Extron Flat Field® Technology Simplifies Sound Field Reinforcement Design

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Executive Summary

Learning challenges within our school systems are exacerbated by poor acoustics and no or inadequate sound reinforcement. At the state level, this inadequacy is being realized and new regulations targeting a minimum 15 dB signal-to-noise level improvement throughout the classroom requires design considerations for both voice amplification and sound pressure distribution. Current day methodologies for creating an even sound field within the classroom, conference room, or boardroom provide mediocre, uneven results. Extron invented a new, patented loudspeaker system called Flat Field Technology that virtually solves the problems associated with designing even, predictable room sound fields.

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white paper

The System Designer's Challenge

Selection and placement of loudspeakers for sound field management in classrooms and conference rooms requires a disproportionate amount of design time compared to the cost of quality speaker components. At best, positioning an array of ceiling speakers constitutes tradeoffs between listening experience versus the number and cost of ceiling speakers within a project. There is also the hidden cost associated with inefficiencies in learning. Studies(1) show that students who experience hearing limitations within a classroom environment are impeded in achievement level. Students in a class or attendees to a conference may leave without a full understanding of the presented information.

Professional AV systems designers know that typical speaker sound wave patterns are conical or circular with a specific area of coverage that is based on a solid radiation angle where speaker coverage increases with distance. As speaker coverage increases, sound pressure level rapidly decreases for listeners located off the main radiation axis away from the speaker's center. We know that sound pressure drops by 6 dB when the distance from the center of a speaker is doubled. This is known as the inverse square law.

Attempting the creation of a level sound field over a wide area requires the installation of a number of speakers located such that radiation angles overlap significantly so as to provide wide area coverage. While classically appropriate, this methodology creates listener positions where sound pressure level varies considerably. Beneath the center of the speaker, sound pressure level is very high; while any other position off axis results in significantly lower sound pressure level. In addition, in locations where sound pressure from two adjacent speakers intersect, areas of sound wave cancellation occur that create sound pressure voids. Audio reinforcement system designs regularly encounter these tradeoffs as illustrated in Figure 1.

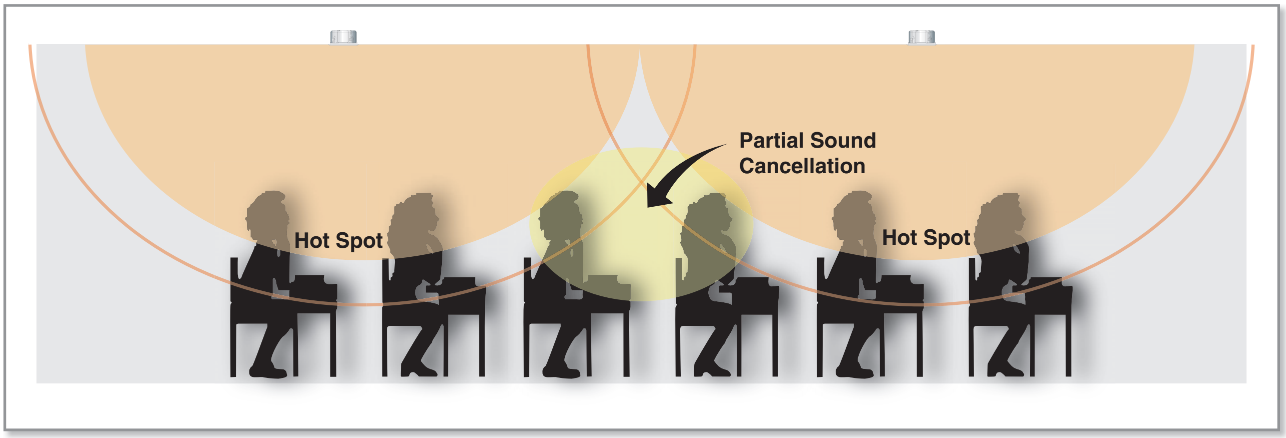


Figure 1: Trade offs with traditional speakers include hot spots, inconsistent coverage, and cancellation

When speakers are driven optimally, only listeners positioned directly under the speaker realize full sound reinforcement. As listener position varies from optimum, a commensurate decrease in sound pressure causes less than optimal hearing ability. System designers must balance sound pressure level between the on-axis "sweet spot" with the depreciated performance occurring at distances away from the speaker's center axis due to the inverse square law mentioned above.

The farther a listener is from the speaker, the lower the volume level. Mathematically, a listener located twice as far from the speaker's axis as another listener suffers a 6 dB loss in sound level compared to the closer listener. Should a listener be so unfortunate as to be located within a cancelation zone, the sound level could depreciate by 12 dB or more.

It may appear that the solution is to turn up the volume. Certainly, some level of loss may be overcome; but at the sacrifice of hearing comfort by those listeners located directly under the ceiling speakers. Compensation for areas of partial cancelation means that increasing volume as much as 12 dB creates a sound pressure level perceived to be more than double to those located directly under, or very nearby, the loudspeaker.

The Solution: Extron Patented Flat Field Speaker Technology

Extron's research over the past five years has shown us that significant progress is still to be realized in audiovisual presentation as it pertains to the learning process; whether in the classroom, company conference room, or executive boardroom. The physics behind sound field management emphasize the aforementioned deficiencies and limitations in typical loudspeaker selection and placement.

Sound engineers have dealt with these issues for years in corporate environments. Now with schools rapidly adopting audiovisual equipment into classroom environments, they run into similar problems – usually with significantly smaller budgets.

The realization of Extron's research into this challenge is a new **patented** speaker performance paradigm where the redirected sound pressure disperses 170 degrees with a virtually flat sound field from the on-axis position to more than 60 degrees off-axis. We call this phenomenon our Flat Field Technology. The radiation pattern of Extron's Flat Field Technology translates to a speaker coverage pattern that is efficient and fully usable with no perceived loss in sound pressure level. Its unique, construction embodies a single, full range speaker having a horn-loaded design that extends low frequency on into medium and high frequencies without need for a crossover network.

