JBL PROFESSIONAL by HARMAN

WHITE PAPER

JBL INTELLIVOX LOUDSPEAKERS BEAM SHAPING

How JBL Intellivox Digital Directivity Synthesis (DDS) Improves Coverage, Frequency Response and Intelligibility

EXECUTIVE SUMMARY

Intellivox has been at the forefront of column array loudspeaker technology for over 20 years. From New York's Grand Central Station to Cologne Dome in Germany, JBL Intellivox Loudspeakers are used in high-profile, acoustically challenging environments due to their ability to provide consistent performance in SPL, frequency response and intelligibility along with exceptional long throw capability.

CONTENTS

THE HISTORY OF JBL INTELLIVOX

The history of digitally controlled column array loudspeakers began in 1996 with the launch of the Intellivox 2C by Duran Audio. At the time of its release, the Intellivox 2C was the world's first commercially available, fully integrated, digitally controlled loudspeaker array with beam steering technology. Beam steering takes advantage of the natural interference that occurs between arrayed components, in tandem with digital processing to direct audio from a loudspeaker to the desired listening area.

At the Institute of Acoustics conference in 2000, Duran Audio presented the theory behind Digital Directivity Synthesis (DDS), commonly referred to as Beam Shaping. The theory of DDS laid the foundation for the technology used in today's Intellivox Loudspeakers, and by 2004 the evolution from beam steering to Beam Shaping had become a reality. In 2014, Duran Audio joined the HARMAN family, bringing its full range of products and technology, including Intellivox.

CURVED VS COLUMN LINE ARRAYS

The two most common types of loudspeaker arrays available today are the curved line array and column line array. The most significant difference between the two is in how they manage high frequencies.

Curved line array systems use waveguides to mechanically aim sound and restrict interference in high frequencies.

Column array loudspeakers, like the Intellivox series, rely on a wide dispersion across all frequencies and take advantage of the natural interference between drivers to focus the coverage pattern produced by the array. Passive circuitry, or active DSP (as found in Intellivox), then provides the necessary compensation in order to maintain a linear frequency response.

It should be noted, however, that in curved line arrays and column arrays alike, the overall length of the array determines the directionality in lower frequencies.

WHAT IS INTELLIVOX FOR?

The acoustics and background noise of any space have direct implications on a person's listening experience. As room reflections increase and background noise encroaches on the direct sound, intelligibility of the original source is often obscured or lost, and the listener may no longer be able to understand the audio.

Intellivox narrows the beam of sound emitted from the loudspeaker array and directs it at the listener, thereby reducing the amount of reflected sound. By avoiding the loss over distance associated with conventional loudspeakers and passive arrays, background noise can be consistently overcome without overamplification in any one listening area. To best demonstrate the benefits of Intellivox, it helps if we think of a loudspeaker as a spotlight instead of a floodlight, directing sound where we want, without "illuminating" surrounding areas. This concept is the foundation by which Intellivox maintains high speech intelligibility.

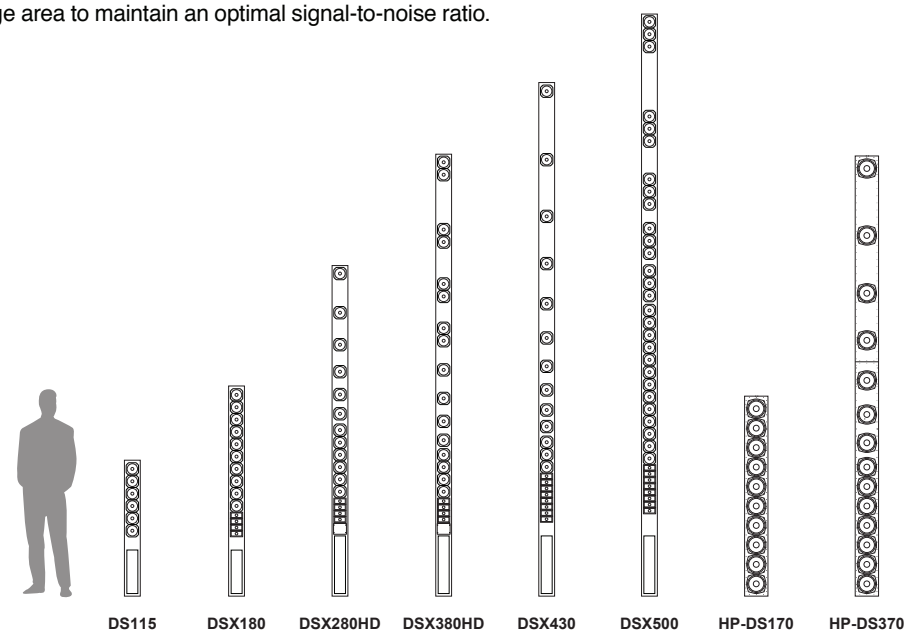
THE GOAL: SPEECH INTELLIGIBILITY

Speech intelligibility is an area of critical importance that relies heavily on two factors—the direct-to-reverberant ratio and signal-to-noise ratio.

Direct-to-Reverberant Ratio is the ratio of direct sound to reverberant sound.

Signal-to-Noise Ratio measures the amount of background noise compared to the direct sound. High levels of background noise can significantly reduce the intelligibility of a PA system.

