



"A Century of Change Overnight"

HPV TECHNOLOGIES LLC

MAD — Planar Magnetic Surface Array Explained



LT-PMS-54-WG500

Last week, the L.A. Sheriff's Department tested out an acoustic transmitter that makes earlier models look like "children's toys" in comparison, LASD Commander Sid Heal, a world-renowned expert in non-lethal weaponry, tells Defense Tech.

On Thursday, August 4th, we put the magnetic acoustic device (I'm not sure it has a name yet, so this one will have to do for now) to the test on one of our ranges... Using a variety of sounds from human voice to music to sound effects (screams, shouts, gunfire, sirens, and the like), we succeeded in listening to the sounds from the transmitter located one statue mile in the distance!

Introduction

While planar magnetic speakers have been around for quite a while, previous systems have typically been too fragile, too inefficient, and too expensive to be used in professional applications. Even though this “exotic” technology provides one of the best sounding speakers, due to its limitations, it was placed in a small niche market of high-end home stereo systems. HPV Technologies, LLC is the first company who has overcome the inherent problems of planar magnetic speakers and came up with commercially available Professional Planar Magnetic Transducers, branded as MAD (Magnetic Audio Devices). MAD drivers have been specifically engineered to take full benefits of planar magnetic technology and bring it to the professional audio market. Previous limitations were addressed and corrected over a period of years of R&D.



MAD1 Planar Magnetic Transducer -The universal building block of all MAD products

Using MAD transducers as a building block, HPV Technologies has introduced a brand new technology to the professional audio industry - Flat Panel Surface Array (Patent pending).

“This invention relates to a surface loudspeaker array using a plurality of full-range flat panel or planar magnetic transducers, which are mounted closely together on either a flat or a curved surface to produce the controlled sound dispersion in both the horizontal and vertical planes.” ⁽¹⁾

Depending on the required dispersion angles and SPL (Sound Pressure Level), MAD™ Surface Arrays can achieve almost parallel beams of sound or have full 360 degree radiation angles in both horizontal and vertical planes with desired loudness.

MAD™ Surface Arrays deliver extreme clarity and intelligibility from near field to distances beyond one mile. They can be used to reproduce very delicate music details of classical music on one side, or the brute force of Heavy Metal or Hard Rock on the other side.

MAD™ Arrays deliver extremely clear and intelligible full range sound from near field to distances beyond one mile, allowing for a single point to communicate with thousands of people.

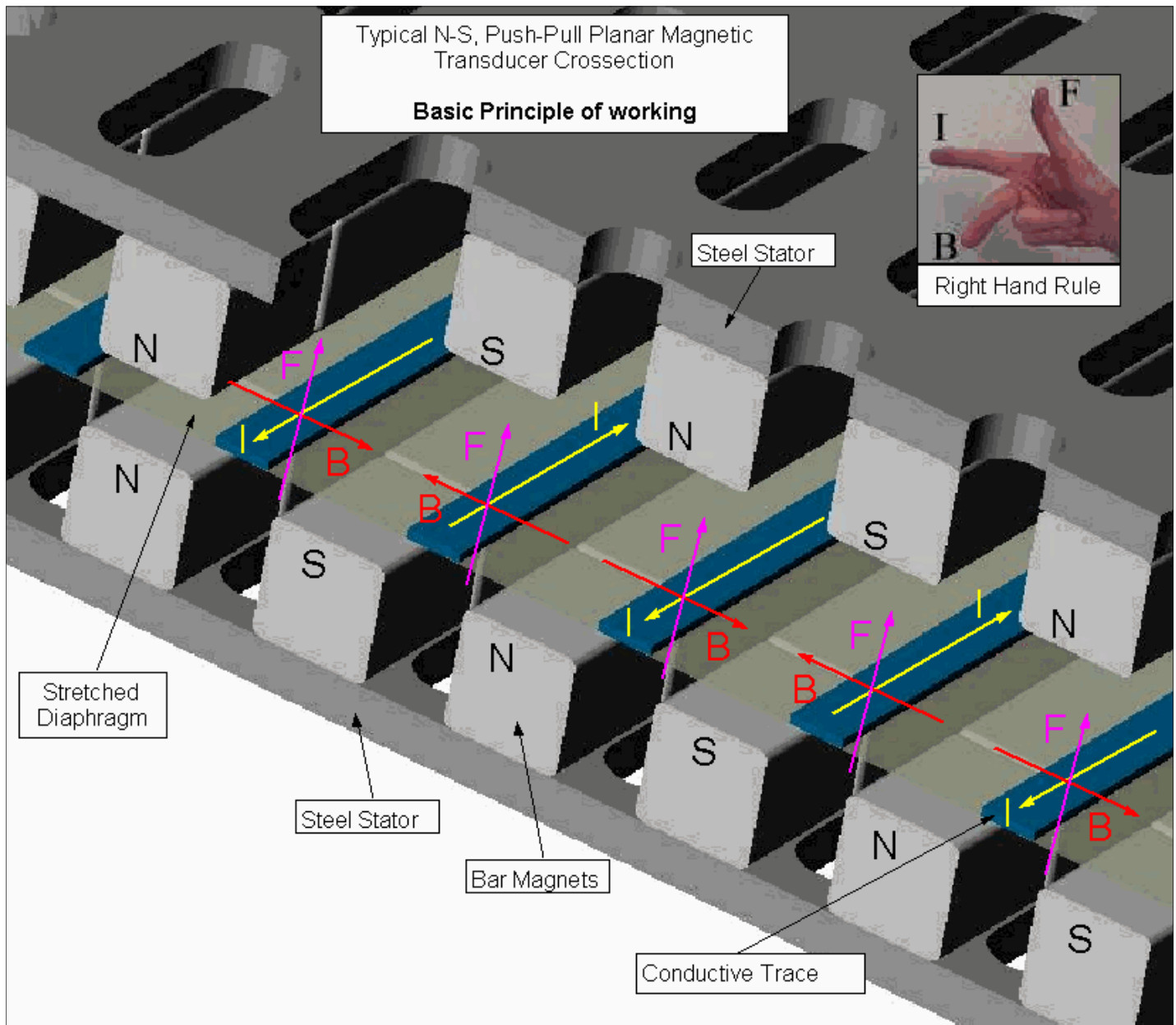
(1) Quote from the patent application

MAD Planar Magnetic Transducer

The MAD planar speaker is fundamentally different from conventional cone speakers or compression drivers as the entire radiating area is directly and uniformly driven by the strong magnetic field.

MAD Planar Magnetic Transducers are specifically designed to work in a tough professional audio environment. Its size, resonant frequency, efficiency, power handling, impedance, distortion, are the parameters all tied together into a design that greatly outperforms similar existing products.

MAD Transducer is typical North-South, push-pull design. It has two identical stators which carry the magnets. Stators are made from stamped and formed steel with extreme rigidity. Very strong Neodymium bar magnets are glued to the inside surface of the stators in arrangement north-south, as shown on the cross section of the transducer below.



Cross section of MAD Transducer. Basic principle of work.