How it works

To understand how Extron's Flat Field Technology works, consider the way in which a basic convex lens focuses light rays. In Figure 2, light rays enter the lens from a distant object. The light rays, for all practical considerations, are parallel. The refractive attributes of the lens bend the light rays to converge on a point some distance behind the lens. The distance at which the rays converge to a single point is called the focal length of the lens.

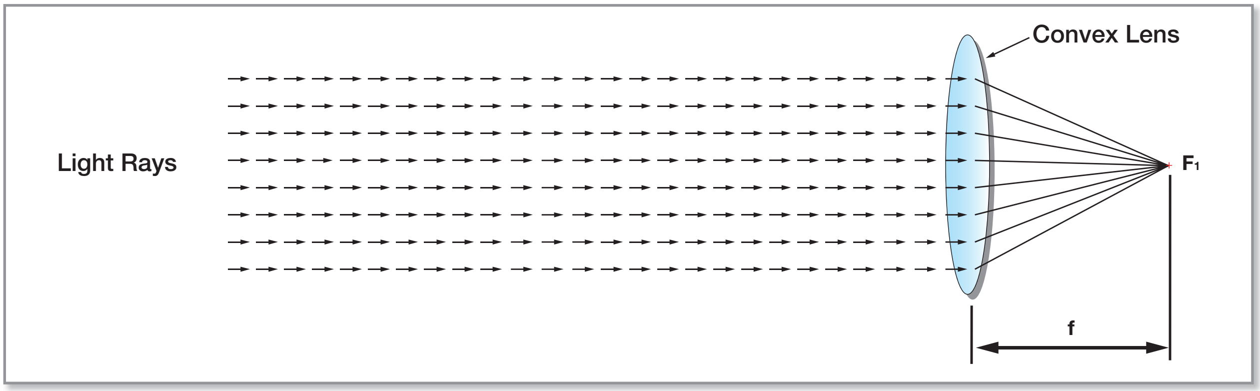


Figure 2: Light rays entering a convex lens are focused at some point behind the lens.

This property of optics can be utilized in reverse. A lens positioned precisely at its focal length in front of a point light source will collect light from the source and redirect it to appear to the observer as a broad, flat light source. In fact, this is similar to how a large screen projector functions. Pixels on an imaging device resting at the precise focus of an objective lens are collected and projected as diverging rays toward the screen. The diverging rays allow for the magnification of the image to a larger size useful for audience presentation. Similarly, sound waves can be directed so as to realize a flat sound field even though those sound waves are diverging from a point source.

Extron's Flat Field Speaker design treats the speaker, the sound source, as a point source. The mechanical design of the speaker and its enclosure represent a closely-coupled point source and 'lens' combination. Radiated sound waves are redirected, somewhat like refraction, to better equalize the perceived sound pressure level over the divergent coverage area of the speaker. Figure 3 illustrates this concept and compares it to the typical sound field realizable from a regular ceiling speaker shown in figure 1. The typical speaker radiation pattern creates an on-axis hot spot plus zones of reinforcement and cancellation when grouped into ceiling arrays.

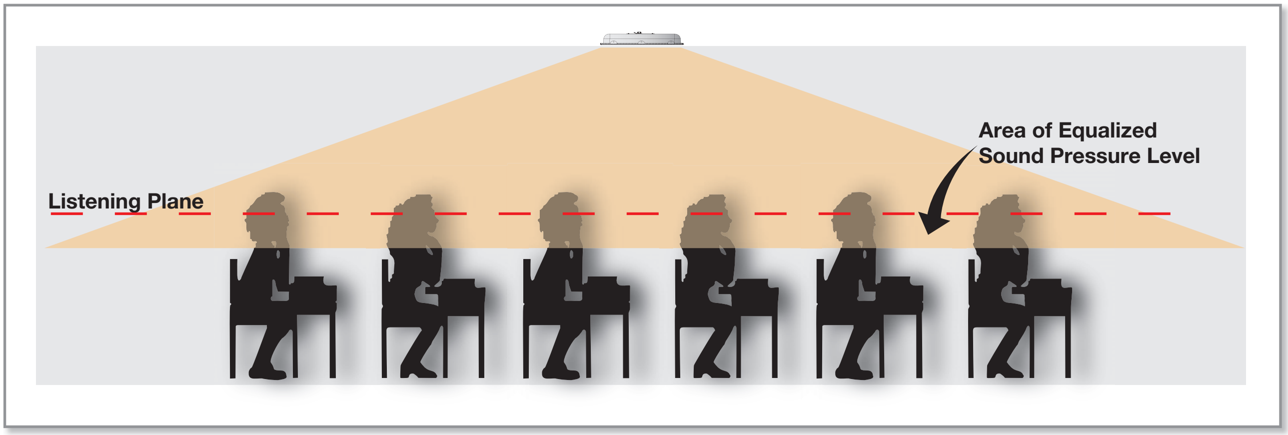


Figure 3a: Coverage pattern of Flat Field Technology showing equalized sound pressure levels.