Intellivox Beam Shaping improves the performance in each of these critical areas. Intellivox focuses the sound on the audience to reduce reverberant energy, and provides consistent SPL and frequency response over the coverage area to maintain an optimal signal-to-noise ratio.



INTRODUCING THE INTELLIVOX LINEUP

The Intellivox lineup of loudspeakers is comprised of three categories—Intellivox, Intellivox High Power, and Intellivox ADC.

INTELLIVOX

The standard Intellivox range features array lengths up to 5 meters, constant SPL up to 70 meters and horizontal coverage of 130 degrees. Comprised of four-inch drivers, horn-loaded tweeters, onboard amplification and DSP, and a low-profile footprint of 5” wide by 3.5” deep, making Intellivox an ideal choice with a low architectural impact. Standard Intellivox solutions include DDS Beam Shaping and are ideal for houses of worship, education, transportation and any large spaces with high reverberance.

Standard Intellivox models include the DS115, DSX180, DSX280 (High Density), DSX380 (High Density), DSX430, and DSX500.

INTELLIVOX HIGH POWER

Intellivox High Power models are available in array lengths up to 3.7 meters and are IP55 rated for outdoor use. They support a maximum peak SPL, up to 105 dB at 30 meters, with 100 degrees of horizontal coverage. The Intellivox High Power series features 6.5” drivers and coaxial HF compression drivers, all in an 8” wide by 7.5” deep footprint. Intellivox High Power loudspeaker arrays also include DDS Beam Shaping, making them ideal solutions for houses of worship, sports complexes, transportation hubs, and live music reinforcement.

Intellivox High Power models include the HP-DS170 and HP-DS370.

INTELLIVOX ADC 70V/100V (ANALOG DIRECTIVITY CONTROL)

The Intellivox ADC series are passively controlled loudspeaker arrays, and unlike the Intellivox and Intellivox High Power series, they contain no DSP. These passive column loudspeakers are for used in 70V and 100V distributed systems in the transportation and life safety markets.

Both models feature fixed electronic aiming with 30 degrees of vertical coverage, with a 5 degree downtilt, allowing for flush mounting in the V90, and 40 degrees of horizontal coverage in the H90. The Intellivox ADC series is also EN54-24 and BS5839-8 certified for broadcast warnings used in fire detection and alarm systems.

Intellivox ADC models include the vertically installed V90 and the horizontally installed H90.

THE TECHNOLOGY BEHIND JBL INTELLIVOX DSP CONTROLLED LOUDSPEAKERS

CLASS D AMPLIFIERS

Intellivox and Intellivox High Power loudspeakers utilize multi-channel Class D amplifiers (8, 12, or 16 channel depending on the model) and logarithmically spaced drivers for improved efficiency and lower power consumption.

> The acoustics and background noise of any space have direct implications on a person's listening experience.

ONBOARD DSP

All Intellivox and Intellivox High Power loudspeakers are outfitted with onboard DSP that includes:

- Eight memory pre-sets with recall capability over the RS485 network
- Two inputs, each with four-band parametric EQ, volume control, and delay
- Output processing utilizing the DDS algorithm for venue specific coverage, plus:
    - Eight-band parametric EQ
    - Delay
    - Gain
- Built-in ANS microphone and processing
- Surveillance features to monitor system status

COLUMN LENGTH AND DRIVER SPACING

It's important to understand the underlying theory behind array loudspeaker design in order to appreciate the impact of DDS on a column array.

THE DEFINITION OF AN ARRAY AND ITS PHYSICS

An array is a collection of loudspeakers that are assembled to achieve a radiation pattern that cannot be achieved with a single driver. Sound waves sum in the target direction and cancel in other directions. This cancelation is relative to the wavelength of a given frequency.

As the audible sound spectrum covers such a wide range of wavelengths, it's important to note that:

1. As wavelengths increase, the array length must also increase
2. As wavelengths decrease, the distance between array components must also decrease
3. Driver spacing at half a given wavelength provides maximum off-axis cancellation

HOW DRIVER QUANTITY AND SPACING IMPACTS COVERAGE

Let's look at how array length and driver density affect an array's dispersion at various frequencies.

Constant Directivity

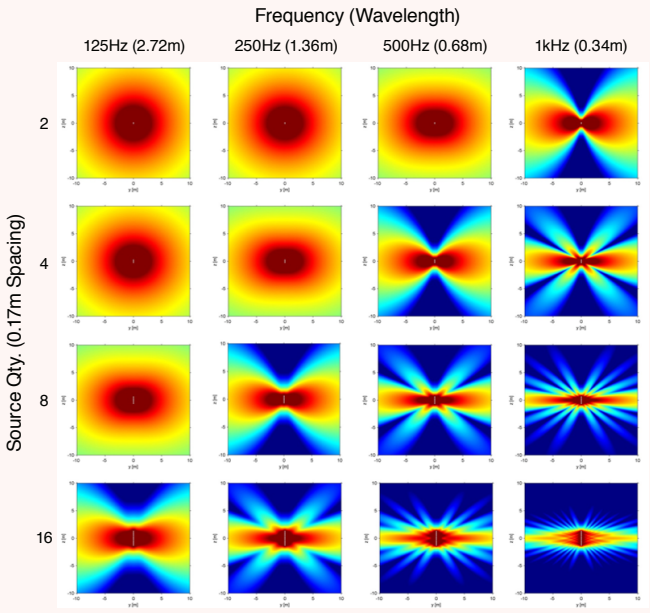


Figure A – The resulting dispersion of sound at increasing frequencies (left to right), and increasing driver quantities at fixed spacing (total array length) top to bottom.

