Kenny Chesney Concert at Dallas Cowboys Stadium Case Study, or How to Make Several System Techs Lose Sleep and Give Them Ulcers

Introduction: For those that don't have access to internet, television, or radio – Jerry Jones built a new home for the Dallas Cowboys in Arlington, Texas, a couple years ago. And, in true Texas fashion, it is big – really big. Here are a few fun facts about the place:

- Currently the largest dome structure in the world.
- Seating capacity of 80,000 for football, with a maximum capacity of 110,000.
- Internal room volume of 85,940,251 cubic feet.
- The scoreboard is 160' long, 72' tall, and weighs in at around 1,000,000 pounds. It normally sits at 90' off of the ground, but can be lowered to 30' and raised to 125'. It is a true HD display at 1080p.
- The two main support beams are 15' wide, 35' high, and are about 1300' long.
- The room has a reverberation time (RT60) of 11 seconds at 60 Hz when empty. For the audio guys – this is not a typo. For the non-audio folks – this is not desirable for a live performance.
- At each end of the venue are glass doors that are the height of the stadium and cover an area about 275' wide. These glass doors can be opened, but due to air flow through the stadium, both must be opened - it has to be both or none. The audio guys reading this will recognize the ramifications of a piece of glass 170' high and 275' wide. For the non-audio folks, glass does not absorb sound, it reflects it – this is not desirable. In this case, it was unavoidable to cover the space without shooting at least some sound at the glass.

Pre-show planning: We started thinking about this show months in advance. Everything we heard about previous tours that played this room was discouraging. We knew we had to take a different approach than what others had done previously in order to be successful. We knew that tying into the house system in conjunction with the touring system would be essential in order to cover the "back" of the room and the upper seating ring. The house system is comprised of six large X-Line arrays, two smaller X-Line arrays, and 14 Xlc arrays covering the upper bowl above the suite level. **Image 1** is a view from the EASE room model, showing placement of the house system arrays relative to the stage being used for the show.

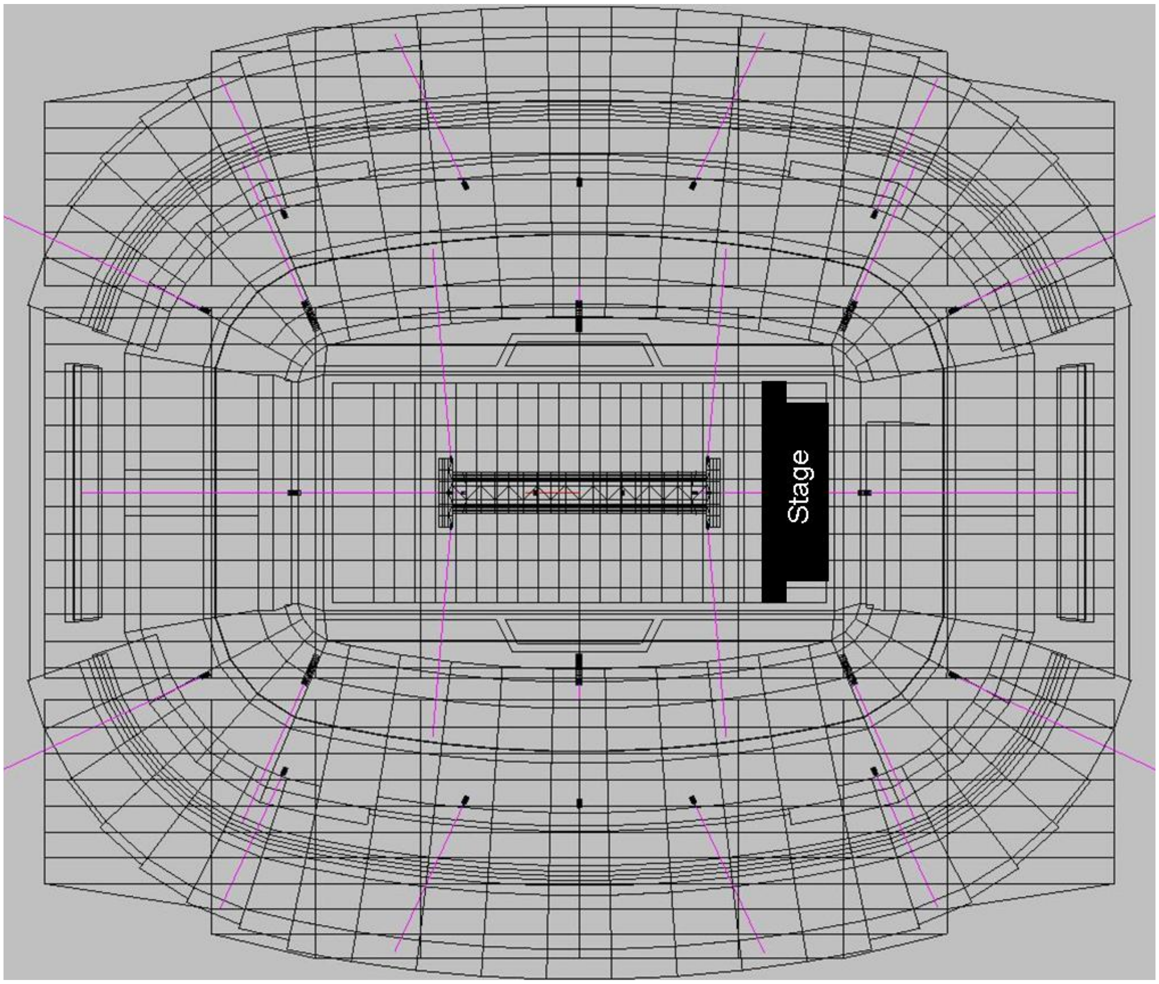

Image 1: *House system loudspeaker arrays relative to the stage.*

We decided early on that we would not try to cover the upper bowl above the suite level with the touring system, due to distances and the vertical angles involved. The touring system includes two 70’ towers that are usually about 225’ back from the front of the stage where delay arrays can be hung from – we considered using these, but chose not to, because at 225’ back they aren’t even half way to the back of the 300-level seating and there are large house arrays right where we needed coverage. **Image 2** is an interior view of the stadium with detail on the seating areas of concern. **Image 3** is a seating map that includes the known coverage areas due to seats sold for the show.