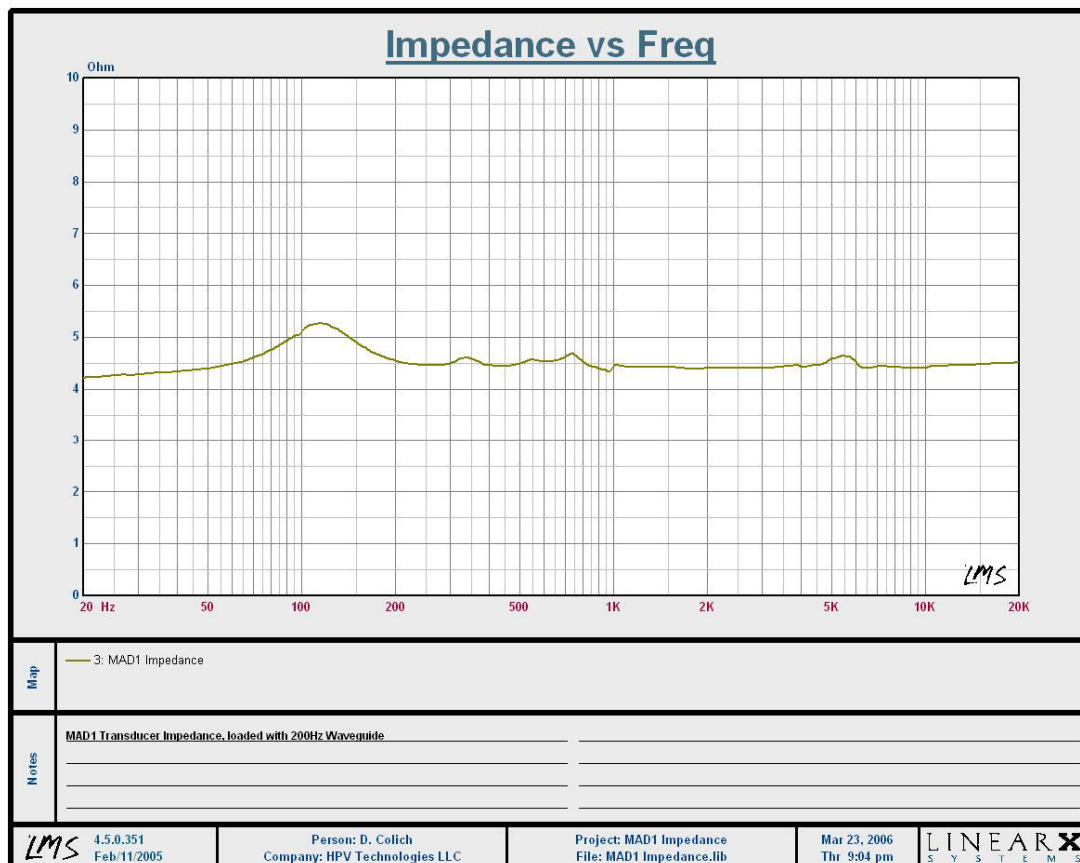
Magnets are arranged in a such a way that North and South poles alternate. Magnetic field lines exit north poles and enter south poles. Steel Stators close the magnetic circuits. Useful magnetic field lies in plane with the diaphragm, hence the name - Planar Magnetic. Stators serve several purposes: to carry the magnets, to close the magnetic circuits between the magnets and to provide perfectly flat surface on which to bond the stretched diaphragm to. On one of the stators, called the active stator, a very thin diaphragm with printed conductive coil is stretched and bonded. Conductive traces are centered between magnets in a predefined pattern. When the amplified signal is brought to the transducer terminals, it creates an alternating current that flows through the conductive traces. The current interacts with the magnetic field and creates the force that moves the traces to one side. Traces are arranged on the diaphragm surface in such a way that force moves them all to one side. When the current changes direction, force moves all traces to the opposite side. Because traces are strongly bonded to the diaphragm surface, the whole diaphragm moves back and forth as a piston. Even though the diaphragm is flexible, it exhibits pistonic movement because conductive traces cover more than 80% of it s surface. When the diaphragm moves back and forth according to the signal change, it creates a sound. Air escapes the transducer through the holes punched in the stators face.

The MAD transducer is dipole. It creates the sound on both sides of the diaphragm with equal intensity, but opposite phase. Front and rear sound waves meet on a side of the transducer and cancel. This creates a typical dipole figure of eight dispersion pattern. Sound on the side, top and bottom is almost completely canceled. This property is very useful in some applications where sound is not desirable on the sides of the speakers.

If a dipole transducer is mounted in a closed cabinet it becomes monopole and radiates only on the front. In the low frequency range monopole is omni directional (radiates sound all around the speaker with equal intensity) and may cause too much output around the speaker in some applications.

If an open enclosure was used and rear waves are absorbed, the transducer becomes cardioid. Cardioid dispersion keeps sound cancellation on its sides with greatly reduced rear radiation.

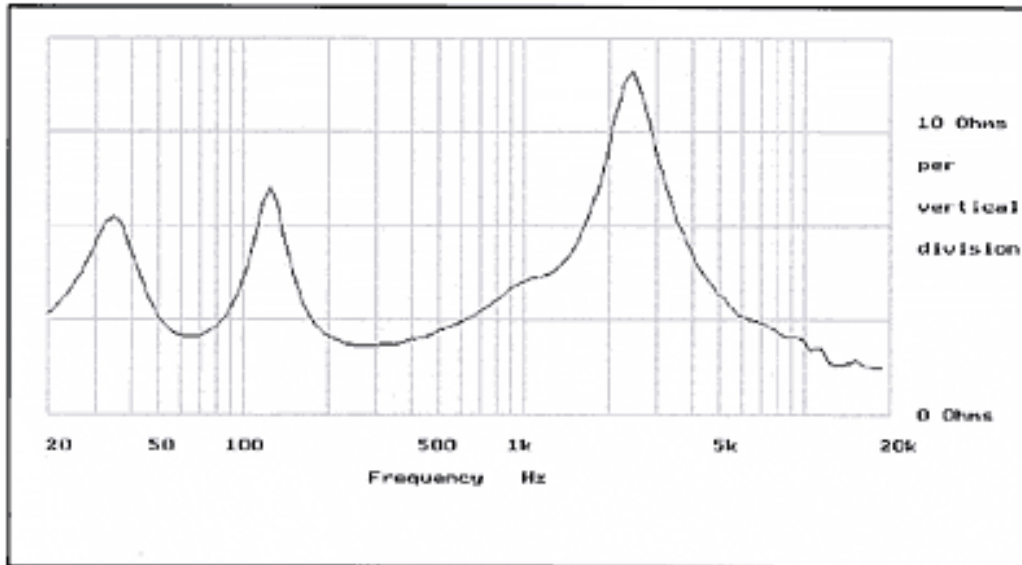
Impedance



MAD Planar magnetic transducers have very flat impedance response throughout the frequency range, which improves the performance capability of any amplifier.

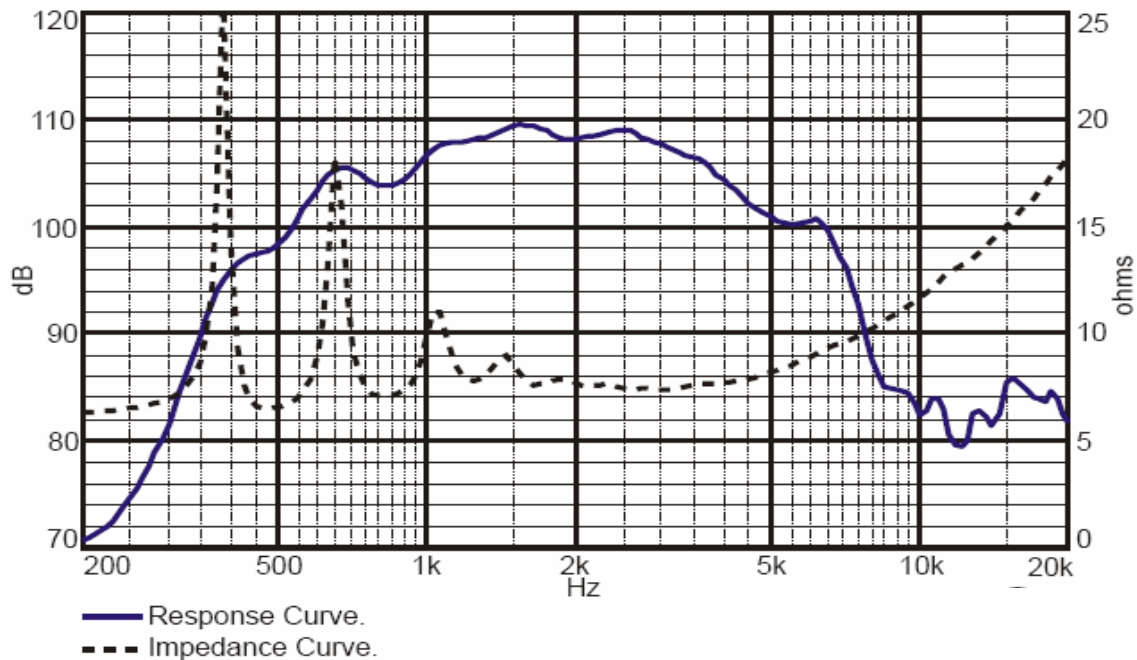
With MAD speakers your amplifier will sound like you paid much more for it!

MAD1 Impedance Curve



Typical Impedance curve of two-way speaker

Conventional drivers have quite variable impedance curves across the whole frequency range. Due to high moving mass, suspension system and high coil inductance, impedance of cone speakers or compression drivers varies dramatically. In the picture above is shown a typical impedance curve of two-way speaker system in a vented cabinet with a woofer and compression driver. The first two peaks are woofer and port resonances in a cabinet. The third peak is created due to crossover components. Variable impedance curve creates a difficult load to the amplifier and may cause sound degradation. The crossover point between woofer and compression driver is in the middle of critical vocal range which may muddle the sound and create lower voice intelligibility.