Spatial Sampling

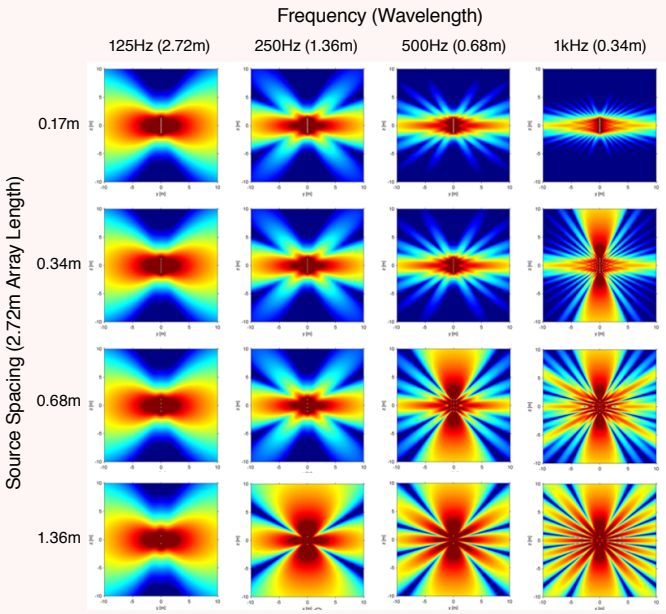


Figure B shows the resulting dispersion of sound at increasing frequencies (left to right), but rather than increasing the size of the array, its length is fixed and the space between drivers is increased (top to bottom) in order to reduce driver density.

Constant Directivity

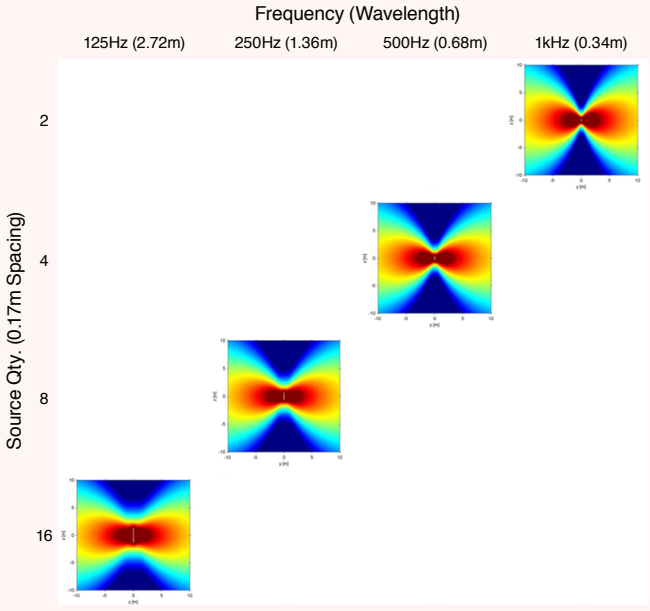


Figure C – As frequencies increase, shorter arrays are needed to generate the same coverage pattern that longer arrays generate for lower frequencies.

Spatial Sampling

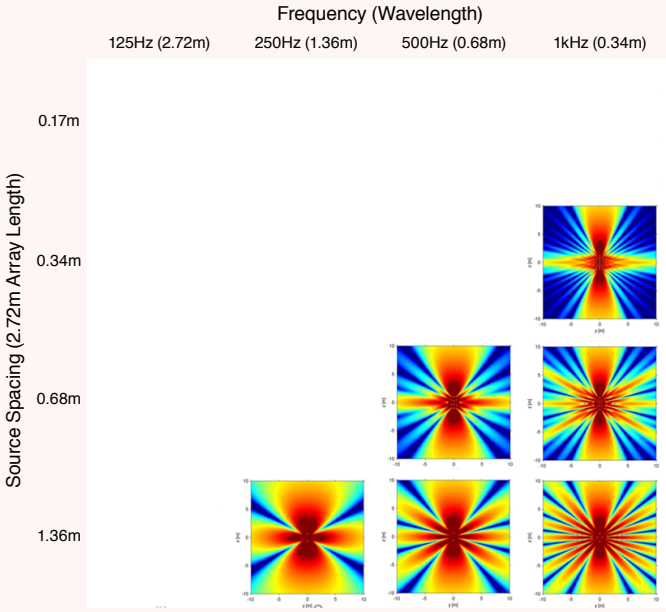


Figure D – As the space between drivers approaches and exceeds the wavelength of a given frequency, the main lobe breaks down and is overpowered by those radiating off-axis.

THE FUNDAMENTAL PHYSICS OF ARRAYS AND THEIR LIMITATIONS

Now that we've demonstrated how speaker arrays and the laws of physics begin to create directivity, we can explore how to improve their accuracy and efficiency.

Intellivox narrows the beam of sound emitted from the loudspeaker array and directs it at the listener, thereby reducing the amount of reflected sound.

STANDARD BEAM STEERING VS DDS BEAM SHAPING

DDS Beam Shaping goes beyond the standard beam steering technology commonly found in the sound reinforcement market.