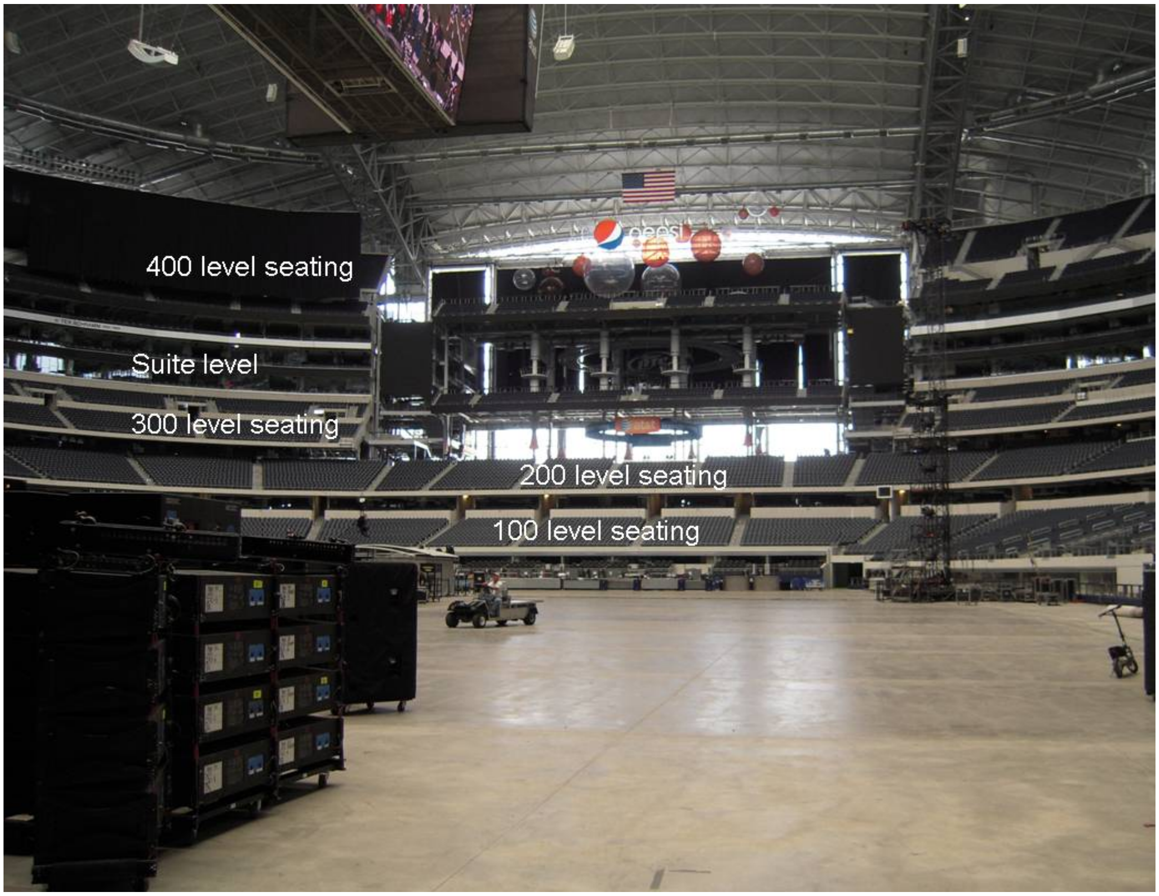

Image 2: *Interior view of stadium with labeling on seating areas.*

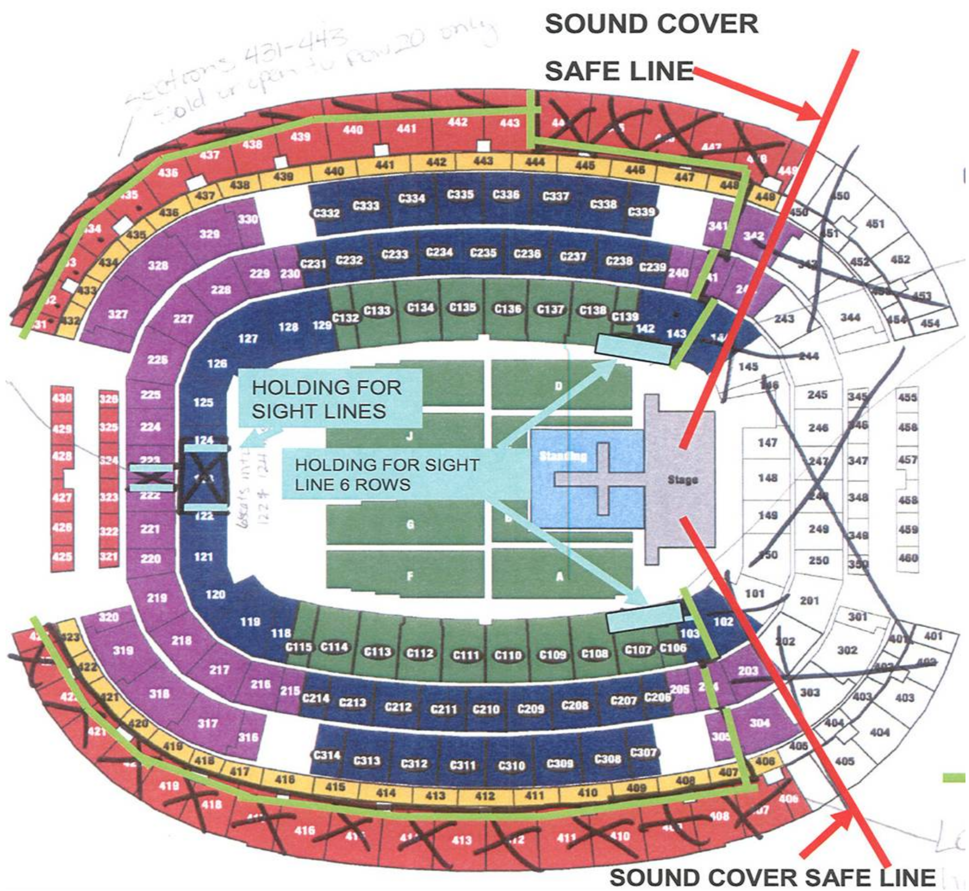

Image 3: *Seating map of DCS with sold seating for the show.*

After staring at drawings for days and talking to the DCS house staff, we finalized our plan on which of the house arrays would be used in conjunction with the touring system. **Image 4** details which of the house arrays would be utilized.