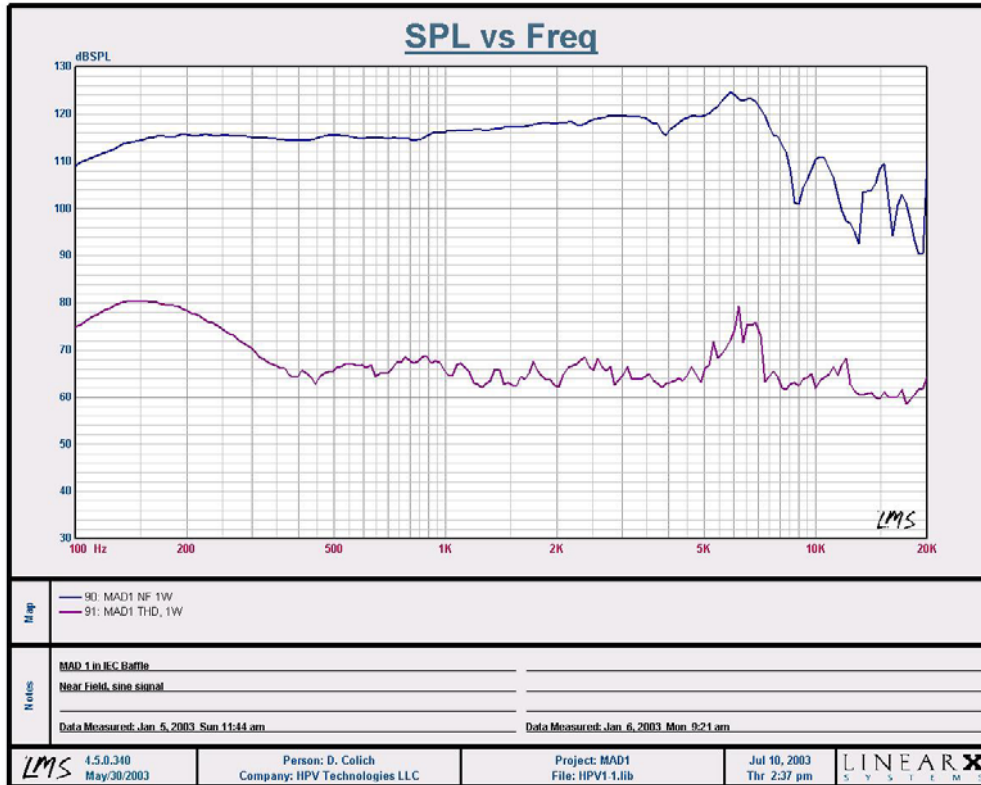


Good quality compression midrange driver

Graphs above show frequency response and impedance curves of good quality midrange compression driver. Frequency response looks nice and smooth while impedance varies quite a lot, from nominal 8 Ohms to max over 25 ohms.

Uniform driving force, uniform diaphragm stretching = low distortion, high performance

To achieve high sensitivity, very low distortion and high-end sound quality, MAD transducers incorporate a very strong magnetic structure. Two pounds of the strongest commercially available Neodymium magnets are used in each transducer. Magnetic field density is very linear between rows of magnets as well as along the depth of the magnetic gap. This creates linear force that moves diaphragm back and forth with minimum distortion. The diaphragm is properly tensioned and stretched on a perfectly flat surface of the Active Stator. This, together with very strong uniform driving force evenly distributed across the surface of the diaphragm, provides excellent sound quality with extremely low distortion. With one Watt of power, a MAD transducer typically has 0.1-0.2% distortion within most of its operating frequency range.



Graphs show near field frequency response and THD (Total Harmonic Distortion) including the ambient noise.

Near field measurement was employed to get better signal to noise ratio. Noise floor at the time of the measurement was around 60-65 dB.

If the measurement was done in a very quiet room THD graph would fall below 60 dB.

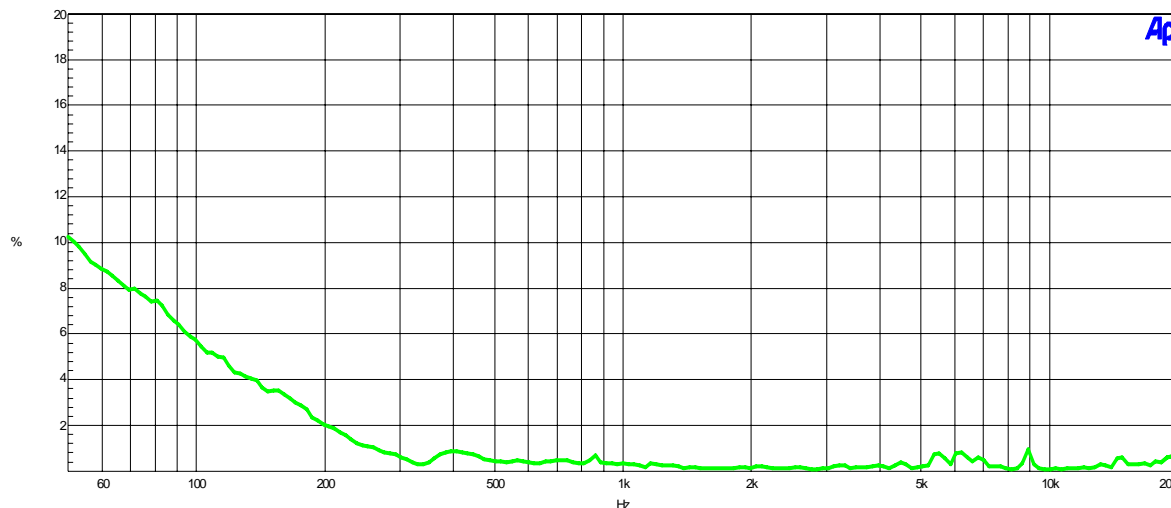
Rugged frequency response above 5 KHz is due to microphone "not seeing" the whole diaphragm area, roughly 5"x7".

Near field graph and 1W Total Harmonic Distortion of MAD transducer

Audio Precision

FREQUENCY RESPONSE

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Another way of showing THD plus noise is to plot THD in % versus Frequency.

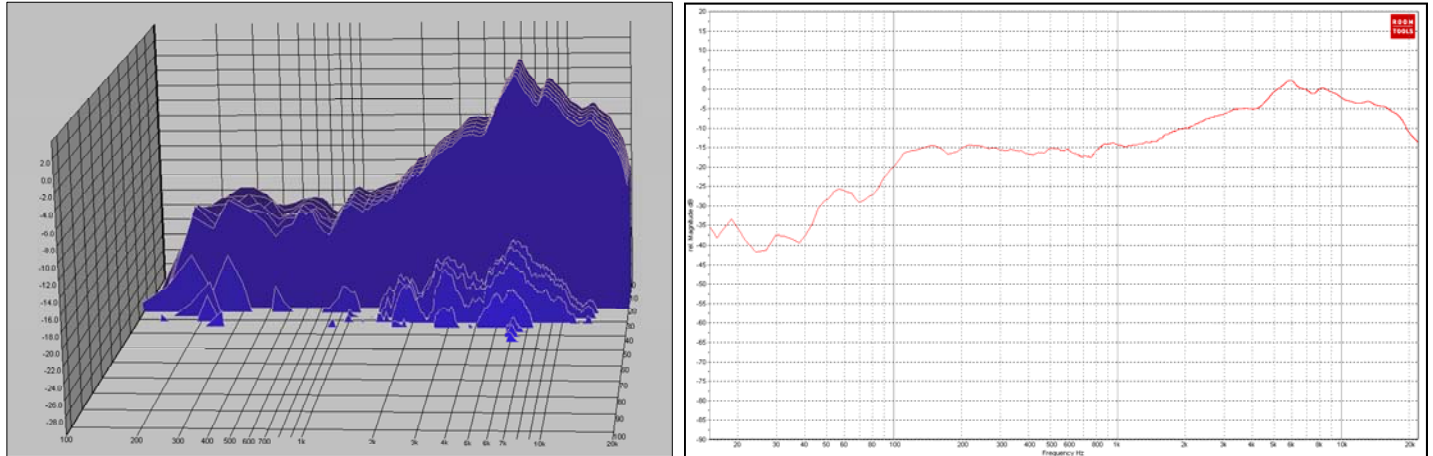
MAD1 transducer, near field, THD plus noise @ 1W input power.

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	4	Anlr:THD+N Ratio	Left	
MAD1 - THD - Near Field (2); 2V (1W) driving voltage							

MAD1-THD-1Watt

Smooth Frequency Response is important but it is just a part of the whole picture

It is very important for each type of speaker to have smooth frequency response. Smooth response is easy to control and correct, if necessary. The whole picture is much bigger though, and one needs to understand other important parameters of the speaker response: phase response, impedance, transient response and manufacturing consistency.