STANDARD BEAM STEERING

Standard beam steering is generally ideal for only the most basic audience planes, and while multiple beams are possible, standard beam steering offers only limited control—most notably the vertical opening angle, aiming angle and throw distance. Standard beam steering offers no independent control of near field vs. far field coverage.

DDS BEAM SHAPING

By contrast, DDS Beam Shaping offers unrivalled beam control with nearly unlimited coverage possibilities. The advanced DDS algorithm provides a great listening experience at every seat in the house as it optimizes Intellivox arrays for both consistent frequency response and SPL, across listener planes. DDS Beam Shaping provides a single, coherent beam for complex audience planes, along with assymetrical coverage allowing for improved linearity in the near field vs far field.

HOW DDS BEAM SHAPING PROVIDES IMPROVED COVERAGE AND INTELLIGIBILITY

When dealing with complex audience planes such as raked seating, conventional beam steering is an inadequate solution. To achieve full coverage, conventional beam steering arrays require multiple beams, resulting in unavoidable hot spots and reduced intelligibility.

The superior technology in DDS Beam Shaping produces uniform coverage, consistent frequency response, and improved intelligibility without the need for multiple beams.

KEY ADVANTAGES OF INTELLIVOX TECHNOLOGY

PHYSICALLY ENGINEERED FOR PERFORMANCE

- The Intellivox system offers column lengths of up to 5 meters for strong, low-frequency pattern control in even the most reverberant spaces.
- Intellivox DSX models are available with tightly-packed, high-frequency elements for better control of higher frequencies.
- Intellivox DSX-HD (high-density) models, the 280 and 380, feature individually driven HF elements for further improved high-frequency shaping.

PROPRIETARY DDS DSP TECHNOLOGY

- The Intellivox and Intellivox High Power systems feature fully customizable “Beam Shaping” for unsurpassed coverage control and remarkable SPL and frequency response optimization.
- Digital Directivity Synthesis is completely driver agnostic, and as such, requires no hard crossover between array elements, allowing all array components to be utilized to their full potential when necessary.
- Multiple Intellivox units can be combined to create custom arrays.
- DDS DSP can theoretically be applied to any loudspeaker or array for pattern and response optimization.

HOW TO CHOOSE THE RIGHT INTELLIVOX SOLUTION FOR ANY ENVIRONMENT

With over 10 models available, it’s important to choose the Intellivox solution that will best meet the needs of your installation environment. There are four factors to consider when choosing your Intellivox system:

- Coverage requirements
- Acoustic properties
- Mounting restrictions

Intellivox Type	Length*	Typical Throw
DS-115	1.15 m / 3.7 ft	10-20 m / 33-66 ft
DS/DSX 180	1.80 m / 5.9 ft	15-25 m / 49-82 ft
DS/DSX 280	2.80 m / 9.2 ft	20-35 m / 66-115 ft
DS/DSX 380	3.80 m / 12.5 ft	30-45 m / 98-148 ft
DS/DSX 430	4.30 m / 14.1 ft	40-55 m / 131-181 ft
DS/DSX 500	5.00 m / 16.4 ft	50-70 m / 164-230 ft

*Lengths are approximate

For applications where high SPL levels are required or full range sound reinforcement then the Intellivox HP (High Power) series can be used.

Intellivox Type	Length*	Typical Throw
HP-DS 170	1.7 m / 5.6 ft	10-25 m / 33-82 ft
HP-DS 370	3.7 m / 12.1 ft	25-50 m / 82-164 ft

*Lengths are approximate

CONSIDERATION 1: COVERAGE

First, how far do you need your Intellivox system to throw? This will be the most important factor to determine what technology and what size loudspeaker is required. The DS and DSX series offer models with throws from 10 to 70 meters. For environments where high SPL or full-range sound reinforcement is required, the Intellivox High Power series is an ideal choice, with a throw range of 10 to 50 meters.

CONSIDERATION 2: THE ACOUSTIC REALITIES OF THE SPACE

Now that you've determined your throw coverage requirements, you can further refine your available options, based on the environment of the installation. In highly reverberant spaces, it may be necessary to increase the array length (relative to throw distance) in order to achieve better overall intelligibility.