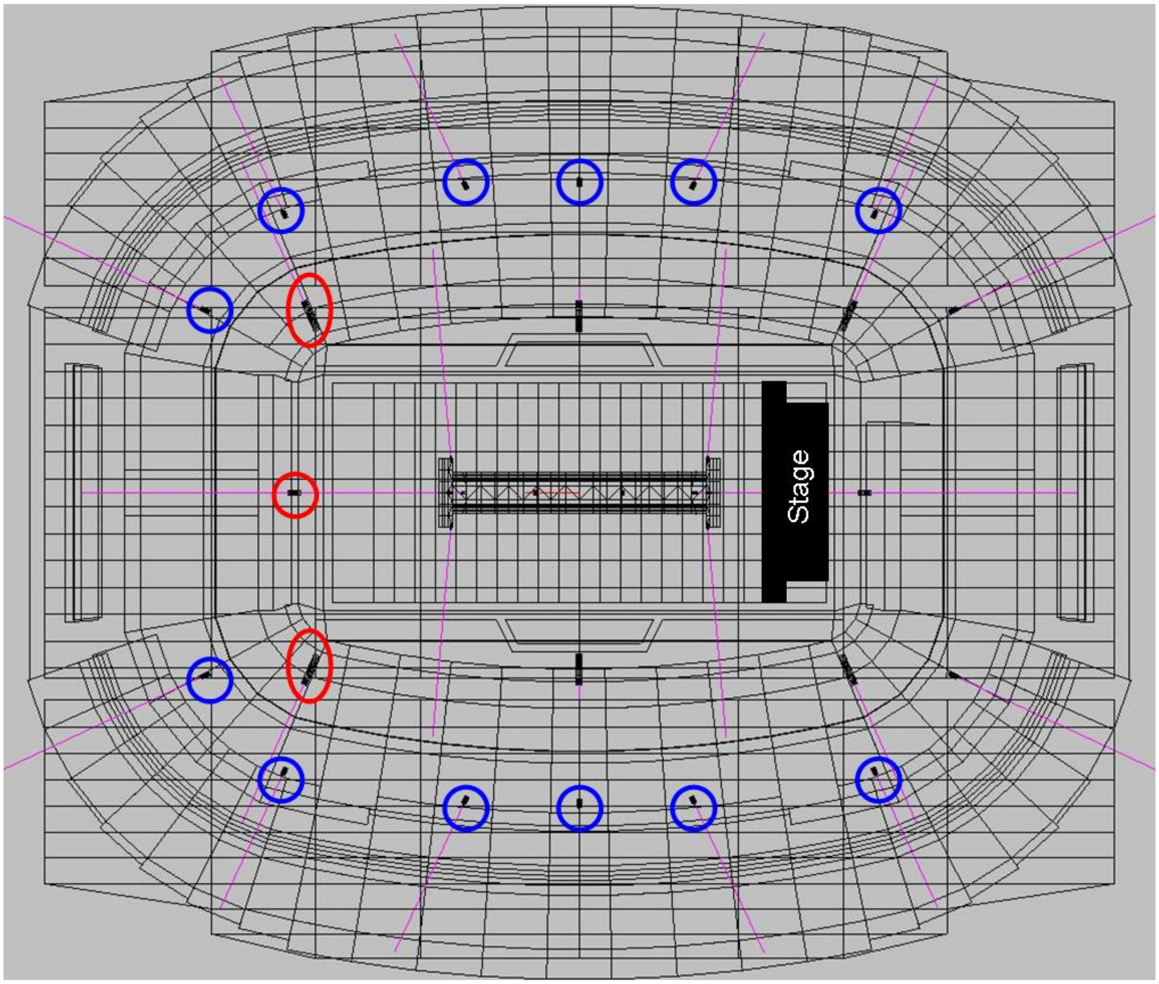

Image 4: *House system arrays to be utilized in conjunction with the touring system; red circles are X-Line arrays covering 100- through 300-level seating, blue circles are Xlc arrays covering 400-level seating.*

Early in the planning phase, we were told by tour management that due to the stage set the main left and right arrays would be spaced 80' apart. Normally on this show, the left and right full-range arrays would each be flanked by a subwoofer array. Spacing sound sources that far apart results in "power alleys" and "nulls" which are particularly noticeable in the lower frequency range. Due to the extra trim height available at DCS, we chose to do a center flown subwoofer array instead of hanging them at 80' apart with the main arrays. **Image 5** and **Image 6** show the differences in horizontal distribution between the two scenarios, making it pretty clear which is the better solution.

The X-Line system for this tour has specially built Xvls and Xsub cabinets that allow for up to 20 cabinets per array rather than the standard 16 cabinets per array. With 20-cabinet arrays nearly 34' tall, the vertical pattern starts to collapse even in the subwoofer frequency band, requiring some signal delay on the top and bottom boxes to widen the vertical pattern enough to cover the areas as needed. **Image 7** is a screen shot from LAPS (Line Array Prediction Software) showing the coverage of the subwoofer array.