Waterfall Plot and Typical Frequency response of MAD transducer installed in IEC Baffle

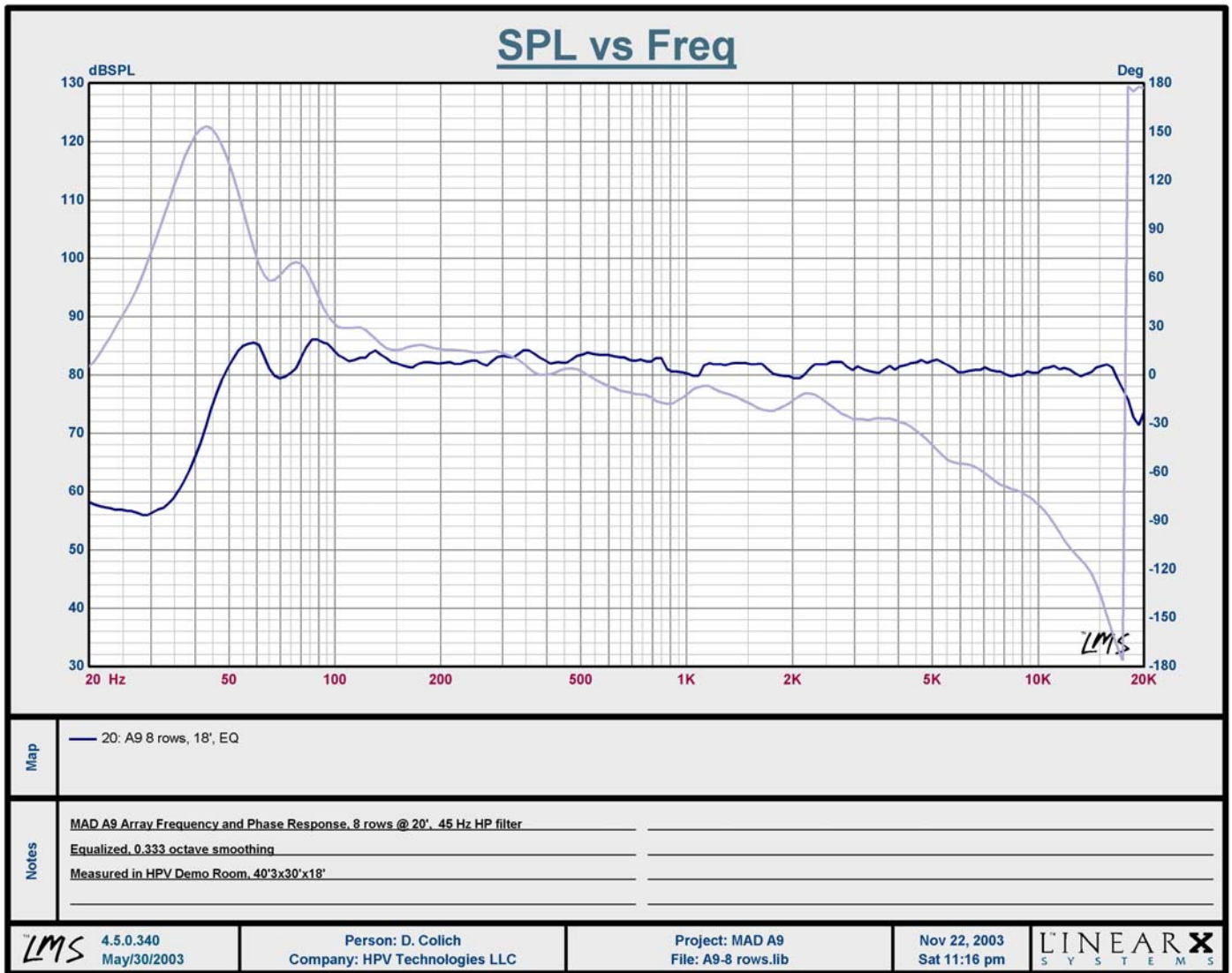
The graph above shows Waterfall plot of MAD transducer and what happens with the output of the speaker after the signal stops. It is visible that the sound dies almost completely and instantaneously.

Frequency response is very smooth. MAD1 driver has high directivity in the upper frequency range and exhibits rising frequency response. This is typically corrected with Digital Signal Processing in concert environment, while it is very useful for long throw applications, where air absorption has a big effect. With natural rising response, sound at large distance is very clear, very natural, and enables excellent voice intelligibility.

MAD transducers have extremely fast transient response due to very strong and linear electromagnetic force and a very lightweight whole surface driven diaphragm. Mass of the diaphragm is so light that it is comparable to the mass of the air it moves during the operation. Strong force and low mass enable the diaphragm to achieve very high acceleration, i.e. it can start and stop almost momentarily if the signal is applied or stopped. Often, speakers have to reproduce very sharp peaks, more like impulses. MAD speakers can reproduce these signal with ease while conventional speakers with much higher mass and poor transient response typically round off and distort these sharp peaks. With MAD speakers one can hear every single, small detail in the sound perfectly well, regardless of loudness. With conventional speakers sound looks like heavily smoothed graphs, or like you are listening to the sound through a heavy curtain. Low level signals are very difficult to understand and typically one needs to turn the volume up to be able to understand clearly what is reproduced.

Flat frequency response is not as important as smooth and consistent response. MAD drivers have very smooth, but not flat frequency response. Rising response is very easy to correct, if required. Manufacturing consistency of MAD drivers is extremely high. Measured frequency response during the regular Quality Control testing shows incredibly narrow spread of curves variations and are typically within 1 dB (+/- 0.5 dB). If one overlays hundreds of curves on top of each other all those graphs would look like one thick line. This is quite impressive compared to conventional drivers where consistency of frequency response graphs from driver to driver can vary quite a lot, 3-6 dB.

MAD drivers are almost like clones and provide a perfect solution for arraying them into any size or shape Surface Array. Flat Panel Surface Array (Patent Pending) brings a totally new level of flexibility and performance into Professional Sound applications.

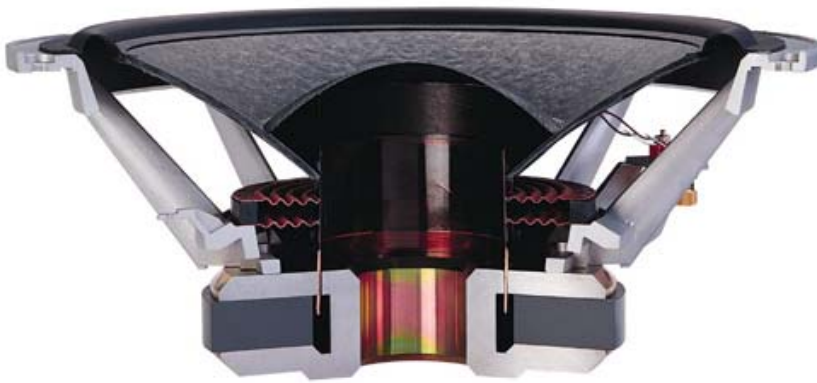


Well Equalized Frequency response of MAD A9 Full Range Planar Magnetic Surface Array

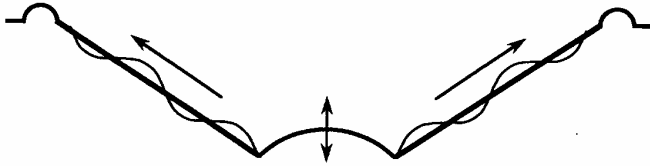
MAD Planar Transducers, closely spaced on a predefined surface shape, act as one giant diaphragm. Raw output is very smooth and predictable. Equalization of the raw response is a breeze, compared to conventional technologies and the final result is perfectly flat frequency response and linear phase response.

MAD surface arrays offer additional benefits that are unique. As you get closer to the array, you are subjected to *less* acoustic output, since you are only being presented with a portion of the total system output. Thus, users can stand directly in front of an array with an open microphone and not cause the system to feed back. This property allows sound engineers to completely rethink their existing experience. Now, they have complete freedom in speaker positioning to achieve maximum system performance.

With conventional technology sound engineers were forced to hang speakers as high as possible to avoid too much output in the front rows of the venues.



Cross section of high quality cone driver

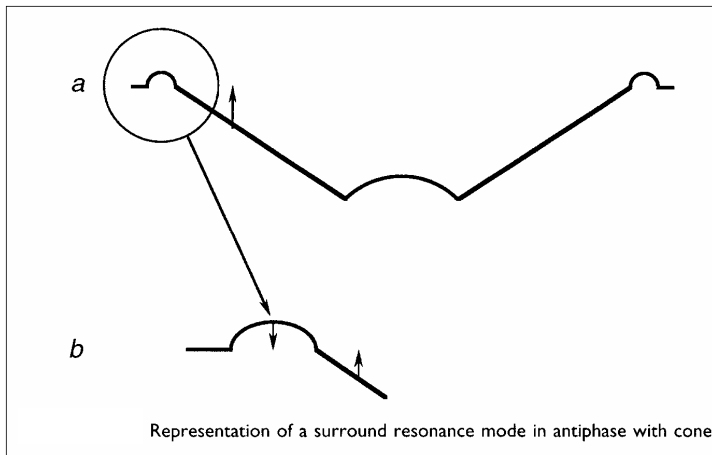


Representation of outwardly traveling waves in a cone.

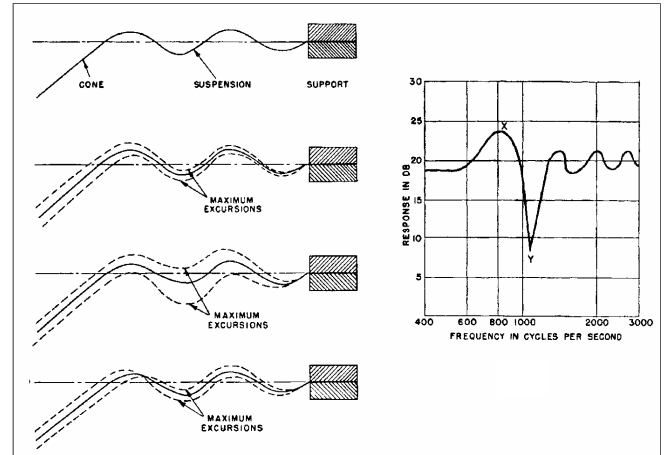
Cone drivers employ complex construction with many parts and glue joints. The unavoidable shortcomings of this construction are high mass of the cone/voice coil assembly, high system inertia (poor moving mass acceleration), inadequate cone stiffness, relatively high distortion and tendency of the assembly to change originally designed parameters over time which gradually decreases the overall performance.