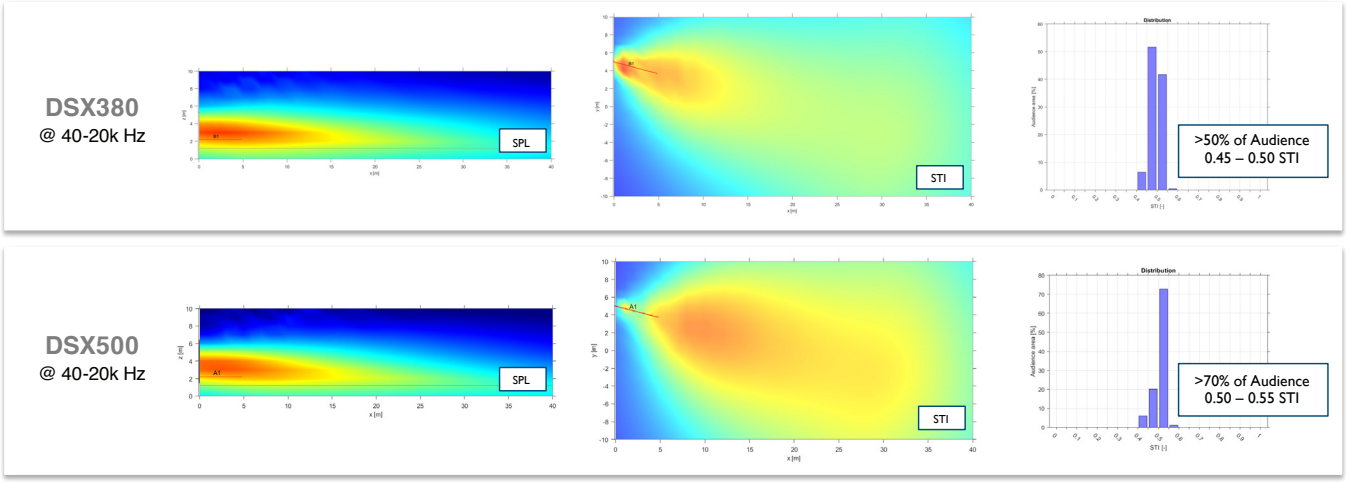
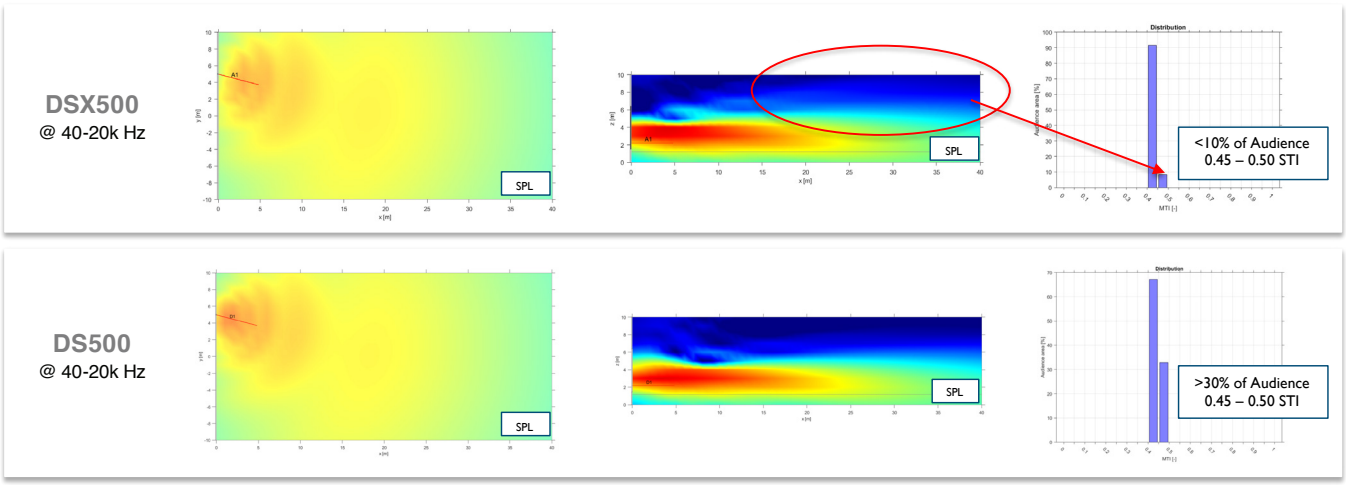


Figure E illustrates how the DSX500, a 5-meter column, provides significantly better STI to a greater percentage of the audience compared to the DSX380, a 3.8-meter column, in the same space. In this scenario, both the DSX380 and DSX500 generate similar overall SPL, though the additional length of the DSX500 provides enhanced low frequency control, leading to more uniform intelligibility throughout the space.



Note: Intellivox DSX models have higher frequency extensions and control, while Intellivox DS models have a longer acoustic length for lower frequency pattern control.

CONSIDERATION 3: MOUNTING RESTRICTIONS

Another consideration may include mounting restrictions within the venue. It's important to note that the best placement of a column array is as close to the audience plane as the space allows. As the array is placed higher, relative to the audience plane, the vertical beam will need to be wider in order to provide adequate coverage, which typically becomes a detriment to the overall intelligibility in the room.

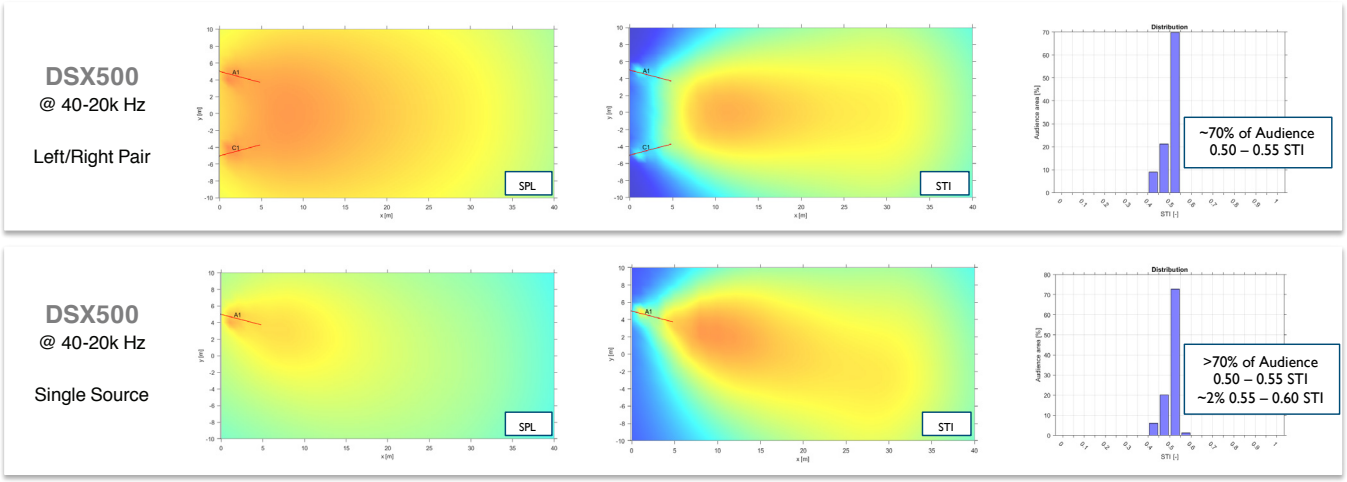
In specific cases—limitations dictated by architecture, for example—this might become an especially important consideration in selecting your Intellivox model. The Intellivox DS series may be useful if a higher mounting position is required, due to the wider dispersion of its full range drivers.