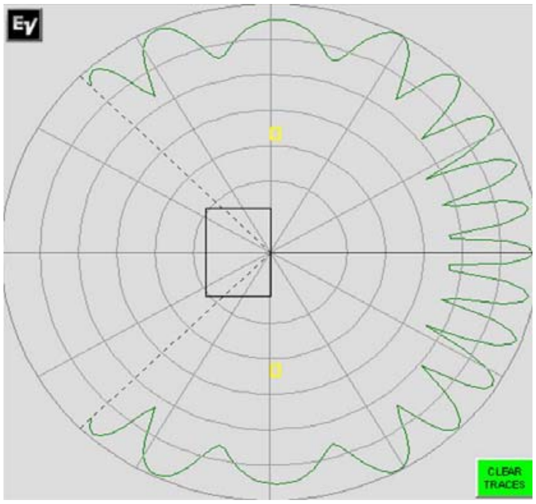

Image 5: *Two Xsubs spaced 80' apart at 80 Hz.*

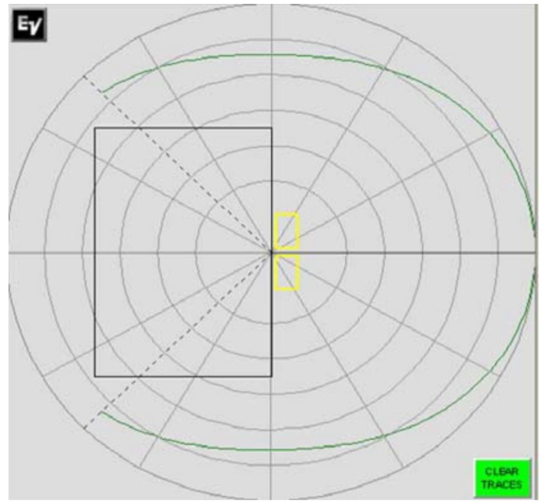

Image 6: *Two Xsubs spaced 1' apart at 80 Hz.*

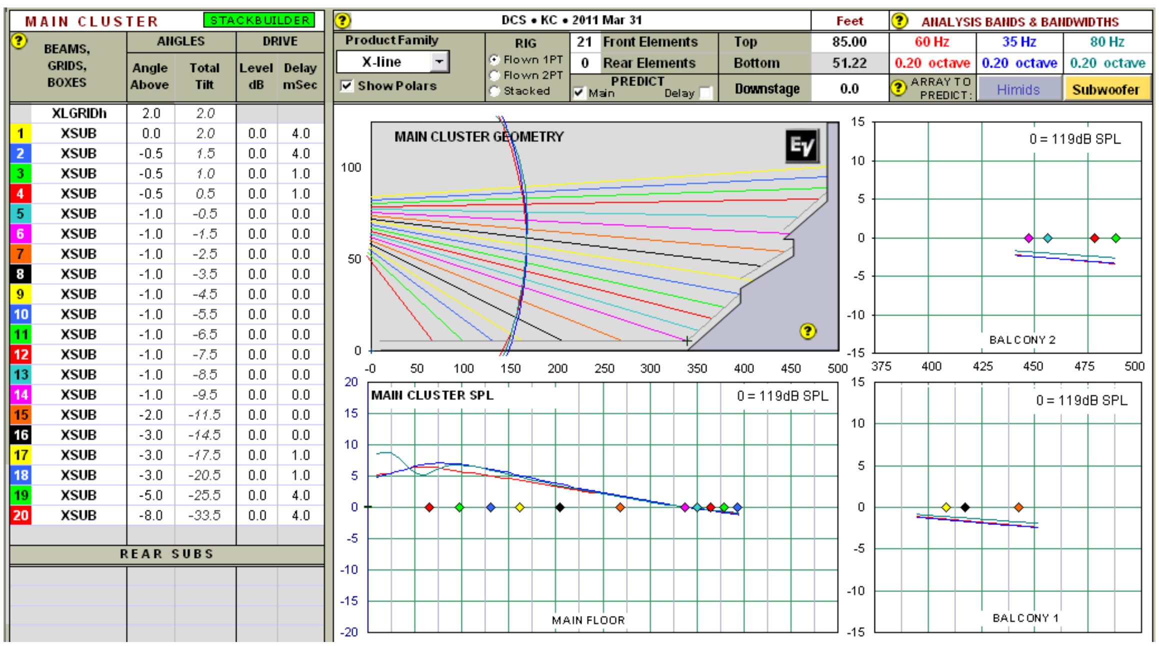

Image 7: *Xsub modeling from LAPS.*

Our maximum trim height allowed by the super-grid flown over the stage was 72' for the main arrays and outfills. For the Xsub arrays, we were able to get two points to high steel which allowed a trim height of 85' so that the arrays cleared the video screens above the stage.

The touring system uses X-Line arrays for main left, right, and outfills in stadiums. 20-box X-Line arrays were used for the main left and right system and 16-box-per-side X-Line arrays were used for outfills. The advantage of long arrays in this situation is the vertical control offered – the 20-box arrays are about 34' long which gives very good vertical pattern control down to a very low frequency. This vertical control helps reduce the amount of sound hitting the dome ceiling, reducing the amount of reverberant-field excitation.

With the maximum trim height of 72' for the main arrays and outfills, we were about 10' below the top seat of the 300-level seats – this meant that our arrays would be pointing up towards the glass on the fronts of the suites, which is not ideal. We asked the venue to remove the glass on the fronts of the suites to eliminate this issue, and they complied. **Image 8** is a screen shot from LAPS of the 20-box main arrays. **Image 9** is a screen shot from LAPS of the 16-box outfill arrays.