A cone speaker uses a voice coil to drive only the small center ring of the speaker, which in turn must push and pull the much larger area of entire cone. This inherent design factor causes what is referred to in the industry as "cone breakup" which negatively colors the sound.

Due to cone break up modes these drivers can not be used as full range speakers and are usually limited as low frequency drivers.



Representation of a surround resonance mode in antiphase with cone.



Cone Surround resonance modes

Beside the cone break up modes other parts of the cone driver can go into a resonance (surround, spider, tensile leads) and create quite irregular frequency and phase response with a lot of distortion.

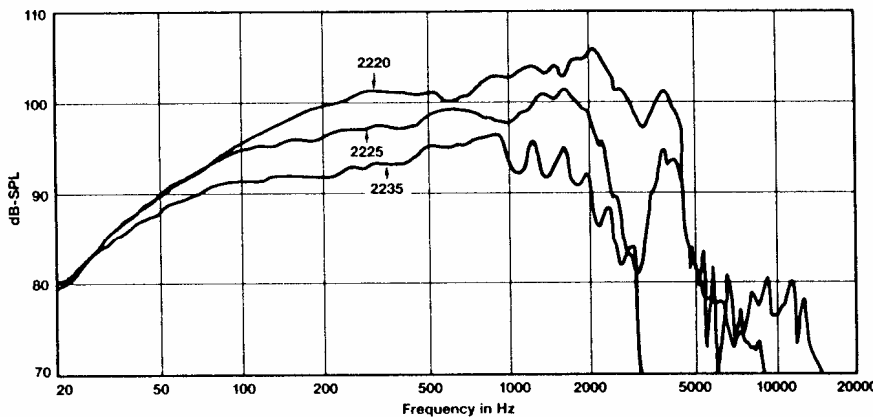
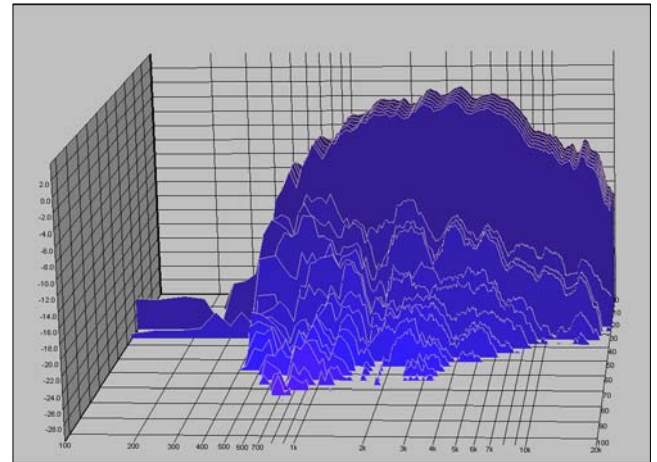
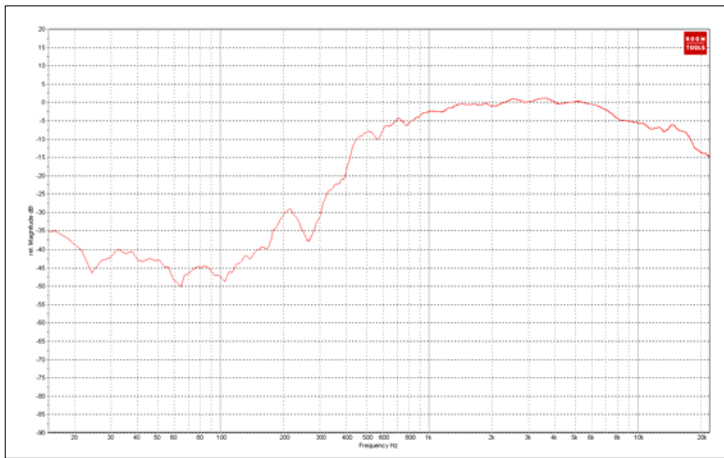


Figure 2-8. On-axis response of JBL Models 2220, 2225, and 2235 LF drivers. (Data courtesy JBL, Inc.)

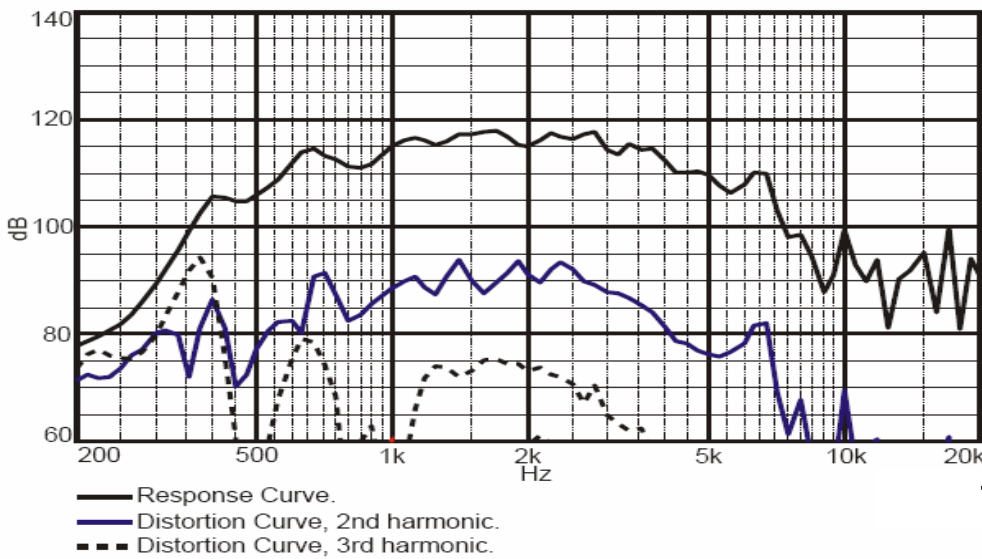
Because of their inherent problems conventional drivers (cone, dome, compression drivers) are typically designed to work in limited frequency range where parameter could be optimized for good performance.

Graphs on the left show frequency responses of three different woofers. They have nice, smooth response up to 1000 Hz and can be used only below this frequency.

For comparative analysis a high-end compression driver was measured. It has very nice frequency response. If you look at the graph, you may think that this is an excellent driver. The real picture is totally different. Waterfall plot shows a lot of ringing that dies slowly. This create colored and distorted sound (typical honky sound of the horns with compression drivers). Listening to complex and fast sounds through this kind of speaker is not very pleasant. Voice intelligibility suffers greatly.

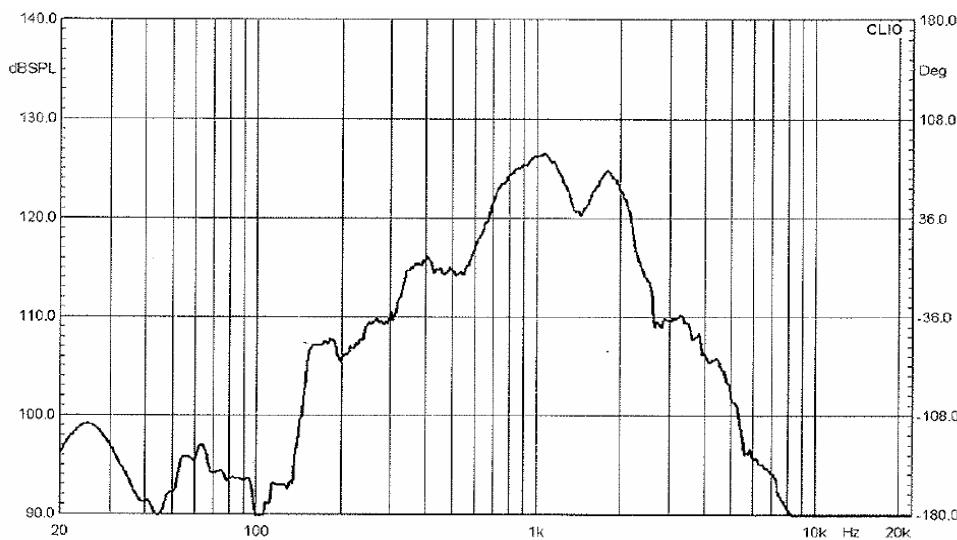


Frequency Response and Waterfall plot of high-end compression driver



Even though this compression driver exhibits smooth frequency response, distortion is quite high. This will create colored sound with poor intelligibility.

Frequency response and distortion curves of typical high quality compression driver



Situation with mass produced, cheap compression drivers with horns is much, much worse than showed above.