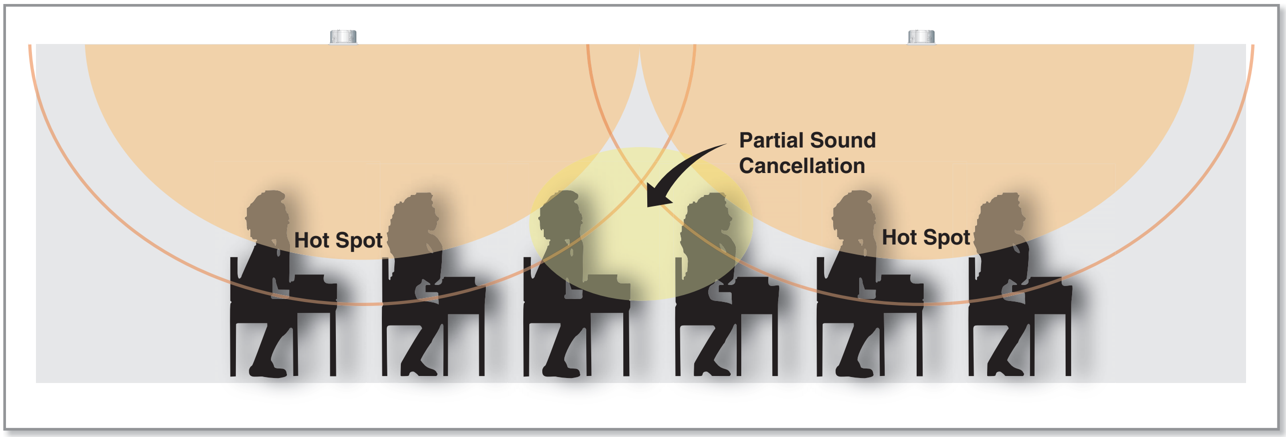


Figure 3b: Coverage pattern of a typical ceiling speaker showing hot spots and area of cancellation.

Figure 4 is a half-space plot illustrating the sound field of the typical ceiling speaker having a 120 degree nominal coverage. The primary radiation zone defines the "ideal constant SPL Line". All listeners positioned along this constant SPL line receive the same sound pressure level. Practically, only one or a few listeners will reside where the SPL is optimum.

Refer to the location of Student 1 in Figure 4. Student 1 and Student 2 reside along an imaginary horizontal plane known as the typical listening plane. The shaded area inside the ideal constant SPL region illustrates a more typical response of a ceiling speaker where the off-axis response is much less than ideal. In many cases, the off-axis SPL at 60 degrees can be as much as 6 dB less than the ideal. Most listeners will reside at some additional distance from the ideal constant SPL line. Student 2 resides at twice the path distance from the speaker as Student 1. Since sound pressure level decreases as the square of the distance, Student 2 will experience another 6 dB loss in level that, when added to the possible 6 dB off-axis loss of the non-ideal ceiling speaker, results in a 12 dB lower sound pressure level overall. This region is shown as the -12 dB SPL line. Student 2 will perceive the sound level as less than half the level Student 1 experiences. The second shaded region inside the 120 degree coverage angle and surrounding the ideal constant SPL line represents the sound pressure level compensation provided by the Extron FF 120 Flat Field speaker system. All listeners within the horizontal coverage plane of the FF 120 will experience the same sound pressure level.

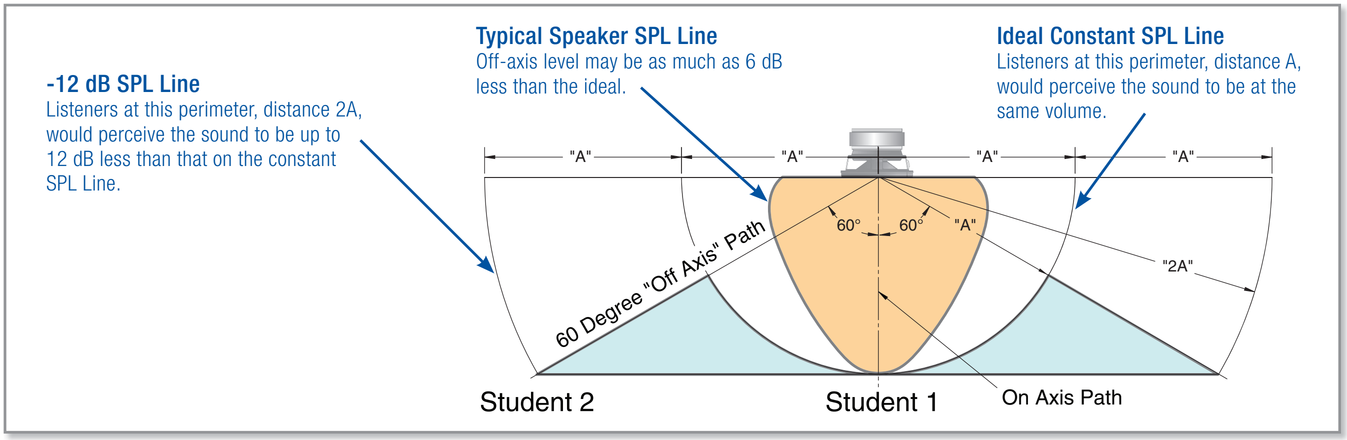


Figure 4: A comparison of a typical ceiling speaker coverage area and the Extron FF 120 Flat Field speaker coverage area to the ideal half-space speaker radiation pattern. For a typical ceiling speaker, Student 2 hears sounds that are up to 12 dB less (less than one-half as loud) than Student 1 hears. Extron's FF 120 speaker compensates for off-axis losses and provides a constant sound level to all students within its coverage area.

Frequency Response and Polar Pattern Graphs

Extron's Flat Field speaker technology manages the sound field such that all listeners within the prescribed coverage area receive virtually the same SPL. Figure 5 shows an actual response graph of the Extron Flat Field FF 120 speaker SPL versus frequency. In this graph, the one-watt, one meter half-space (2π) response is shown as a reference.