Regardless of mounting restrictions, there is an Intellivox system available that will provide exceptional intelligibility and consistent SPL coverage throughout the audience plane.

Notes on Additional System Layout Options:

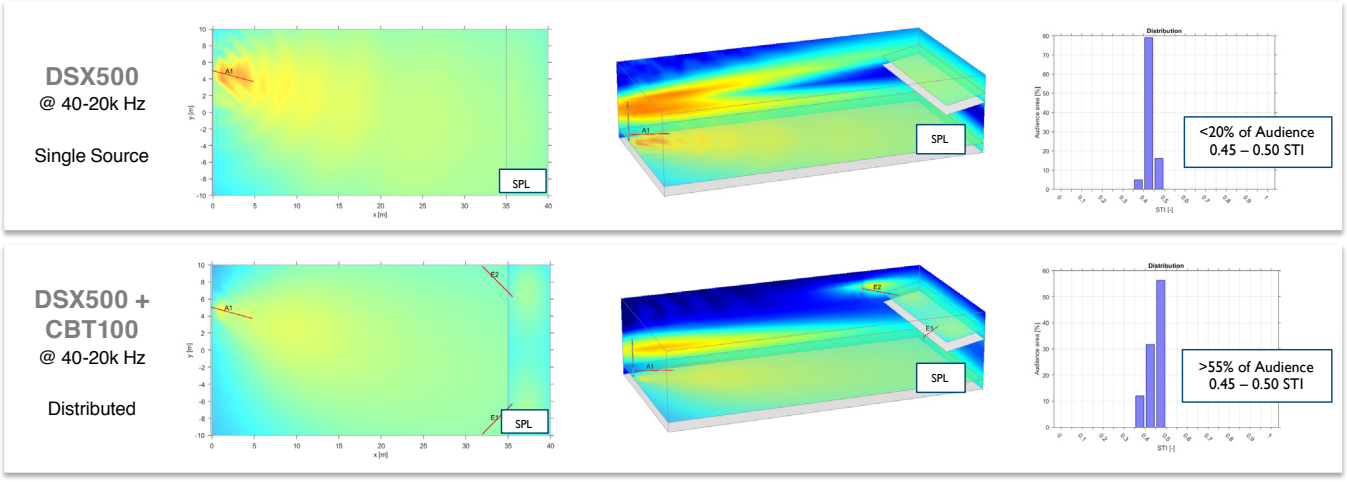
Single Column vs. Frontal Pair

In highly reverberant spaces, intelligibility may be improved by utilizing a single source (one column) instead of a L/R pair. In Figure G, a pair of Intellivox DSX500 arrays shows more uniform coverage than one DSX500, but upon closer scrutiny, the single DSX500 column actually offers slightly better STI (intelligibility) performance.



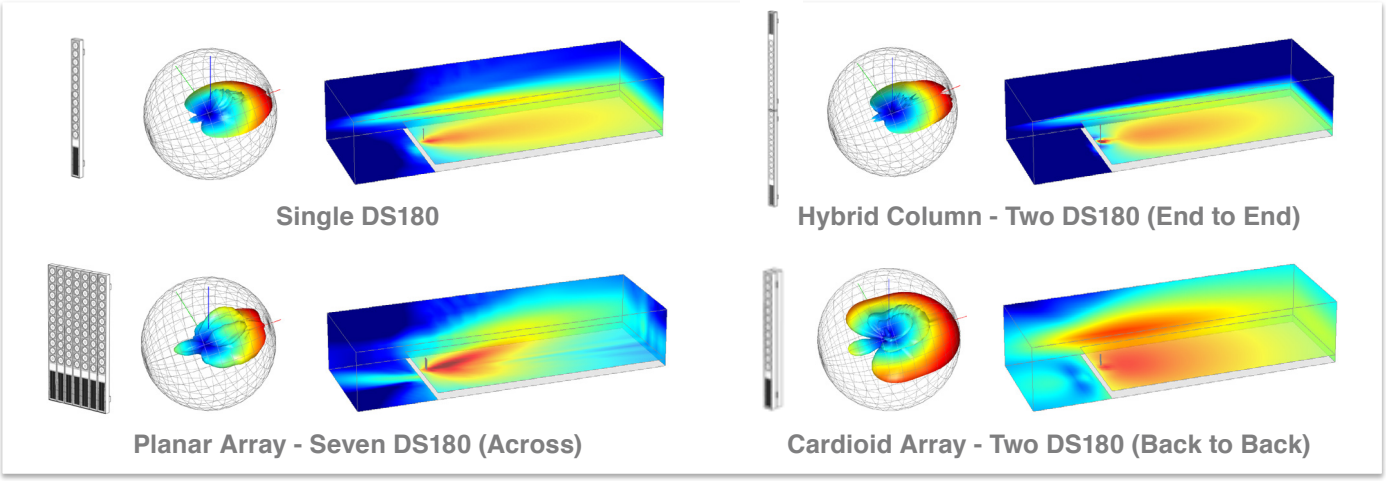
Beam Shaping vs. Distributed Delay Fills