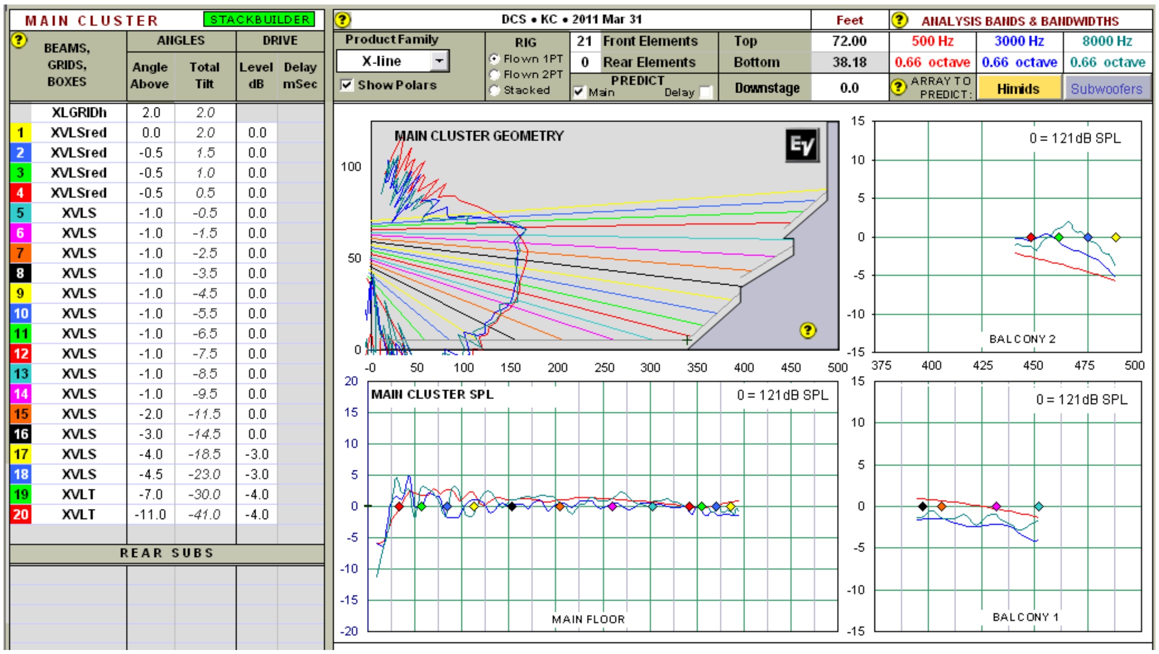

Image 8: *Screen shot from LAPS with the 20-box main arrays.*

Image 9: *Screen shot from LAPS for 16-box outfill array.*

At this point, we all felt as good as we could about our plan. There were a lot of "I wonder if we could" or "what if we" -type phone calls and discussions, but in the end we always came back to the original plan. Now all we had to do was turn the plan into reality.

Execution: Thanks to the tour's production manager, we had two full days of setup time before show day. When we arrived on site, the super-grid was in place and ready to go. **Image 10** is a picture of the super-grid trimmed to show height.

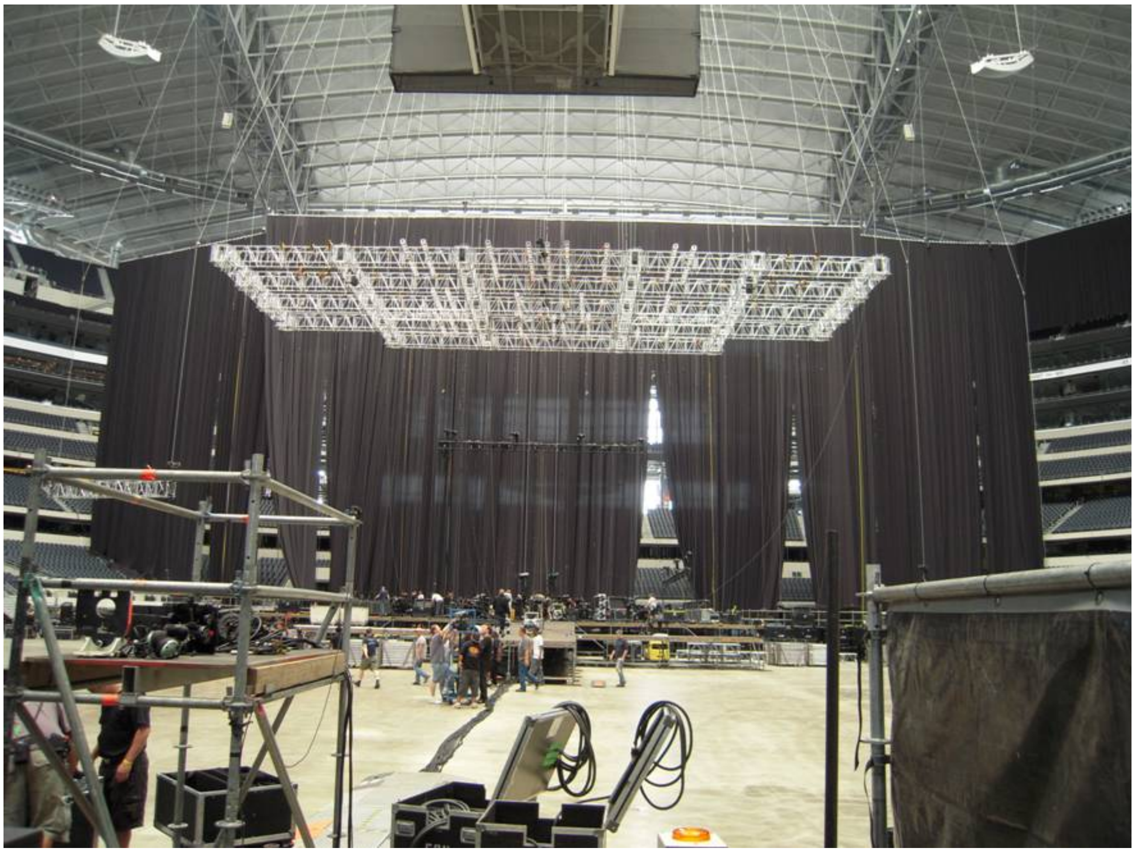

Image 10: *Super-grid at show height*

We verified all venue dimensions and made a few last-minute changes to the LAPS files. All of the touring arrays went up quickly, although the wire looms had to be extended for the subwoofer arrays. **Image 11** shows the final stage set with all arrays, lighting, and video. As previously mentioned, the main left and right arrays are 20-box X-Line arrays with 18 Xvls cabinets and two Xvlt cabinets. The outfill arrays are 16-box X-Line arrays with 14 Xvls cabinets and two Xvlt cabinets. The center array is the subwoofer system with two hangs of 20 Xsubs. It surprised all of us how small this much PA looked in this venue.