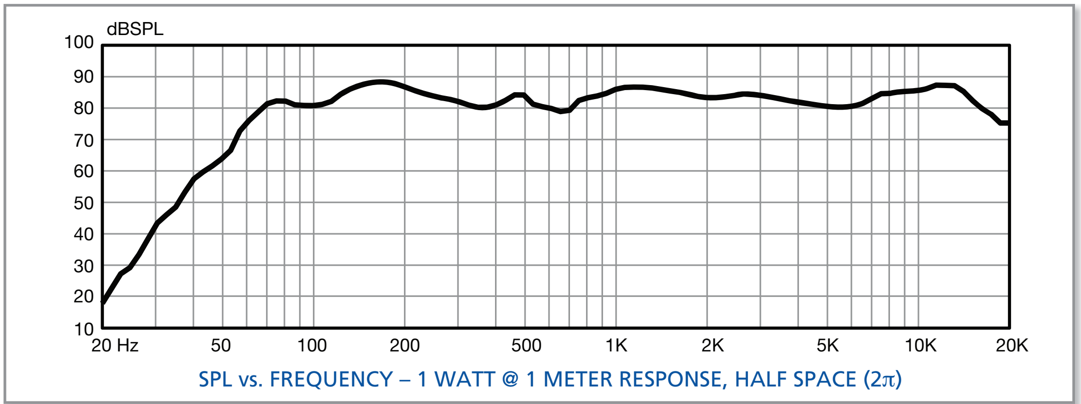


Figure 5: The FF 120 frequency response extends from 68 Hz to 18 kHz (-10dB) with particularly flat response in the vocal range.

Figure 6 shows how the FF 120 off-axis response measures up over the usable frequency range. Within zero to forty degrees off axis, the FF 120 produces a constant SPL to all listeners within that sound field area.

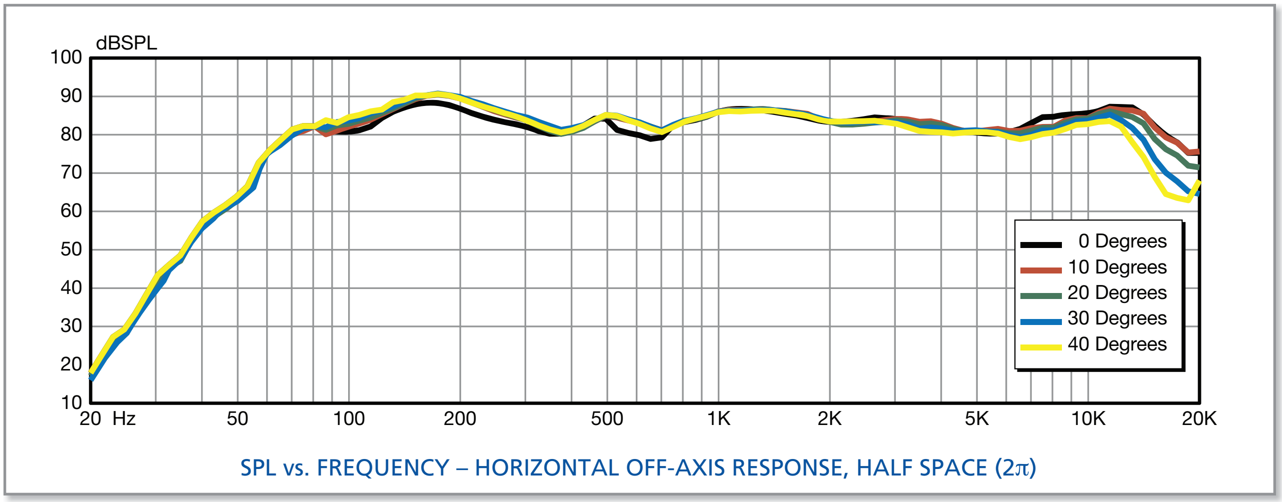


Figure 6: The FF 120 Off-Axis Response Chart demonstrates the speaker's ability to maintain its frequency response without off-axis coloration.

A polar response plot is used to clearly illustrate the basic radiation performance of a speaker over a wide range of off-axis angles. The zero degree point in the plot represents the FF 120's on-axis radiation, which is used as the reference measurement. This point is directly under the speaker where its sound pressure is normally assumed to be the greatest.

Further Reading

For more information on third-octave analysis of loudspeakers see Appendix 1.

Measurements in one-third octave increments characterize the full performance of the speaker in steps that make visualization much easier. The polar plots of Figure 7 shows how the FF 120 speaker manages SPL from 630 Hz through 3.15 kHz, the frequencies that convey most voice patterns of presenters. This one-third octave grouping represents the region containing most frequency components of human speech. You will see that the SPL increases +6 to +10 dB at approximately 45 degrees off-axis and beyond. This increase in off-axis sound pressure is the unique dispersion characteristic of the Extron FF 120 speaker. The FF 120 maintains sound pressure level for those off-axis listeners positioned twice as far away from the speaker's on-axis reference line, as shown in Figure 4. To see the complete polar response chart for the FF 120 and a competitive ceiling speaker, see Appendix 2.