Although Intellivox arrays provide excellent pattern control and complex coverage, there are times when the use of distributed fills in conjunction with Intellivox arrays can provide an even better result. In this figure, we can see how a distributed fill, like a CBT100, improves intelligibility for a significant portion of the audience plane.



Budget-sensitive installations may favor Beam Shaping, while SPL needs or highly reverberant spaces may benefit from distributed fills.

JBL INTELLIVOX OFFERS UNPARALLELED FLEXIBILITY



The DDS algorithm can manage virtually any configuration of drivers and loudspeakers, including single columns, hybrid columns, planar arrays and cardioid arrays. Here are four examples that demonstrate how different arrangements of the Intellivox DS180 can be configured to achieve complex coverage patterns, though this same concept applies to any Intellivox or Intellivox High Power product.

JBL CBT AND INTELLIVOX COMPARISON

Above, we demonstrated how a distributed CBT speaker can be used in conjunction with an Intellivox array to improve intelligibility in complex environments. Though both product lines take advantage of column array technology and can excel in a variety of musical and speech applications, each have specific strengths.

JBL CBT PASSIVE LOUDSPEAKERS

JBL CBT Loudspeakers are available in a variety of sizes with increasing pattern control and SPL. In contrast to Intellivox, they are passive loudspeakers with switch selectable vertical coverage patterns and require mechanical aiming.

JBL INTELLIVOX LOUDSPEAKERS

Unlike their passive siblings, Intellivox Loudspeakers are digitally controlled and self-powered with internal processing. Intellivox arrays offer the best pattern control available and can be aimed independent of mounting, allowing for flush and recessed installations. Multiple models are available in a variety of sizes to meet pattern control and SPL requirements.

COMPARING ARRAY SOLUTIONS ACROSS MANUFACTURERS

IT'S ALL ABOUT THE PHYSICS

The laws of physics apply to all array products, regardless of the manufacturer.

- LF beam control is governed by acoustic length—a longer acoustic length is going to give you better low frequency control.
- Steering and shaping is destructive—extreme steering reduces overall SPL and introduces additional artifacts.
- Lower, consistent SPL maintained over distance relies on keeping the audience consistently off axis from the main beam.
    - The DDS algorithm does help mitigate this better than other solutions given its ability to independently control the near field and far field.
- Multiple beams reduce the overall performance of any column array including it's SPL potential.

TESTING STANDARDS

It is very difficult to compare loudspeaker arrays across different manufacturers. A lack of standardized testing procedures in the industry makes it virtually impossible to directly compare critical performance specifications, such as SPL and coverage. Whenever possible, JBL recommends the use of common prediction platforms (EASE, CATT, etc.) and real world testing to compare products across manufacturers.

To best demonstrate the benefits of Intellivox, it helps if we think of a loudspeaker as a spotlight instead of a floodlight, directing sound where we want, without "illuminating" surrounding areas. This concept is the foundation by which Intellivox maintains high speech intelligibility.

POWERFUL SOFTWARE TOOLS BY JBL

DIGITAL DIRECTIVITY ANALYSIS

Free JBL Intellivox Prediction and Modeling Software

DDA, or Digital Directivity Analysis, is a free 3D modeling environment that was built for use with all Intellivox products along with any Common Loudspeaker Format (CLF) file from any manufacturer. Models can be imported from EASE, CATT, Odeon, or Sketchup and DDA will predict a variety of measurements, including direct SPL, direct-to-reverberant ratio, STI and frequency response. DDA also generates the precise beam files required to load into Intellivox arrays.

WINCONTROL

Free Software Control and Monitoring for Intellivox Products

WinControl enables you to upload DDA-generated beam files to Intellivox products, though for basic coverage situations, you may also set beam configurations without DDA, if necessary. With WinControl, you have quick access to the entire suite of DSP parameters including parametric EQ, delay, Autogain, surveillance parameters, pilot tone detection, priority switching, and preset selection.

Included within WinControl is Rapid DDS, a graphical interface for configuring the beam settings of Intellivox.

JBL also offers an EASE DLL/GLL, which enables you to model Intellivox performance directly in EASE using the same graphical interface as Rapid DDS in WinControl. It offers intuitive controls for mounting height, coverage start and end distance, audience plane rise and listener height. For more detailed modeling, the EASE DLL/GLL supports the loading of DDA-generated XGLC files.

