

THE EMBEDDED TRANSMISSION LINE

THE PROBLEMS

All loudspeaker drivers encounter diaphragm breakup when driven as a piston at the apex. Apex drive of a conical shape has been proven the most useful compromise for woofers while midrange and tweeter drivers can have a convex (dome) or concave (conical) diaphragm due to small diaphragm area. Different diaphragm materials shift the breakup region with different patterns occurring with different diameters and shapes. The open back driver experiences somewhat predictable breakup in free air but will encounter many pressure related variations of these patterns when mounted in enclosures or have the rear of the diaphragm terminate in a sealed or ported chamber. Modern driver designers can take static breakup modes into consideration when operating in free air to minimize their acoustic contribution. Dynamic pressure created when the diaphragm is enclosed greatly negates any efforts of the driver designer to reduce predictable static breakup.

Presently the engineer must choose from various permeable materials introduced into the enclosure in an effort to absorb portions of the rear wave. This is ineffective in critically damping the dynamic pressure waves. In many cases the rear wave is used to enhance the bass level of the loudspeaker using variations of the sealed enclosure. In all of these efforts there is a predicament involving proper dissipation of pressure related resonate energy immediately behind the diaphragm. Eliminating the energy would cause under damping of the diaphragm so the desired goal is to provide critical damping for the lower through higher frequencies not just at the primary lower resonance. Broadband critical damping of the driver means that it is aperiodic and has a proper acoustic load for the full range of frequencies and levels associated with its use. Critical damping involves proper acoustic termination of each element of the composite wave in a single cycle. If elements of the composite wave are permitted to reflect back to the diaphragm due to pressurization then standing waves are produced. Standing waves cause unnatural pistonic behavior of the diaphragm that adds additional acoustic output in some cases or a subtractive effect in others.

Typically drivers driven at the apex region utilize a dust cover to protect the voice coil gap from dust and external physical abuse. This cover actually becomes a diaphragm for the higher frequency range of the driver typically with limited dispersion. The dust cover (radiator) also traps energy behind its radiating surface creating breakup modes that become acoustical and are referred to the main cone as well. This trapped energy will be related to all frequencies produced by the driver. This dust cover (cap) is sometimes replaced with a phase plug, which prevents cancellation of the output near the apex. The phase plug is sometimes preferred over the dust cap in conventional high quality mid and high frequency drivers using conical diaphragms that extend away from the voice coil.

THE ETL™ SOLUTION

In order to provide real time critical damping at all frequencies a broadband acoustic absorber must be introduced which terminates excess wave energy that is present behind the diaphragm. The result is a dynamic pressure, which is constant and represents the electrical signal presented to the voice coil. This maintains a linear frequency related pressure gradient relative to the static ambient air pressure. The inherent benefits cause broadband piston motion for the driver without breakup. Cone breakup, the enigma normally associated with an audio driver alters dispersion qualities. The dynamic power handling of the driver is also improved as the constant internal pressure minimizes the tendency to compress with peak signal related dynamic diaphragm travel. A flat impedance curve is possible for subwoofers.

The **Embedded Transmission Line (ETL™)** is located within the air mass behind the associated drivers diaphragm as a part of the driver or its enclosure. Its purpose is to maintain the proper enclosure volume by involving the real time dynamic creation of **Independent Unidirectional Vortices (IUV)** to cause excess energy dissipation within the **ETL™**. The dissipating action is that of causing pressure to heat conversion by trapped vortices that are isolated from the main chamber by a pressure differential created within the **ETL™**. The low profile of the **ETL™** is necessary to stimulate the formation of boundary layer vorticity (**IUD**) inside **ETL™**.