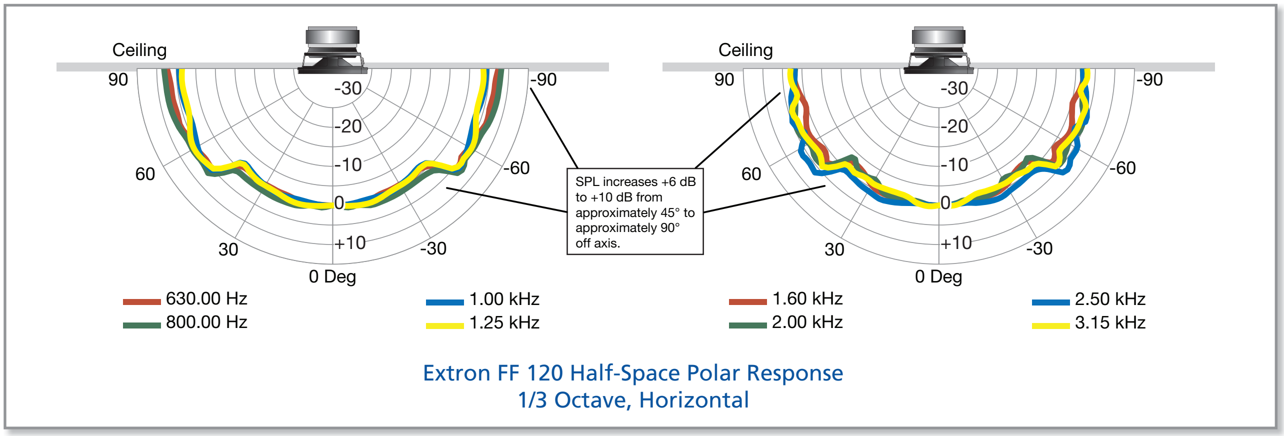


Figure 7: The FF 120 Polar Plots at one-third octave increments for frequencies supporting speech.

Maintaining SPL for frequencies supporting speech, such as from 630 Hz through 3.15 kHz, ensures more intelligible presentations. With regular ceiling speaker designs, a listener sitting along the maximum off-axis angle experiences sound level that is perceived to be less than one-half as loud.

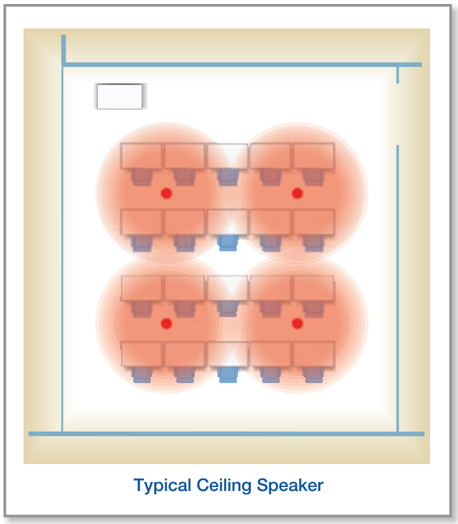


Figure 8: A plan-view illustration of the typical layout for ceiling speakers to obtain enough overlap for sufficient sound field coverage.

How Extron's Flat Field FF 120 Speaker Helps You

Figure 8 illustrates a typical plan view for a classroom speaker sound field. Regular speakers produce a circular sound field having 6 dB SPL loss at the limit of their specified radiation angle. A sufficient quantity of speakers must be installed with significant overlap in order to accomplish full room coverage without perceived SPL loss over the listening area. At best, regions of sound reinforcement and regions of sound cancellation still occur as discussed earlier. System design and speaker selection must be done very carefully. On average, more speakers are needed in order to approach an even sound field for the room.

Efficient Coverage

Figure 9 shows the sound field created by the Extron FF 120. Overlap requirements of the FF 120 are much less critical since the speaker's radiation pattern is highly efficient. It requires less overlap and will have virtually no sound cancellation zones. This means that, with minimized overlap required, fewer speakers are needed to ensure even coverage. This translates to simpler installation and lower cost, both in speaker components and installation labor time. For example, in a room with a ten foot ceiling and an average listener ear height of four feet above the floor, the FF 120 provides uniform coverage diameter of 20.75 feet that translates to 338 square feet. This is in contrast to the typical ceiling speaker technology which provides a 12 foot diameter of reasonably level SPL for a coverage area of only 113 square feet.

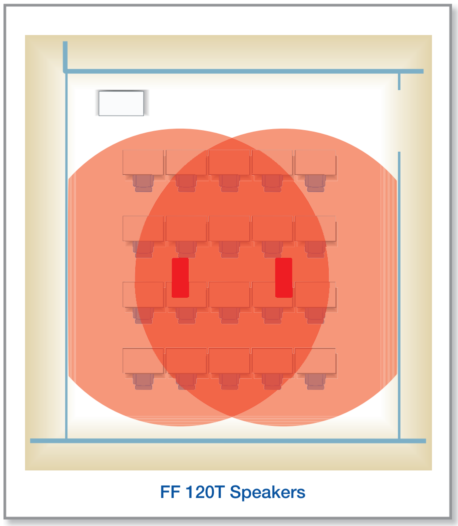


Figure 9: A plan-view illustration of how the Extron FF 120 layout attains enough overlap with fewer speakers.

In his white paper "Classroom Sound Distribution", Michael Teixido, M.D.(2) cites recent adoption of new school construction standards in the State of Delaware that specify a +15 dB signal-to-noise ratio requirement in all areas of the classroom. This means that the teacher's voice, the "signal", must be 15 dB, or more than twice as loud, as the room background noise level. How school system officials will accomplish this while staying within a budget is left solely to them. Ultimately, the responsibility shifts to the room audio system designers.

Dr. Teixido goes on to point out that "cognitive problems, hearing loss, and language unfamiliarity are common among today's students. In a first grade classroom, 15-20% of students may have mild hearing loss on any given day because of middle ear infection, pressure or fluid related to Eustachian tube dysfunction from colds or allergies. 10 to 15% of children will have some degree of mild learning disability and, for 5 to 11%, English will be their second language. All of these children have learning challenges in acoustically optimal conditions that are compounded in suboptimal acoustic environments."

There are many current studies relating to academic gains through improvement of the classroom sound field. A growing collection of actual measurement data within classroom environments all point to the importance of maintaining a consistent signal-to-noise ratio of about +15 dB over the average ambient noise level within the room. Other acoustic anomalies, like reverberation time, impact the overall experience as well. Extron believes that the FF 120 Flat Field Technology is an important and proactive step toward creating the optimum room sound field, which enhances student learning. Careful redirection and control of sound reinforcement at the outset just makes good sense while costing less in the long run.