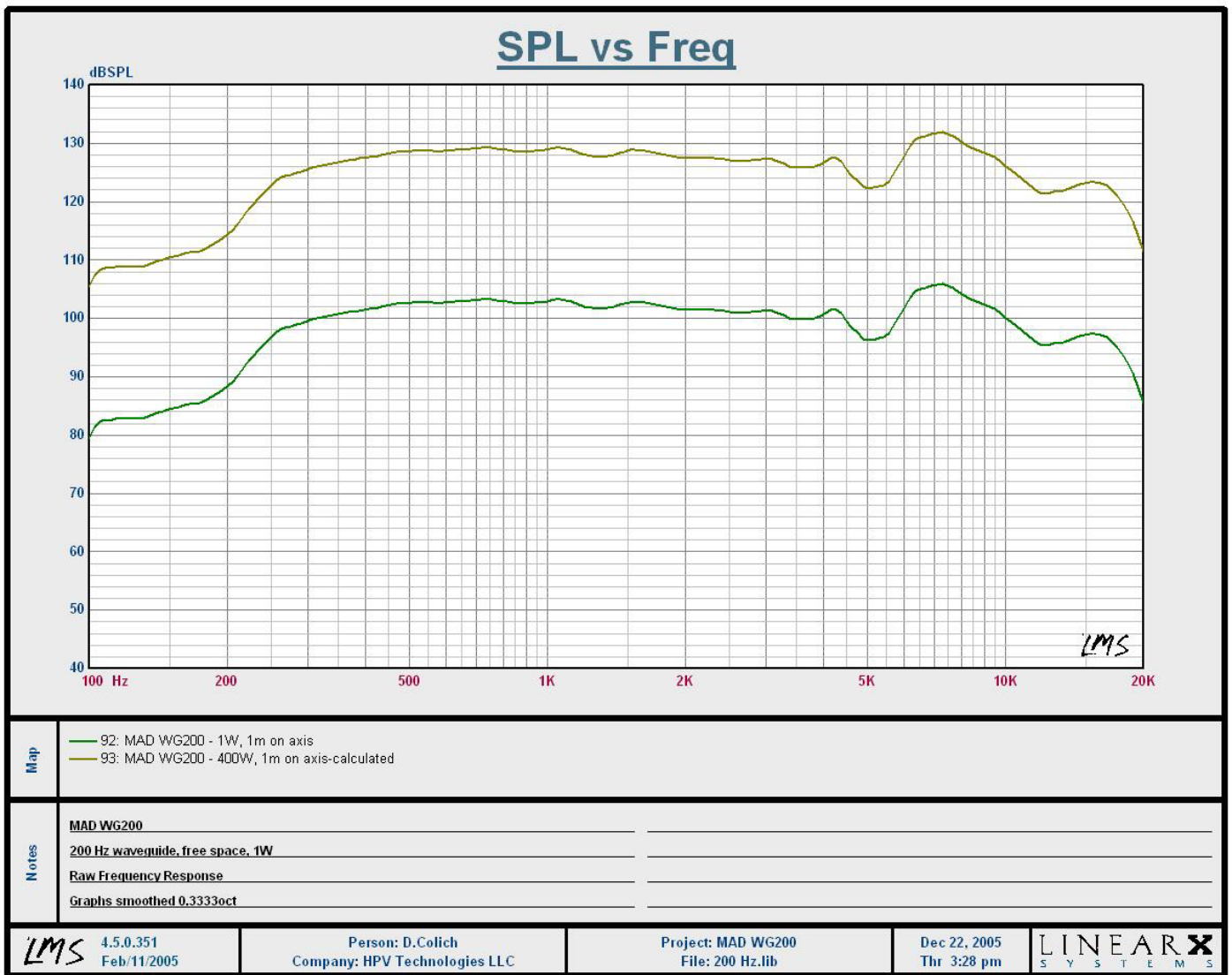
Frequency response is typically very rugged, waterfall plots look quite bad and distortion is very high.

Frequency response of the typical narrow band compression driver used in commercial PA systems for voice and mass notification applications.

Efficiency

MAD transducers have very strong magnetic motor structure and a very lightweight diaphragm, which creates a transducer with high efficiency. High efficiency enables very large sound pressure reproduction with a small amount of amplifier power required. Less power means less thermal stress on the driver and more reliable operation.

In MAD WG200 speaker system, (Mass Notification System) a MAD single transducer is properly loaded with a 200Hz waveguide and has very high efficiency of 103 dB/1W/1m across the whole frequency range. This is comparable to average compression drivers sensitivity. With high power handling and extraordinary peak power capabilities of 1000W (100 ms), WG200 cabinet can produce 133 dB peak output at 1m. Arranging WG200 cabinets in a Line Array configuration, this system could be very effectively used for very long throw, full range mass notification system with perfect intelligibility.



1W/1m Frequency Response Graph scaled for maximum calculated SPL (400W) at 1m

In another example, MAD LT-PMS-54-WG500 (see image on the front page) surface array has measured efficiency of 100 dB at 10m (33 ft). Utilizing full power of 13500W from built in amplifiers this speaker can produce an incredible full range SPL of 141 dB. Story doesn't stop here for this speaker system. LT-PMS54-WG500 is a Surface Array and projects sound to long distance with minimal loss of SPL and clarity. During one official MAD demonstration, measured output was 112dB @300m with only 1000 W applied. With full power output SPL would have been way above 120 dB!!

Reliability and life expectancy

MAD transducers have only one moving part. Once the diaphragm is properly stretched and glued in place, performance remains stable for years of operation without degradation. If the amplifier power is kept within the factory recommended safe operation range, life expectancy can be very long, in excess of 10 years.

There are planar magnetic speakers still in operation (Magneplanars from Magnepan) that were produced over 30 years ago. With proper care to avoid mechanical damage, and keeping power under control, planar magnetic speakers have almost an unlimited life. Of course, the assumption is that the materials (magnets, metal parts, ...) don't degrade over time.

MAD transducers use Polymer diaphragm substrate with aluminum conductors. This material is very strong and stable. Initial tension in normal operation doesn't change. It is thermally very stable. Designed upper operation temperature of all MAD transducers is 120 deg C without performance change. Overdriving the diaphragm can not damage it, even if it slaps hard against the magnetic structure.

The Stators are powder coated while the Neodymium magnets are plated with high quality coating. All of this can provide reliable long term operation even in the worst environmental conditions.

MAD speakers can work reliably in any environmental conditions, extreme cold, extreme heat, snow, rain, dust, ...

On the contrary, conventional drivers have very complex construction, with a lot of parts and glue joints that are susceptible to environmental and mechanical changes during long term operation. A typical problem is performance degradation of the moving system. The suspension gets looser and provides less and less centering support of the voice coil. Frequency response and distortion constantly slip away from the originally designed parameters. All of this can explain why some of the old PA system sound so terrible.

Due to thermal expansion, the coil very easy gets skewed or distorted and can rub against parts within very narrow magnetic gap. This can create audible mechanical noise or even complete failure. Overdriving the coil above excursion limits may cause the coil to get knocked into back plate of the magnetic structure and gets destroyed. If any of the glue joints fail (voice coil to coil former, former to spider, former to cone, cone to surround), performance will suffer badly. Life expectancy of conventional drivers is 3-5 years.

Full frequency range operation

MAD drivers and systems are designed for full range operation. There are no crossovers, no two-way, three-way systems. Full range is very desirable and currently Planar Magnetic Technology is the only system to provide this.

Conventional drivers can not work as full range and they are designed for limited frequency bands. For full range application designers are forced to use different kind of drivers—woofer for low frequency range, cone or compression drivers for midrange and dome or high frequency compression drivers for high frequencies. If human voice is to be reproduced it has to come through three very different devices, crossover network and in active systems through three different amplifiers. Different devices have different properties and different problems. All of this degrades the sound quality, creates anomalies in phase response and off axis response, which ultimately ruins the voice intelligibility.