With everything now in place and making noise it was time to start tuning and aligning. We started by tuning the touring system and getting that main system aligned first. It didn't take long for us to realize that the predicted RT60 of 11 seconds at 60 Hz with the room empty was very real – there were several looks of panic, muttered expletives, and "what are we going to do with this?" -type comments. With the main system tuned and aligned, we started walking the room and listening. As part of the process we listened to a spoken word track that was a left/right system check. The speaker said "left," waited three seconds, then said “right” and repeated. At the front of the stage we heard the initial word, then about one second later we heard it come right back at us about 3 dB down in level – this created more looks of panic and a lot more muttered expletives. It became very clear that the artists would need to keep their in-ears in place at all times, we were going to have to control show levels, and we were going to have to hope for a full house on show day.

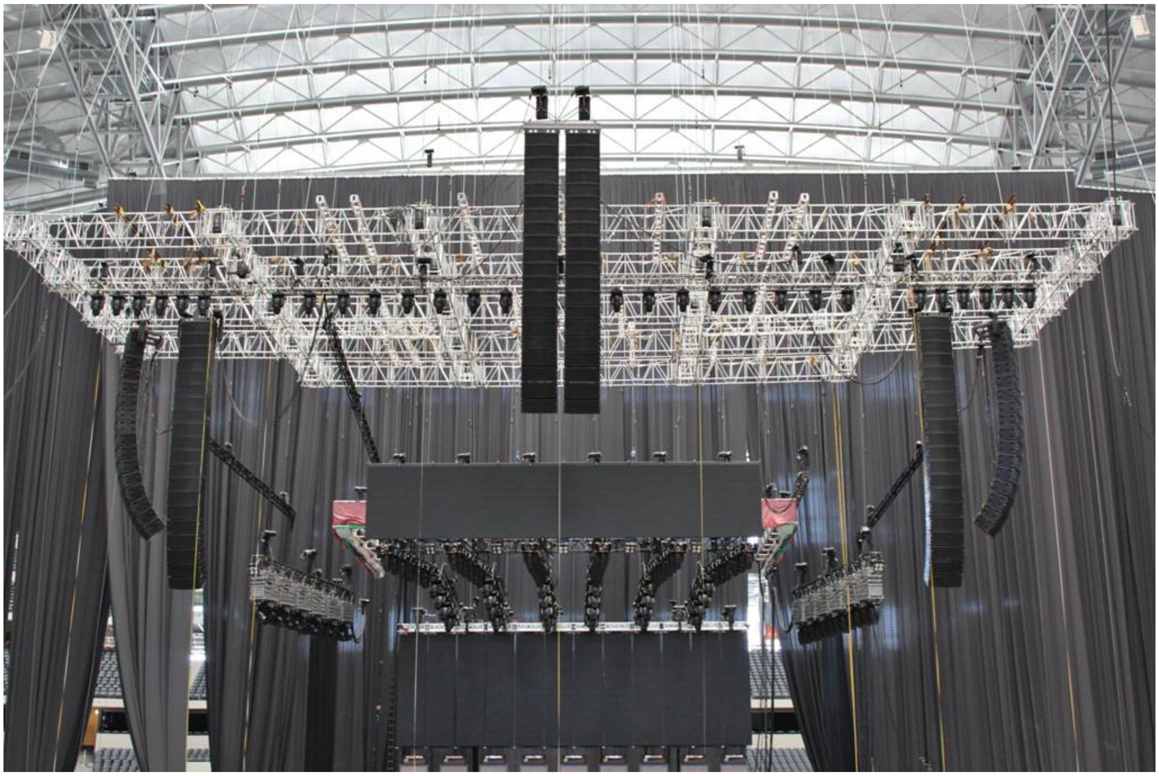
Image 11: *Super-grid with all arrays at trim along with all lighting and video.*

Tying into the house system went relatively smoothly. Even though the house system is all timed and aligned to the star on the 50-yard line, there was enough forethought in the system design to allow it to be reconfigured as needed. It took a combination of feeds from the touring rig and working with the house AV staff to get the delays set between the touring and house systems, but in the end it all worked well. The biggest challenge was aligning the two house X-Line arrays to the main system – these two arrays are firing down at the 100- to 300-level seating and are angled out about 35 degrees to match the seating area. We ended up time aligning to the on-axis point of the array and adjusting levels and tuning to best match the main system. It wasn’t perfect – at the outer edges of the coverage you could start to hear some time alignment issues to the main system – but it was far better than not using the house arrays. The Xlc arrays covering the 400-level seats worked very well because they are so close to the seating – a few of us commented that the cheap seats may have had better sound than some of the more expensive seats. The LF in the 400-level seats wasn’t great, but certainly was acceptable.

On the morning of show day, we decided to play a track at what would be normal show level for the Kenny Chesney show – somewhere between 97 and 100 dBA – with the room empty. We were able to distinguish the first two or three kick-drum hits, then everything fell apart in the LF and it sounded like pink noise – more looks of panic and muttered expletives. From what we could determine, 90 dBA was about the loudest you could go in an empty room before the room ate your lunch. We encouraged all of the FOH engineers to start low and work up in level. The other suggestion we made was to EQ the kick drum different than normal – instead of trying to get a bump at 40-60 Hz, move the bump up to the 80- to 100-Hz range. This would help get around some of the room RT issues and still allow for some of the felt frequencies.

When the first band went on, there were about 35,000 people in the house. The FOH engineer kept the level around 90 dBA and it sounded just fine – the bodies in the room helped dampen the acoustics considerably. By the time Kenny Chesney went on, there were about 60,000 people in the house and the FOH engineer was able to run at about 93 dBA without the room getting away from him.

So, we learned that it is possible to have a good sounding show at Dallas Cowboys Stadium. In our experience, the following tips are what worked for us:

- Use the house system to supplement the touring rig. There is no way the touring system will cover everything – this is a big room with long throw distances and a lot of vertical area to cover.

- Keep levels reasonable.

- Recognize what the room does at certain frequencies (particularly in the LF) and work around it.

- Ask the house AV staff for help and suggestions – they are some of the most accommodating folks we have ever met and want your show to be as successful as you do.