The FF 120 easily installs into a 2’x2’ or 2’x4’ suspended ceiling tile system

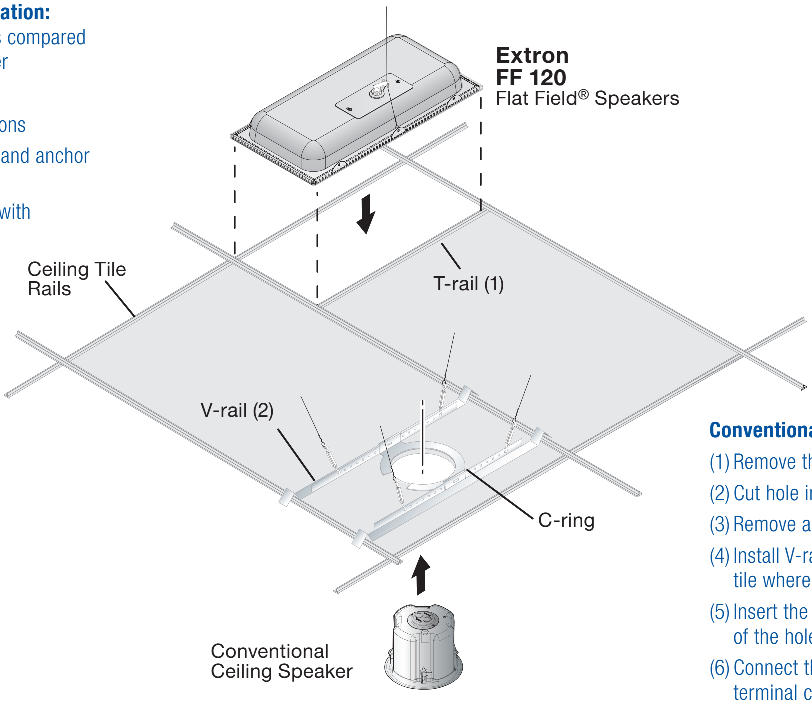
Simplified Installation

From the installation perspective, the FF 120 speaker will save time and cost since its design is a simple rectangular shape created for ease of installation into a suspended ceiling grid. Installation requires only that the end of a ceiling tile insert be cut and the speaker assembly dropped into place alongside the ceiling tile. There are no circular holes to cut or mounting rings and clamps to maneuver. After installation, the Extron FF 120 is easily lifted out of the ceiling grid without disturbing the other components of the ceiling work. In addition, the height profile of the FF 120 is lower than most ceiling loudspeakers that use a metal back box. The Extron Flat Field loudspeaker supports both small and large system installations since it is available in both eight ohm and 70 volt models.

Ceiling speaker installation comparison

FF 120 speaker installation:
Requires 50% less steps compared to a conventional speaker

(1) Remove ceiling tile
(2) Make wiring connections
(3) Place FF 120 on grid and anchor with seismic tabs
(4) Trim ceiling tile to fit with provided T-bar



Conventional speaker installation:

(1) Remove the ceiling tile
(2) Cut hole in the tile; reinstall the tile
(3) Remove adjacent tile
(4) Install V-rails and C-ring across the tile where speaker is to be installed
(5) Insert the speaker through the bottom of the hole in the ceiling tile
(6) Connect the wires to the speaker terminal clips
(7) Place speaker in C-Ring and anchor seismic support line
(8) Install the speaker grille

The FF 120 speaker is easier and quicker to install then conventional speakers

The inconspicuous white grille allows the FF 120 to blend into the ceiling.

Theft Deterrent

A not-so-obvious benefit of the FF 120 design is that it has the same appearance as an air handling vent in the suspended, or drop-in tile ceiling. This means that it is less prone to theft or tampering since most people will not recognize it as audio equipment. Extron designed it to blend into the ceiling structure as much as possible. Its Flat Field dispersion characteristics make it even more difficult for individuals to localize in the room as a speaker component.

UL 2043 Listed for Plenum Application

Mounting ceiling loudspeakers is most often accomplished by modification of and insertion into suspended ceiling acoustic tiles. The space above the ceiling tile, in many cases, is used as an air return space for the building heating and cooling system. UL refers to this space as “other air handling spaces”, but in the AV vernacular, we typically refer to it as a “plenum” space.

In order to comply with local building safety codes, ceiling speakers need to be “plenum rated” if mounted within a designated air handling space. The plenum rating requires listing specifically to UL 2043.

The FF 120 Flat Field speaker design concept began with UL 2043 plenum application approval in mind. It conforms to NFPA90A, NFPA70, and UL 1480 requirements. The FF 120 is unique not only for its technological edge, but it is one of a very few ceiling loudspeakers that actually pass the stringent UL 2043 flame test requirements for heat and smoke release in air handling spaces.

Flat Field Technology and the Extron S3 Philosophy

We are proud of our Flat Field speaker technology and invite you to listen to it yourself and decide. Extron is excited and motivated with the opportunity to provide meaningful technical solutions to our industry, our educators, and most of all to those whose life can be enriched through better learning. We see Flat Field Technology as yet another important Solution to offer you that exemplifies our S3 philosophy of Service, Support, and Solutions.

REFERENCES:

(1) Various research and studies highlighted at The Institute for Enhanced Classroom Hearing, http://www.classroomhearing.org/index.html

(2) “Classroom Sound Distribution” by Michael Teixido, M.D., white paper page 3, April 2007, found at the web site on classroom hearing: http://www.classroomhearing.org/index.html

Appendix 1: Why use third-octave analysis to measure loudspeaker performance?

There are many tools available for audio and acoustic measurement and characterization. As with most tools, they can be used in more than one application. The difference resides in how efficiently a particular tool operates or in the outcome it provides. In the audio realm, there are two commonly encountered measurement situations: near-field measurement of components (such as a loudspeaker) and far-field measurement of components or rooms – that is, the acoustics. Each of these situations can use two basic test signal types: pink noise or discrete third-octave sine waves.