Sound Radiation

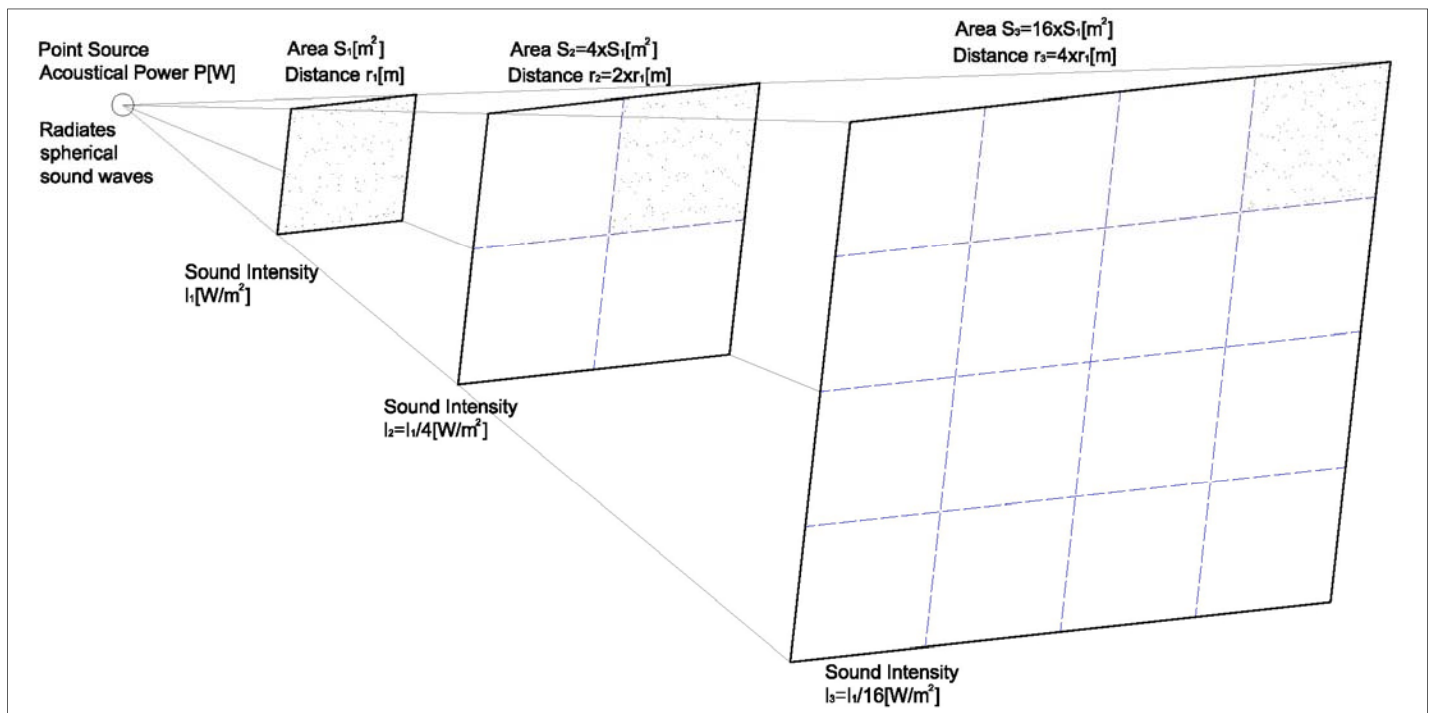
There are three types of ideal sound sources:

- Point Source - most common
- Line Source - Recently common in Professional Sound reinforcement Applications
- Plane Source - MAD Surface Array Technology - new, unique technology on the market

Point Source

A Point Source can be imagined as a small pulsating sphere that radiates sound all around. Every closed woofer cabinet at low frequencies (below 200-300 Hz) represents a Point Source. Point Source radiates spherical sound waves.

For easy representation Point Source radiation can be presented in a simplified way, taking into account spherical radiation.



The energy radiated from the Point Source is evenly distributed over the surface of an expanding sphere. The surface area of the sphere is inversely proportional to the distance (radius of the sphere) squared. If we double the distance, surface of the sphere will be four times larger. This is the famous Inverse Square Law.

Sound intensity is directly proportional to the covered surface. Converting Sound Intensity into SPL (in dB), SPL from an ideal point source radiator will fall at the rate of 6 dB per doubling of distance.

Line Source

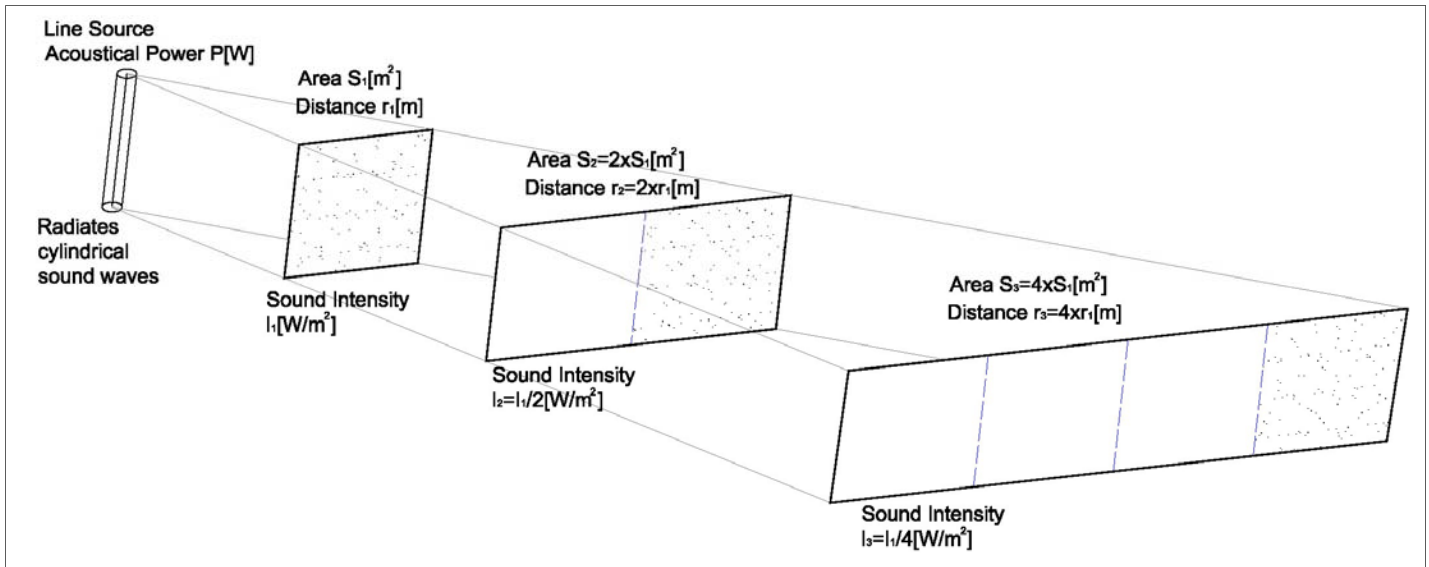
Line Source can be imagined as an infinitely long, small diameter pulsating cylinder that radiates sound. A practical example for the line source would be traffic noise radiated from the busy highway. A Line Source radiates cylindrical sound waves.

The energy radiated from the Line Source is evenly distributed over the surface of an expanding cylinder. The surface area of the cylinder is directly proportional to the distance (radius) of the cylinder. If we double the distance, the surface of the cylinder will be twice the size. Since the sound intensity is directly proportional to the covered surface, converting Sound Intensity into SPL (in dB), SPL from an ideal Line Source radiator will fall at the rate of 3 dB per doubling of distance.

If the Lines Source has limited size, it will behave as a Line Source in a limited frequency range and throw distance.

For easy representation Line Source radiation can be presented in a different way, taking into account cylindrical radiation.

A simplified graphical representation for Line Source can be used to explain the Line Source Radiation Properties.

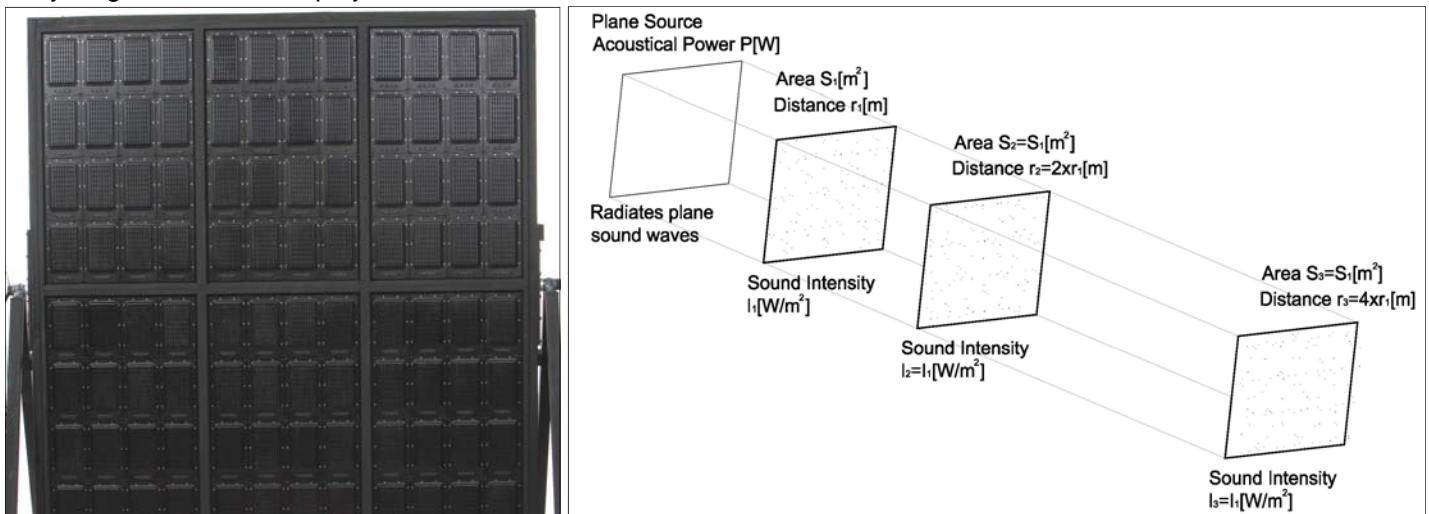


Plane Source

Plane Source can be imagined as infinitely large flat surface that radiates sound. Real life example for plane source would be traffic noise generated in the middle of the long tunnel that propagates towards the tunnel exits.