Additional thoughts and tech talk for the audio guys reading this: As you have seen, we really didn't do anything out of the ordinary to make this work – no magic, voodoo, or broken rules of physics here. We used the tools available to us – LAPS, EASE, years of practical experience, and advice from outside sources – to make the best of it. In many cases, knowing the limitations and capabilities of the tools at your disposal is the most important bit of knowledge you can have. The following is a more in-depth look at a few of the topics discussed in the main body of this paper:

Line Array Prediction Software (LAPS): LAPS has the ability to model the room coverage at three frequencies. The default frequencies are 500 Hz, 3 kHz, and 8 kHz. These frequencies were chosen as a default to help the user achieve an array that has even tonal balance front to rear in the venue. With short arrays it may not be possible to achieve even SPL front to rear, but at least it can sound the same front to rear assuming the user can get all three frequency bands to track the same. All three of these default frequencies can be changed by the user to any frequency and any bandwidth. The default bandwidth is 0.33 octave which is fairly narrow – 0.66 octave is a good starting point bandwidth resolution that provides good information without too much detail that may lead the user down the wrong path.

The effective line-array control frequency (the point in the frequency spectrum above which all frequencies in the vertical plane behave the same when a change to the array shape is made) can be calculated. First, divide the array length by five, which is a good general rule of thumb for the wavelength of the control frequency. Then convert the wavelength to frequency: speed of sound in feet per second/wavelength in feet = 1,130ft per second/wavelength in feet. Everything at and above this frequency will behave much the same. For the 20-box X-Line arrays, that frequency is calculated to about 165 Hz, and for the 16-box X-Line arrays that frequency is calculated to about 210 Hz. Keep in mind that control doesn't just stop at this frequency and the polar "explodes" – below this frequency the polar will gradually begin to open up or change shape unlike the higher frequencies. **Image 12a** below shows the 20-box X-Line array again at 500 Hz, 3 kHz, and 8 kHz for reference. **Image 12b** shows the 20-box X-Line array at 165 Hz (our calculated line-array control frequency), 3 kHz, and 8 kHz. **Image 12c** changes the LF frequency from 165 Hz to 125 Hz to show that the control doesn't just disappear below our calculated frequency. **Image 12d** changes the LF frequency to 50 Hz to show the loss in control lower in frequency below our calculated value.

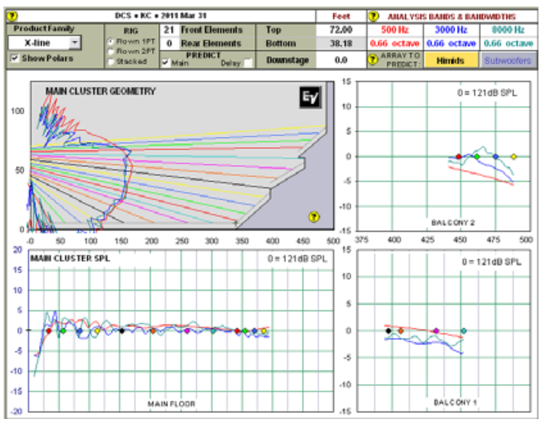

Image 12a: *20-box X-Line array at 500 Hz, 3 kHz, 8 kHz.*

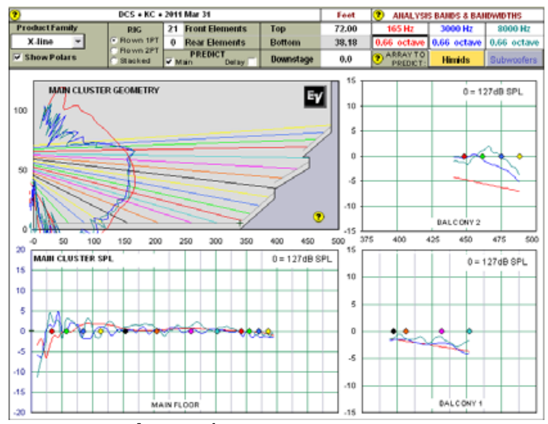

Image 12b: *20-box X-Line array at 165 Hz, 3 kHz, 8 kHz.*

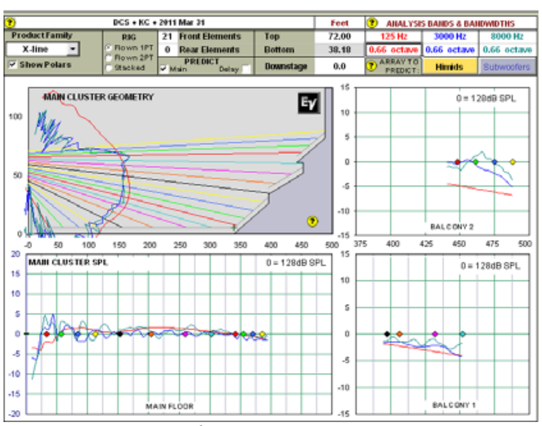

Image 12c: *20-box X-Line array at 125 Hz, 3 kHz, 8 kHz.*

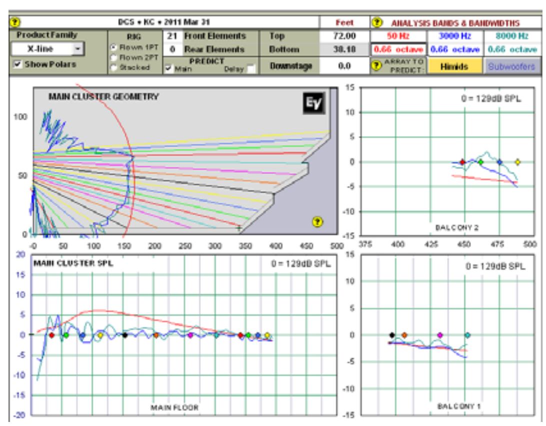

Image 12d: *20-box X-Line array at 50 Hz, 3 kHz, 8 kHz.*

While LAPS shows what is happening at these three frequencies, the modeling on this tab in LAPS does not include any effects from the room, or air absorption of the higher frequencies. There is a separate tab in the LAPS program that estimates air absorption over the distance used in that particular modeling simulation including the ability to change temperature and humidity. In the case of the Kenny Chesney show at DCS, the

20-box X-Line arrays were covering a distance up to 488’, which meant we would incur some HF loss. This is why we chose to use the house 15-box X-Line arrays to cover the back of the venue in the 100- to 300-level seating – this area was the furthest away from the main arrays and would incur the most HF loss due to air absorption. **Image 13** shows loss of HF due to air absorption incurred on the 20-box X-Line arrays over 488’ at DCS. In addition to reinforcing the HF in these areas, these 15-box arrays also helped get direct coverage in these areas, reducing the amount of perceived room reverberation heard.