The **ETL™** (see Fig 1 below) receives the negative going (positive pressure) **Lumped Composite Wave (LCW)** from the diaphragm through an aperture of predetermined dimension and position. This aperture size will determine the input velocity of the **LCW** and speed of **IUV**. This directional acoustic energy is introduced as a pressure wave and becomes a **Primary Ring Vortex (PRV)** on the opposing side of the aperture within the **ETL™ Open Area (OA)**. The **OA** must be maintained at narrow height dimension to stimulate the formation of **IUV**. The **PRV** contains the negative going kinetic energy of the diaphragm and is introduced into the foam cell structure of the **Vorticity Multiplier (VM)** upon incident and at right angles. The **VM** acts to stimulate the formation of **IUV** to begin the heat dissipation process breaking the **PRV** into **IUV** as the energy progresses towards the terminus. The **IUV** generated vary in energy levels relative to intensity and frequency content of the **LCW** and rotate at individual rates as they isolate and remove the **heat** energy through a viscous reaction with the cell walls of the **VM**. All energy is retained within the **ETL™** with **PRV** cascading vortices contained at the terminus of the **ETL™** as a **Stationary Ring Vortex (SRV)**. The **SRV** forms in the terminal area above the **VM** and continuously dissipates the energy of the **PRV** generating micro-scale **IUV** within the **VM**. The **PRV**, **SRV** and **IUV** exist within the **ETL™** as separate energy conveyers in shear to remove heat from the composite (the combined energy in the current wave) to allow for expanding dynamic levels and wavelengths of input

signal. The **PRV** maintains pressure differential within the **ETL™** via the aperture since the energy source always contains the higher pressure of the **LCW**. This **IUV** vortical activity remains within the **ETL™** structure throughout its dissipation period compensating for excess acoustic energy levels associated with the **LCW** in real time. Positive diaphragm motion serves to maintain the pressure compensated volume created by the **ETL™**, as the air molecules are spaced apart thereby reducing heat accumulation. Positive motion begins from a nominally constant pressure at the end of the negative cycle. A single event is represented on the internal cone surface and therefore on the external cone surface. A consistent pressure differential with the ambient is always maintained by the internal impedance compensation to allow for a proper acoustic power transfer with varying frequency. Simple low energy storage diaphragm materials are preferred when using the **ETL™**.

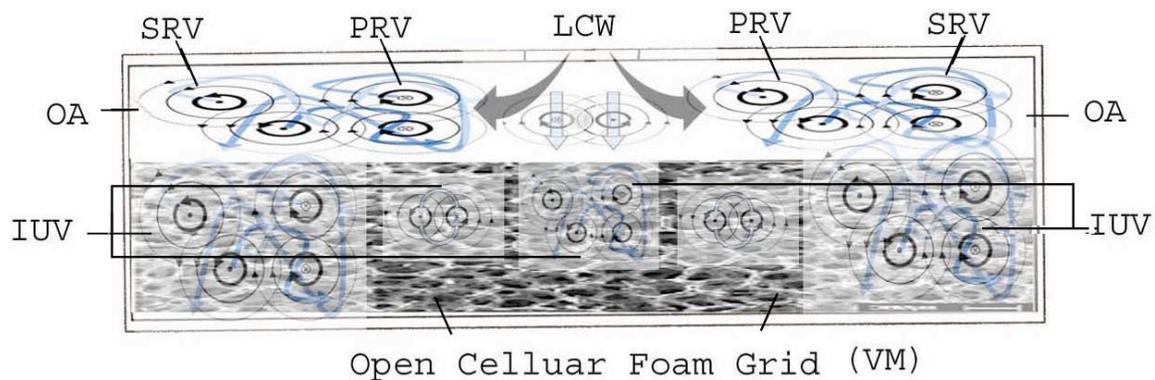


FIG 1 - Embedded Transmission Line

DRIVER OR ENCLOSURE

The **ETL™** can exist as a part of the driver as a **Pole Piece ETL™ (PPETL™)** bringing its benefits to any driver with a voice coil cover/diaphragm or it can exist as a part of the enclosure for open frame drivers normalizing the pressure created by the main cone. Combinations of the **ETL™** module can be used within a common enclosure to afford fine-tuning of a driver or system. This combination can be driver(s) based **PPETL™**, which is a single piece solution and/or in combination with enclosure based **ETL™** modules of different dimensions that can acoustically adjust the frequency-power response of the driver. We utilize the term power response since any gain in output when tuning is not associated with the introduction of additional electrical power into the speaker coil. The effect that the **ETL™** has is that of normalizing the impedance of a speaker system. This process inherently improves the critical damping, dispersion and distortion characteristics of the speaker system. High frequency systems can have less breakup, lower distortion and better dispersion. Low frequency systems can have consistent impedance and a constant phase shift with frequency and operate without high mass and associated resonance.