Pink noise is often used in conjunction with a Real Time Analyzer, or RTA, in the so-called 'far-field' to analyze room acoustics and the relative contribution of a loudspeaker or speaker array. Pink noise is a filtered version of white noise, which is a fully broadband, equal energy noise source at all frequencies. Filtering is important in pink noise such that it creates a proportionate decrease in energy level as frequency increases. Pink noise contains equal energy throughout each octave range. The result is a decrease in energy concentration of 3 dB per octave, which more closely represents human hearing perceptions. This type of measurement typically utilizes filtering or averaging that 'looks' at the combined energy from the audio source over some timeframe. Pink noise provides instantaneous energy that when combined with room acoustic anomalies, like reverberation, provides averaged sound pressure information that is meaningful for room tuning.

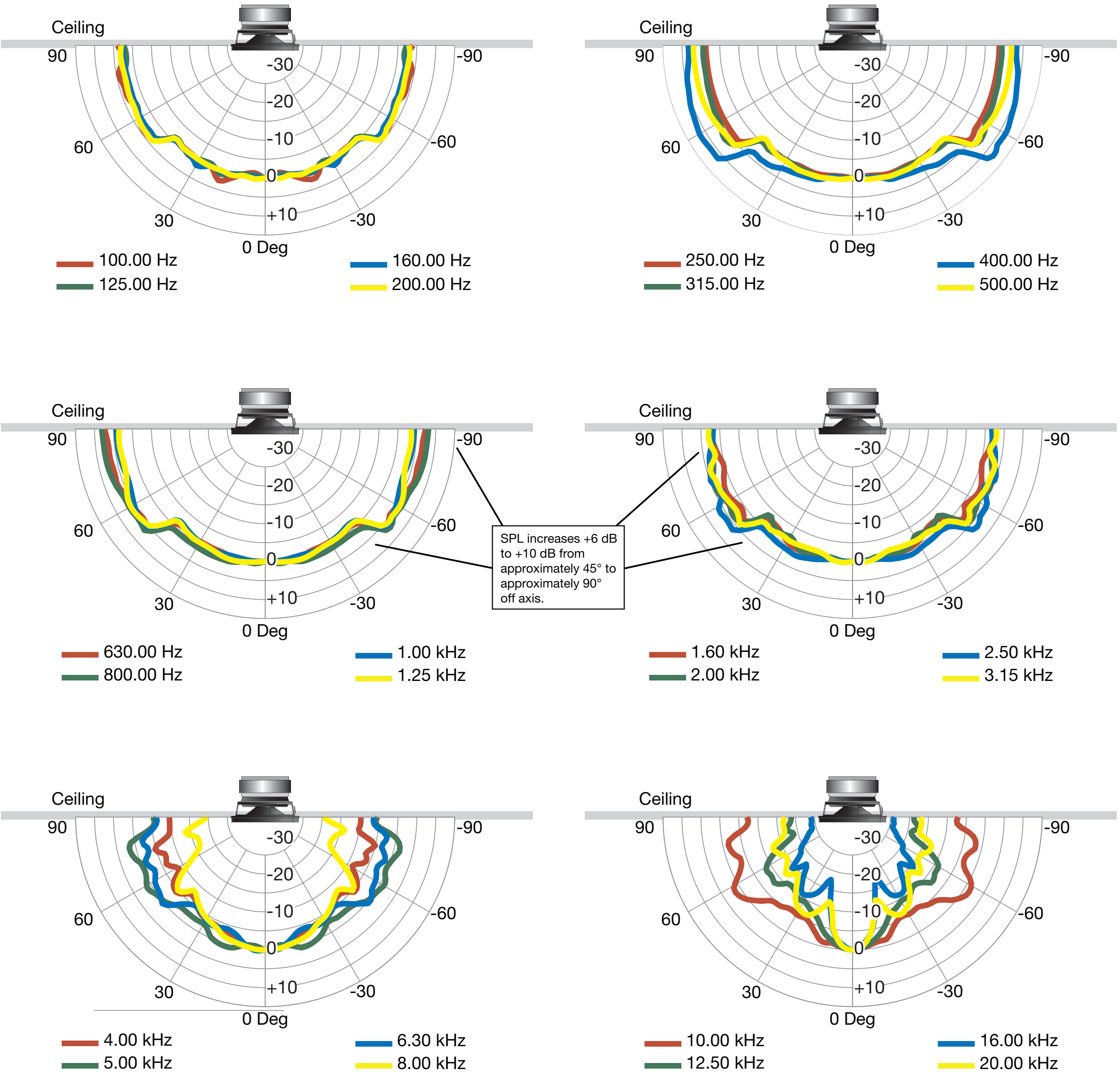
The human auditory system is very complex and not fully understood. There are competing theories on just how we perceive sound. Further, the response of the ear is not physically able to resolve frequencies above about 5 KHz based solely on its physical makeup and the results of actual data that measures the rapidity with which the hair-like receptors within the auditory complex 'fire' messages to the brain. The combination of two theories: the frequency theory and the resonance, or place, theory tend to explain the complex interactions that seem to support our ability to hear high pitch sounds without the direct means to do so. These two theories attempt to address the seemingly coordinated way in which the hair-like receptors are physically arranged along with their individual electrical responses. All this is to say that measurement of specific audio components alone should be done in such a way as to mimic the human hearing complex as closely as possible.

This is where third-octave analysis comes into play. The accepted range of human hearing, 20 Hz to 20 KHz, can be divided into ten octaves. It seems that our ears tend to subdivide, or have regions of sensitivity, that handle smaller ranges of frequencies. Further dividing the ten octaves into thirds delineates regions of frequencies that more closely mimic human hearing than broadband noise sources. The frequencies listed in the accompanying speaker response charts represent those third octave regions. Precise measurement at third octave frequencies provides more correlated and repeatable measurement data that compares favorably to the type of response reported by human listeners.

