woofer on the floor will have more bass than if it is hung in the air.
    - Sub woofer near a wall will have more bass.
    - Sub woofer in a corner will have the most bass.
  - Surfaces can reflect or absorb mid and high frequencies.
    - If a room is too reverberant, try to aim the speakers so the sound reaches listeners before it reflects off walls.
    - Mirrors or glass surface can reflect high frequencies.
  - People are excellent absorbers of sound. If you want the sound to get to the back of a room place the speakers up high.

Speaker Height

- If a speaker is too low relative to the crowd, a lot of the sound will be absorbed by the front rows of people.
- If the speakers are set higher more sound will go over the head of the front rows and reach the back plus the sound level in the front rows will be somewhat reduced. It will increase ceiling reflections and that may also help get sound to the back row but can also be a problem if there are soffits or other ceiling structure.





Delay Speakers

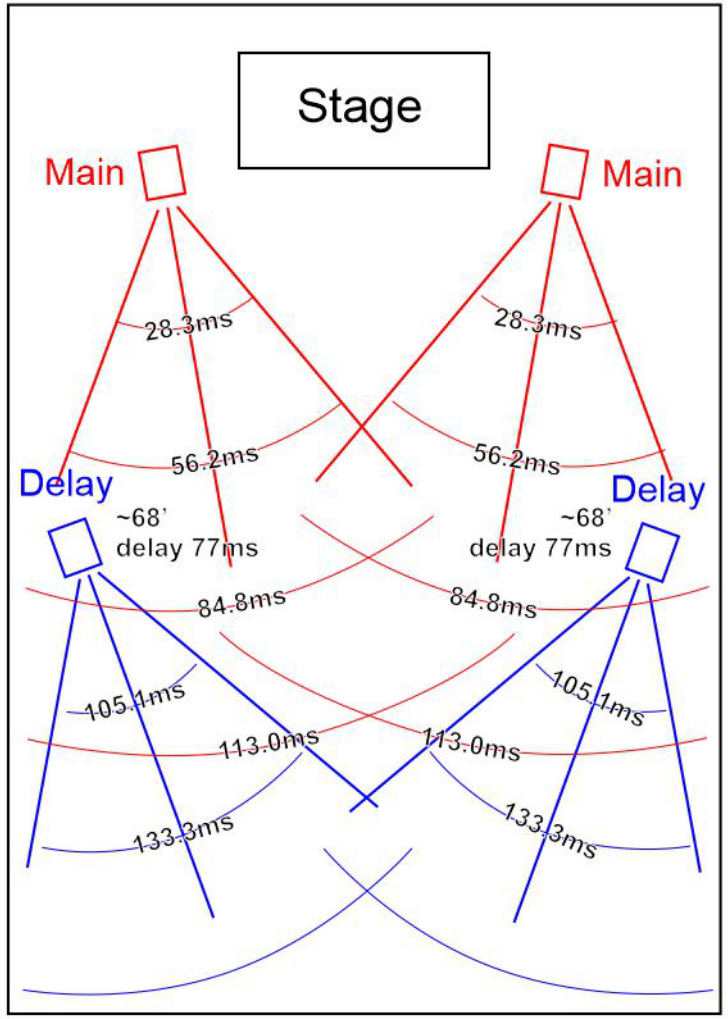
- If you need to get sound to the back of a long room, you will have problems with the sound being too loud at the front by the time it is loud enough at the back.
- Putting the speakers up high and using direction speakers will help, but….
- With delay speakers you put a set of speaker part way back in the room, the key is you must delay the signal to those speakers, or the audience will see the stage their ears will localize the sound to the nearby speakers.
- If you delay the signal the right amount any sound from the stage and sound from the delay speakers will all arrive at your ears at the same time, and it will seme like all the sound is coming from the stage.
- Sound travels at approximately 1.13 feet per millisecond (ms), you need to delay sound by 1.13ms for each foot.

Delay Speakers 2

- The figure on the right shows:
  - Main speakers in red with 25’ radius lines and delays.
  - Delay speakers in blue with 25’ radius lines and delays.
- The delay speakers are on an approximately 68’ radius line from the mains and needs to be delayed by approximately 77ms.
- Sound from the mains and delay speakers should reach the same points at the same time.

Distance (ft)	Delay (ms)
25	28.3
50	56.5
75	84.8
100	113.0
125	141.3
150	169.5
175	197.8
200	226.0

Distance and approximate delay times. The speed of sound varies with atmospheric conditions, you need to do a final tuning by ear.



How Much Power Do You Need

- Speakers will typically have a continuous rating; this is typically for a test tone at a specific frequency. Speakers will also typically have a peak rating that is for a short duration. For music, the speaker can typically take somewhere in the middle because music is dynamic with peaks and valleys. A speaker with a 300-watt continuous rating and a 1,200-watt peak rating, can typically handle 600-watts of music.
- Impedance – speakers will have an impedance rating, typically between 4 and 8-ohms. The amplifier you drive the speaker with will have a maximum power output that will depend on the impedance of the load. An amplifier that puts out 200 watts at 8-ohms will often be able to put out 400 watts into 4-ohms.
- If you hook two speakers together in parallel, you cut the impedance in half – 2 - 8-ohm speakers in parallel equals 4-ohms.
- If you overdrive your amplifier and it doesn't have the right kind of built in protection circuits, you can "clip" the signal and feed a tweeter destroying signal to a speaker even if the amplifier is rated below what the speakers can handle. Generally, an amplifier that is too big is better than one that is too small, just don't turn it up all the way.