As the sound waves propagate from the plane sound source, they do not expand but continue to pass through the same area as the source itself. Therefore, the energy density at any point in space is equal to the energy density at the sound source plane itself. The sound pressure level is constant everywhere in the vicinity of a plane sound source. SPL is independent of the distance from the plane assuming that there is no loss in acoustic energy due to environmental conditions.

MAD™ Surface Arrays represent the closest approximation to the plane sound source. Plane Source is the ideal for very long distance sound projection.



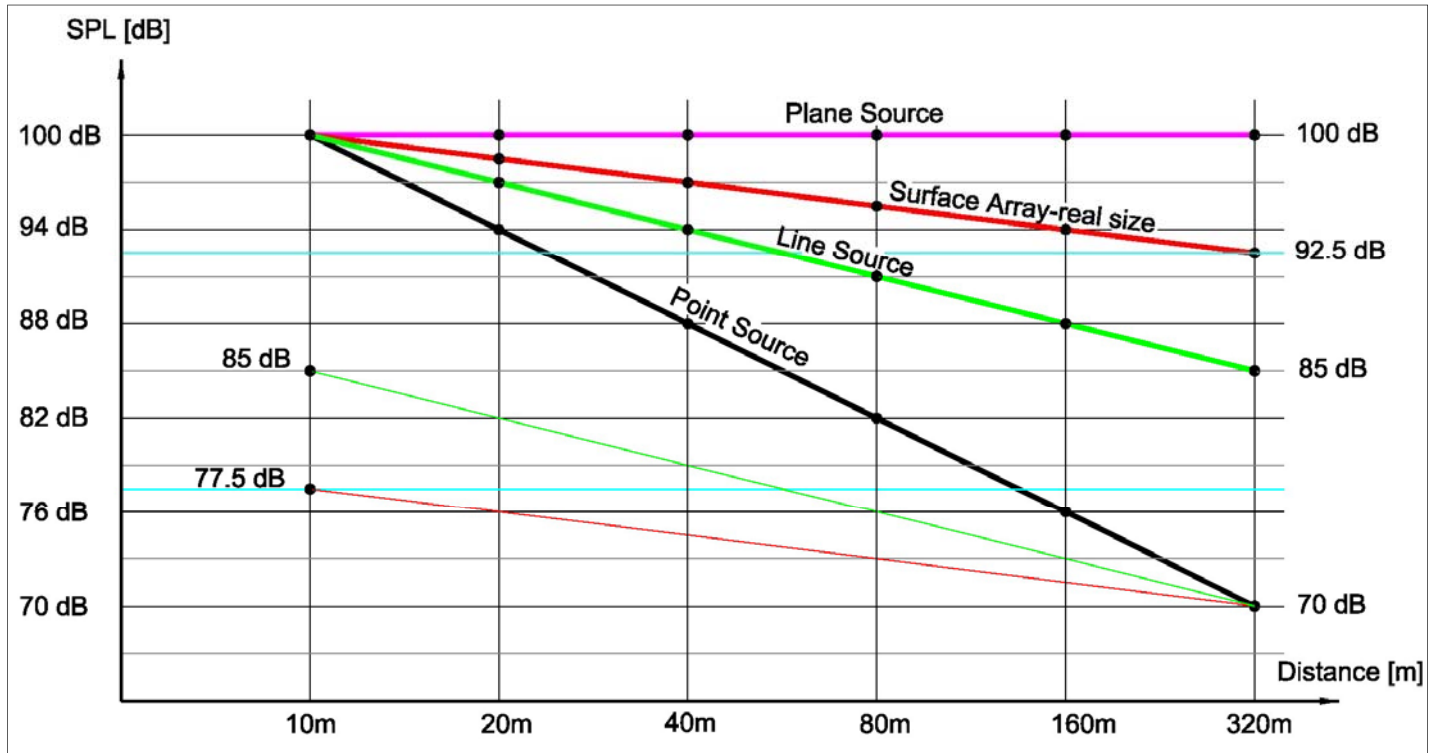
Simplified graphical representation of the Plane Source sound radiation.



MAD LT-PMS96 - Planar Magnetic Surface Array
 -The closest approximation to an Ideal Plane Source.
 Projects full range sound over one mile distance with perfect clarity.

Comparative analysis between different types of sound sources

Graphs below show SPL drop off versus distance for three types of ideal sound sources - Point Source, Line Source and Plane Source. MAD Surface array was included to show where it belongs compared to the other ideal sound sources. This is greatly simplified example for easy understanding of the differences between the different sound sources.



If we assume that the starting SPL at 10m needs to be 100 dB, final SPL at 320m will be quite different for different sound sources.

Point Source SPL drops 6 dB per doubling the distance. At 320m point source will produce SPL of 70 db.

Line Source SPL drops 3 dB per doubling the distance. At 320m line source will produce much higher SPL of 85 dB. This is 15 dB higher output than from the point source.

Plane Source SPL is independent from the distance and will produce the same SPL as at 10m - 100 dB. This is 30 dB higher SPL than from the point source.

MAD Surface Array lies between Line Source output and Ideal Plane Source. On average it will lose 1.5 dB per doubling the distance and it will reach SPL of 92.5 dB @320m.

If we assume that the output of 70 dB at 320m is adequate, and project the Line Source and Surface Array curves back to 10m, it is shown that the Line Source needs to start with 85 dB at 10m while a Surface Array needs to start with only 77.5 dB at 10m. Of course, an ideal Plane Source will have to start with 70 dB at 10m.

This shows that for the same SPL at 320m, a Line Source will require ~32 times less power, the surface array will need ~178 times less power while the ideal Plane Source will need 1000 times less power.

For a Line Source to reach the same SPL at 320m as Surface Array it would require ~6 times more power.

Even though real life is different, this simplified example shows that the Surface array has huge advantages compared to other sound sources for very long throw applications.



Satellite image of the site for the first official 1 mile demonstration Of MAD LT-PMS96 Surface Array and actual photo during the demonstration.

MAD Surface Arrays can be designed to fulfill any desired SPL or dispersion pattern.

Radiation can be very narrow as in LT-PMS series of products (see next page) or very wide as in MAD A9 or A8 series of curved Surface Arrays for Professional Sound Reinforcement industry, shown below.



MAD A8 Curved Planar Magnetic Surface Array



MAD A9 Curved Planar Magnetic Surface Array



LT-PMS-1-WG500



LT-PMS-1



LT-PMS-2



LT-PMS-4



LT-PMS-6



LT-PMS-24-Stop



LT-PMS-54-WG500



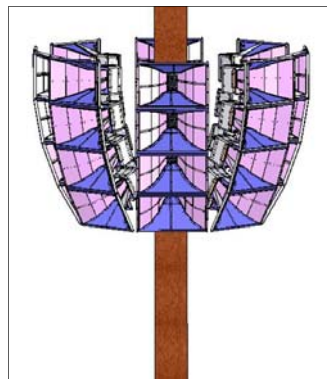
LT-PMS-96



LT-PMS-24

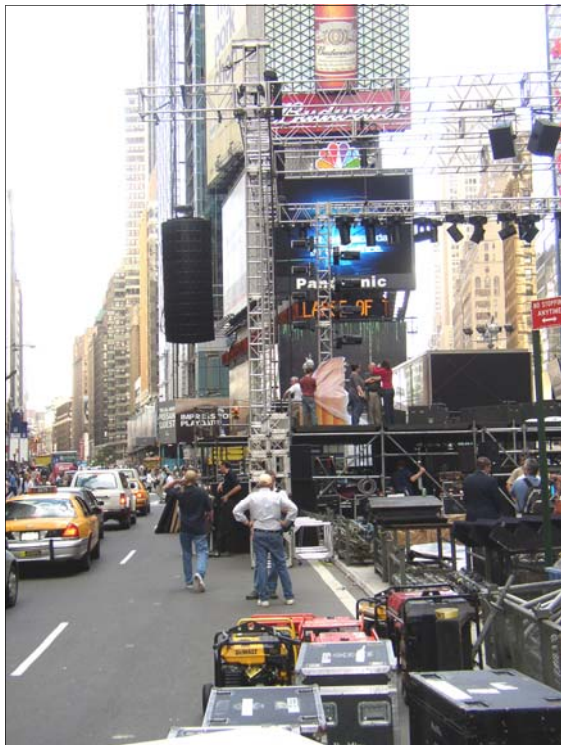


WG-200



WG-200 Mass notification System

8 Line Array clusters Provide 360 degrees, 1 mile diameter uniform coverage with perfect intelligibility



Examples of MAD Surface Array in use.