INTELLIVOX OPTIONS

- Intellivox DS
  - Offers longer acoustic lengths and narrower horizontal dispersion
  - Useful in challenging acoustic environments where limited bandwidth for speech-only applications is acceptable
  - Models include DS180, DS280, DS380, DS430, and DS500
- Amplifier Module Position
  - All DSX and DS Intellivox products are available with the amplifier placed at the top or bottom of the column array
  - Provides additional flexibility in the placement of the acoustic center
- Weathering
  - For outdoor and exposed installations Intellivox HP series is rated IP55 for all models
- Power
  - Standard 115V power supply
  - 230V power supply option available
- Free Custom RAL Color Matching
- Input cards, brackets, and other accessories.

WHERE TO FIND INTELLIVOX IN USE

TRANSPORTATION

Intellivox is ideally suited for use in the wide variety of spaces found in transportation centers. Intellivox is currently installed in the ticketing area of New York City's JFK International Airport and the main hall of Grand Central Station.

For these heavily trafficked public spaces, Intellivox offers superior performance where it really counts:

- **Consistent SPL and frequency response** over long distances, especially where distributed speaker placement may be impossible or costly.
- **Improved Intelligibility** where difficult acoustics and STI requirements make beam-controlling loudspeakers the only viable option.
- **Redundancy and System Monitoring** with multiple inputs, automatic switchover, pilot tone detection and a suite of onboard status features to ensure worry-free operation in critical life safety environments.

LARGE VENUES

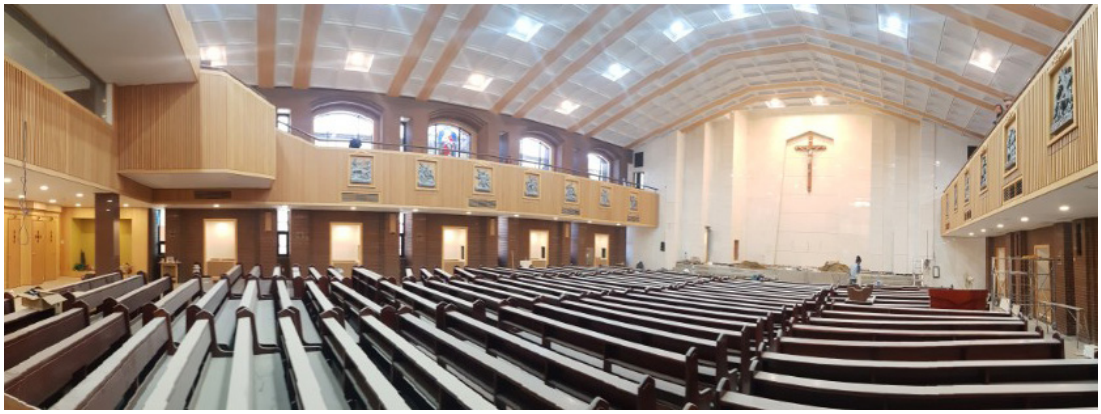
Intellivox HP is ideally suited for use in the difficult and populous open spaces, associated with large venues.

Intellivox HP offers performance that provides the best audio experience possible in large venues with:

- **Consistent SPL and frequency response** over long distances, especially where distributed speaker placement may be impossible or costly.
- **Long throw capability** to project sound hundreds of feet to cover distant audience areas with the same power and intelligibility as those nearby.
- **Redundancy and System Monitoring** with multiple inputs, automatic switchover, pilot tone detection and a suite of onboard status features to ensure worry-free operation in critical life safety environments.

HOSPITALITY

Intellivox is ideally suited for use in various hospitality-related venues, from houses of worship to theaters to retail.



For these types of installations, Intellivox offers desirable features including:

- **Low-profile footprints** with a small width and depth combined with flush or recessed mounting, for very inconspicuous installation.
- **Improved intelligibility** designed to provide optimal coverage of the audience while reducing overall energy and unwanted room reflections, even in the most challenging acoustic environments.
- **Customizable vertical coverage** to ensure consistent SPL and frequency response performance from the front row to the rear of the balcony—and with no need to physically aim the speaker.

Intellivox hospitality-related installations include the Holy Trinity, Abu Dhabi Grand Mosque, Cologne Dome in Germany and Covington Cathedral in the USA.

CORPORATE, EDUCATION, AND GOVERNMENT

Intellivox is ideally suited for courtrooms, boardrooms and lecture halls.

When speech intelligibility is critical, Intellivox provides unmatched performance and flexibility with:

- **Low-profile footprints** for very inconspicuous installations, with a small width and depth combined with flush or recessed mounting.
- **Improved intelligibility** by design so that consistent near and far field SPL overpowers background noise without overpowering the audience.
    - Additionally, built-in ambient noise sensing microphones allow for level adaptation in response to changes in environmental noise.
- **Reduced microphone bleed and increased gain before feedback** thanks to tight vertical pattern control and consistent SPL across the audience plane.
    - This results in optimal coverage without excessive volume and reduced amplified sound returning to the microphones.

CONCLUSION

From public service announcements and outdoor concerts, to houses of worship and lecture halls, it has always been the goal of loudspeaker manufacturers to provide the most consistent performance in SPL, frequency response and intelligibility to the audience.

JBL Intellivox, featuring DDS Beam Shaping technology, achieves this pinnacle in performance and enables listeners to experience better audio whether seated in the front row or at the back of the balcony. And with virtually unlimited ways to configure and combine Intellivox loudspeaker arrays (and even co-mingle with CBT loudspeakers), there's an Intellivox solution that's perfect for almost any budget and acoustic environment.

Learn more at jblpro.com