Monitor Speakers

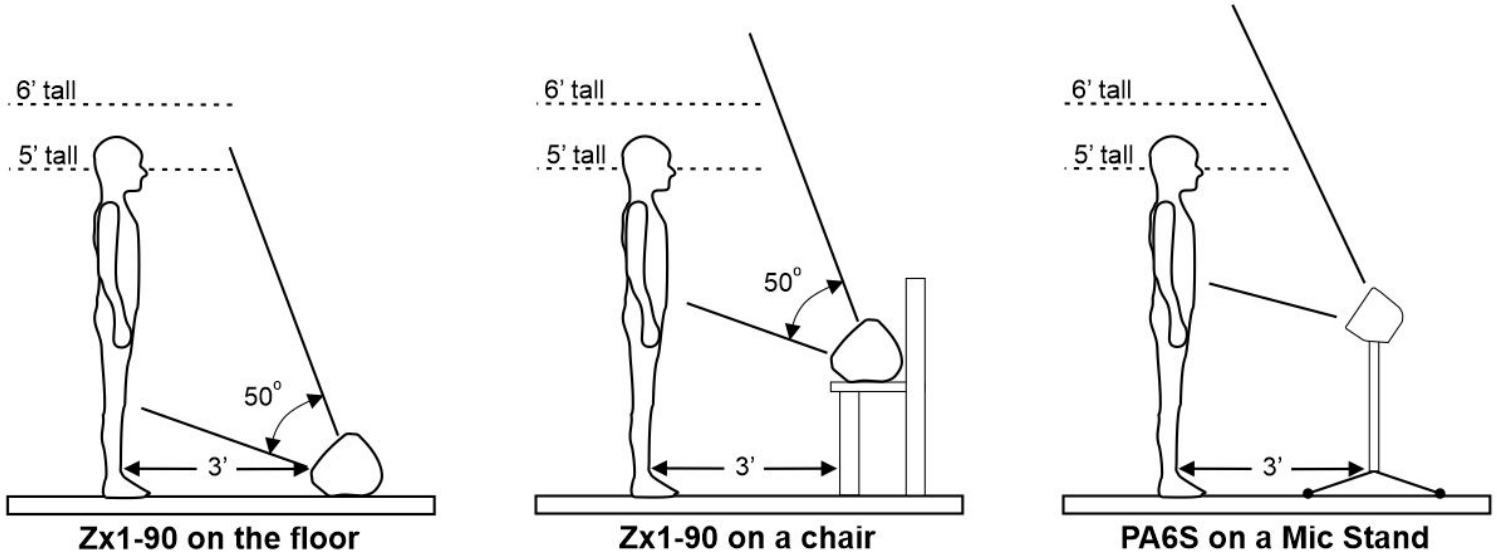
- For the performer to hear well they need monitors.
- The monitors will mostly need to fill in the mids and highs, the lows will wrap around from the mains (at least in most small to mid size venues).
- The stage should ideally be the quietest place in the room but acoustic drum kits, and amplifier drive up the volume, encourage artists to moderate their volume as much as possible, let you set the volume out to the audience. This is particularly important in small venues where sound bleed from the stage can be a significant part of what the audience hears.
- The monitors should be pointed away from the microphones most sensitive pickup angles – this will be discussed in the third video.
- In ear are great but each artist needs their own ear buds.

Monitor Speakers 2

- Point the monitors towards the artists ears, Floor wedges can work angled up or you can place them on a chair if needed. The Zx1-90 and Sx300 speakers discussed in earlier slides can be used as floor wedges.
- I have had good luck with small hot spot monitors on mic stand bases because they are up closer to the artist's ear. Galaxy Audio makes the PA6BT powered speaker with a 6.5” woofer and 1.5” tweeter. They have a mount in the bottom that can accept an insert that threads onto a mic stand. This puts the monitors up just above waist level for artists and without needing a lot of volume lets them hear very well. I have had a lot of artists comment on how much they like them.

Monitor Speakers 3

- On the bottom three different monitor configurations are show:
  1. A floor wedge – in this case the Zx1-90, others will be similar.
  2. A floor wedge on a chair, once again a Zx1-90.
  3. A PA6S hot spot monitor on a mic stand.
- In general, the closer the monitor is to the performers ears the easier it is for the performer to hear.
- The PA6S is the closest to the performer and does a great job of filling in the mids and highs (the PA provides the low). The mic stand can be easily adjusted up if needed, but if the artist is sitting may be too high even at the lowest height.



Feedback

- When sound comes out of a speaker and is captured back into a microphone, amplified and then fed back out to the speakers again, you can get a feedback loop.
- Feedback will typically be a specific narrow frequency where there is a peak in a speaker, microphone or venue frequency response.
- High frequency is typically the monitors, low frequency is typically wrap around from the mains.
- Run an analyzer during the gig to help visualize the frequency if you can’t identify frequencies by ear.
- Notch the feedback frequency out with a narrow band equalizer.
- Try sweeping the frequency with a parametric equalizer to find the feedback frequency.
- If all else fails, turn down the volume until you figure out the frequency.

Conclusions

- Selecting good speakers is essential for good sound. A combination of specifications and listening should be used for speaker selection.
- Always set up and tune your speakers at the beginning of each gig before starting to mix.
- Tuning can be done with pink noise and an analyzer or by ear.
- Monitor speakers are essential for the artists to hear.
- Monitor speakers primarily need to provide the mid and high frequencies because the low frequencies wrap around from the mains.

Resources

- Our production page has a resource section with the presentations used to make these videos and other live sound reference material available to download.
- https://scottenjones.com/production/