The measurement of loudspeakers is typically a near-field measurement. The near-field is often one meter distant from the front plane of the speaker and may be even closer depending on the speaker design and whether it consists of a single driver or multiple drivers. The intent is to measure only the performance of the speaker component and not the surroundings or room acoustics. Third-octave measurement is carried out by performing discrete measurement of the component repeatedly while changing the frequency in third-octave sine wave increments. Over the duration of each sine wave frequency, the calibrated microphone is moved in a controlled radial arc around the speaker. In the case of measurement data shown in this paper, the microphone is moved over a semicircle rather than a complete circle. This measurement is called “half space” as it mimics the installation of a speaker within a confined space such as a ceiling. The constant sine wave provides consistent, repeatable results though it takes longer to perform the measurements.

Appendix 2: Comparison of FF 120 Flat Field Speaker to Conventional Ceiling Speaker

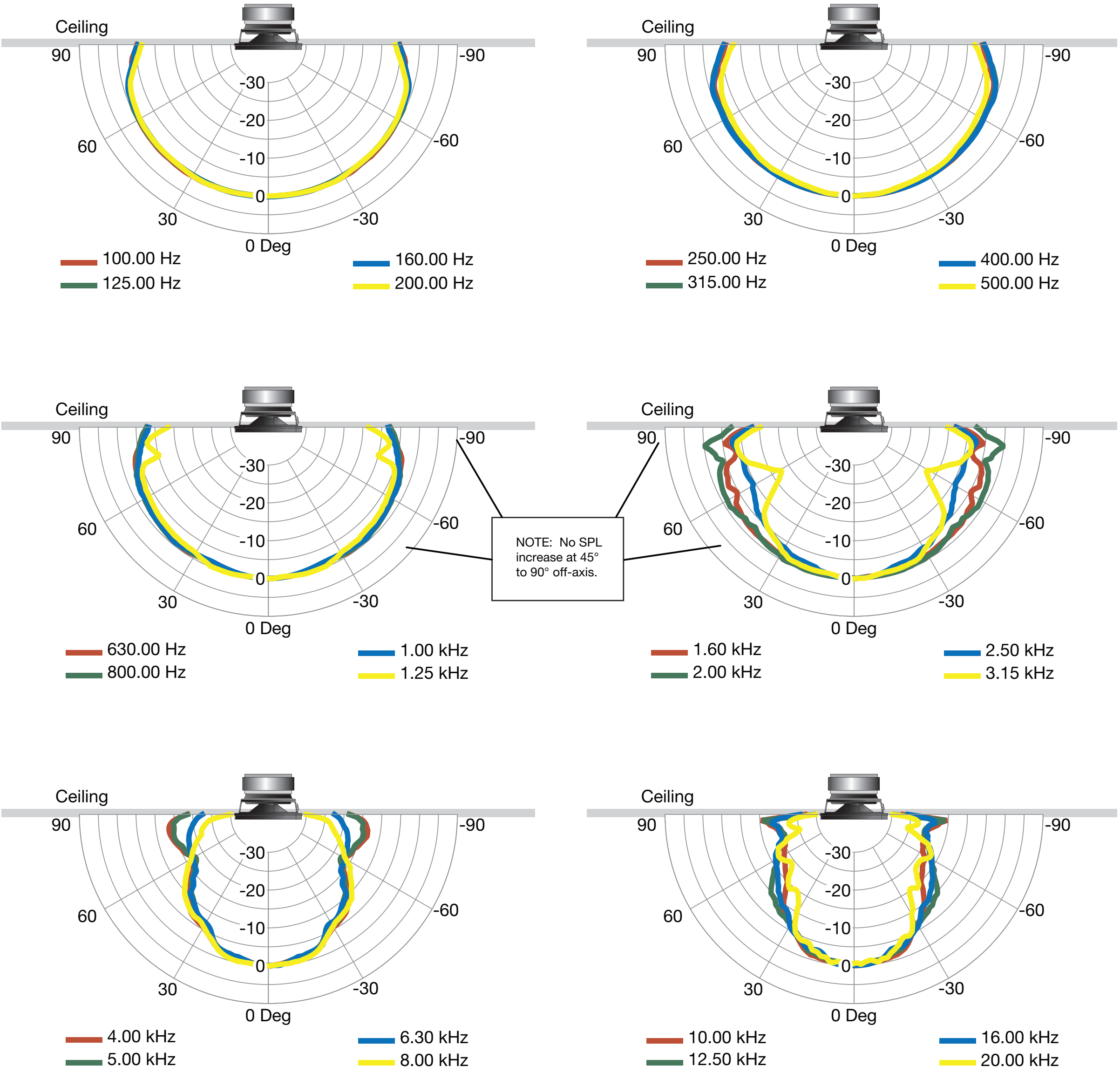
Speaker with Flat Field Technology



SPL increases +6 dB to +10 dB from approximately 45° to approximately 90° off axis.

FF 120 Half-Space Polar Response 1/3 Octave, Horizontal

Standard Ceiling Speaker



NOTE: No SPL increase at 45° to 90° off-axis.

Half-Space Polar Response 1/3 Octave, Horizontal of Typical Ceiling Speaker

Notes

Notes

Extron Electronics, headquartered in Anaheim, CA, is a leading manufacturer of professional A/V system integration products. Extron products are used to integrate video and audio into presentation systems in a wide variety of locations, including classrooms and auditoriums in schools and colleges, corporate board rooms, houses of worship, command-and-control centers, sports stadiums, airports, broadcast studios, restaurants, malls, and museums.

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