ISOCHORIC LOUDSPEAKER OPERATION

P- Physics L – Loudspeaker physics

1P - Suppose a quantity of gas at pressure P is enclosed in a cylinder with a movable piston of area A . Force $F=PA$ will be exerted on the piston by this enclosed system.

1L – The loudspeaker diaphragm represents a piston with the box and the air a system. A force, $F=PA$ will be exerted on the air mass when the diaphragm is in motion. This means that when the diaphragm is driven negative the air will exert a nominal force against it if the input levels are adequate.

2P – If the piston is allowed to move a small distance Δx , allowing the gas to expand slightly, the piston will do work on the external mechanism. The quantity of work done is given by the quantity of the force F (gas) and the displacement Δx of the piston. The system is now doing the work on the piston.

2L – The loudspeaker as a piston should only to respond to signals input from its driving source amplifier. In the piston analogy the diaphragm is assisted by compressed air in returning to neutral or a positive state of direction. While this may not seem a likely problem considering the small motion of the diaphragm in reality this is the source of much discrepancy in loudspeaker performance. This is analogous to an acoustic diode with energy created by the cone different for each input signal polarity. The external mechanism is the diaphragm, which is operating into non-symmetrical pressures producing distortion that impairs linearity and detail performance.

3P – If the piston moves as a result of the external mechanism then work is done on the system. This is the desired result since we want to control the system with an input signal. The gas will be compressed in this case so heat must be removed while the piston is expanding to maintain the pressure constant.

3L – If the diaphragm moves as a result of an input signal then it will compress the air behind its diaphragm. The force required to compensate for this pressure is nonlinear and cannot be predicted by amplifier design or overcome with raw power. This causes an inherent distortion component with this force rebounding in addition to the input signal to increase the velocity of positive going signals. If these inherent pressures are acting on the diaphragm they will have additional distortion components not related to the input signal harmonics.

4P+L – Most uses of a piston for balanced performance involve multi-cylinder operation. The external mechanism (spark plug) moves the piston down while the crankshaft (shared by all pistons) provides the restoring force to remove the explosive gases from the cylinder. The loudspeaker must do this alone and with little mass while outputting a broadband audio signal unlike other pistons. The **ETL™** is the only solution to provide balanced isobaric operation for all loudspeaker drivers. This restores a broadband flatness to the impedance curve.



ETL - STATIC BREAKUP MODES

Driving the cone at the apex introduces traverse nodal lines (Fig 1 a) and traverse nodal circles (Fig 1b) across the cone and represent solid waves observable upon sine wave stimulation in free air. Fig 1c represents pistonic motion with ETL module at all frequencies. Nodal lines are necessary to cause motion but affect little cone area.