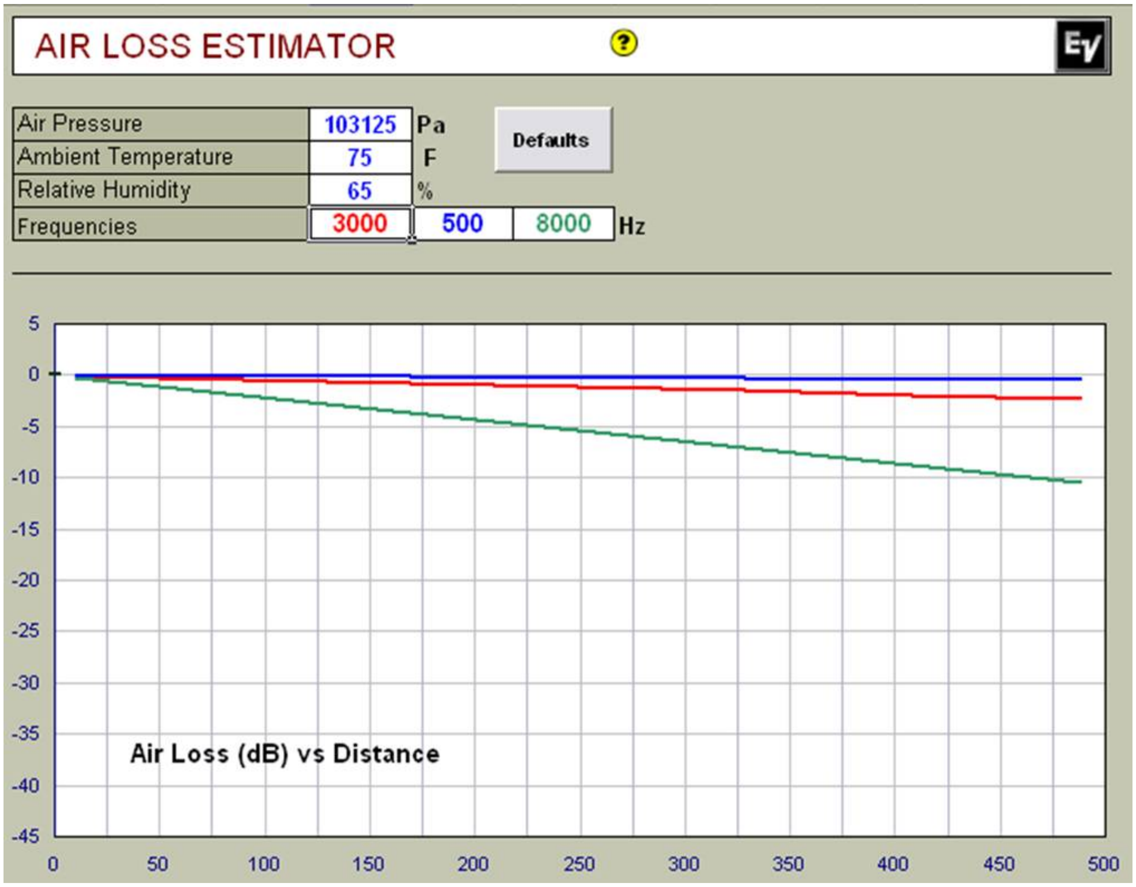

Image 13: *Air absorption on 20-box X-Line arrays over 488’ throw distance.*

Time aligning the systems: This was the most difficult portion of the “execution” process. As mentioned in the main body of this paper and shown in **Image 4**, the house 15-box X-Line arrays are at an angle relative to the main 20-box X-Line arrays, and cover an area in the 100- through 300-level seating close to 200’ wide. This meant that there had to be a compromise somewhere in the coverage area as to the alignment of the two systems. As previously mentioned, we ended up time aligning the on-axis point of the 15-box arrays to main 20-box arrays. In addition, we EQ’d the 15-box arrays with a bit more roll-off in the HF than normal in order to blend more effectively with the main 20-box arrays – this, along with close attention to the overall level of the delayed arrays, got us a reasonably balanced blend in the overlapped coverage areas.

The Xlc systems were difficult to align. As previously mentioned, the main X-Line arrays were aimed to cover up to the back of the 300-level below the suites, so there was no direct coverage up to the 400-level from the main system. Also, due the array length, the only sound from the main system making it up to the 400-level was the very LF. Our first approach was to align each Xlc array to the main X-Line arrays. This did not work as well as we had hoped, and resulted in a few more muttered expletives. Our next approach was to align the first Xlc array on each side to the main X-Line array, then align each successive Xlc array to the Xlc array before it, progressively back from the stage. This ended up working well because the Xlc arrays do overlap each other a bit in their coverage. Like the main X-Line arrays, the Xsub subwoofer arrays were aimed to mainly cover the main floor and 100- through 300-level seats – this meant that very little very LF was making it up to the 400-level seats. To round out the sound in the 400-level seats, we added an EQ bump in the 80 Hz to 100 Hz range on the Xlc arrays. While we didn't achieve thundering bass in the 400-level seats, we did get a good full-range sound that had many of those sitting there dancing the night away.

Glass-fronted suites: Between the 300- and 400-level seating there are three levels of suites, all with glass fronts. These three levels of suites account for an area about 40' high all the way around the venue that is glass. Fortunately, all of this glass is in sections and hinged, so it can be easily removed much like an air wall. Getting this much glass out of the listening area was a big deal, greatly reducing reflections back onto 300-level seating area.