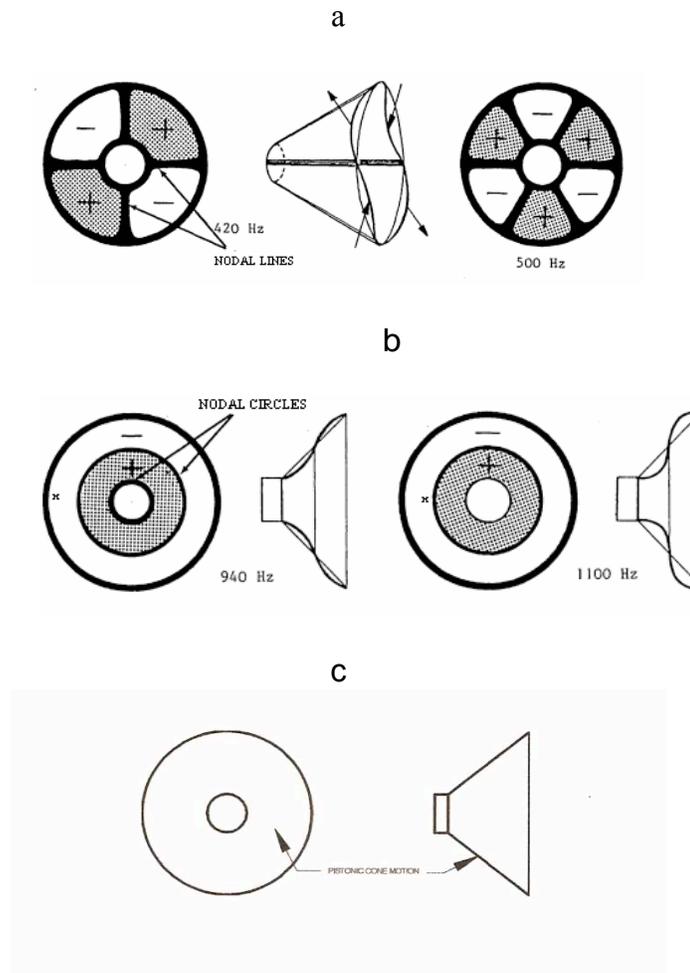


Fig. 1 - Resonance phenomena in unenclosed loudspeaker cones:

- a) Traverse nodal lines*
- b) Traverse nodal circles*
- c) ETL prevents nodal circles*

The frequency range of these waves can be divided in three parts. The first part (fig. 2a) is characterized by proportional longitudinal (right) and traverse (left) displacements below the anti-resonant frequency. The left graph shows accurate traverse speaker cone motion without resonance. The second part (fig 2b) is characterized by the presence of a point called the transition point (x). This point

moves from the outer edge of the cone to the inner edge as the frequency increases (x on Fig 1b). Between the cone's base (voice coil area) and the transition point x , the traverse displacement is determined by a longitudinal wave of high wavelength (fig 2a), and between the transition point (2b) and the outer edge, there is only a bending wave of short wavelength (2c). The cone is submitted to a succession of traverse resonance as the distance continues from the voice coil connection towards point x . As illustrated in figure 2c, the cone is entirely covered by bending waves in the third part. It is the desire of the speaker designer to assure that the driver operates only in the first part (2a) for its range of frequencies. When the driver begins to exhibit the effects of 2b and 2c for traverse displacement then the speaker is exhibiting its resonant range. The angular velocity of the cone (w) concerns waves traveling through the cone itself (undesired traverse) at right angles relative to the longitudinal (desired) velocity (v) of the cone, which determines its linearity relative to the input signal. The traverse waves change the desired sound by generating nodes and anti-nodes on the cone itself (flexing) at frequencies non-harmonically related to the input signal. Traverse waves (fig 1b) are traveling through the cone faster because it is a solid structure creating shorter wavelength waves with the same frequency. Solid longitudinal waves appear (fig 1a) and travel the length of the cone (voice coil to surround) as it moves but are less contributive to audible breakup modes than the axial modes (fig 1b), which appear on the continuous circular area. These modes are of great concern to the driver designer and they create the phenomena seen in the traverse section of Fig 2b and 2c. The longitudinal traverse waves (fig1a) and the traverse axial modes (fig 1b) are created when the diaphragm flexes relative to the voice coil position creating multiple cancellations on the cone surface. Attempts to suppressed these resonant modes by careful driver design can help but they can only be minimized by critically damping the diaphragm at all frequencies to stop motion quickly before point x (in time) is reached (2b, 2c). The **ETL**[™] provides real time molecular heat dissipation to maintain a constant pressure assuring pistonic motion throughout the drivers frequency range. The driver relies on the **ETL**[™] to maintain the acoustic impedance assuring linearity of motion at all operating frequencies and to resist modulation from reflections or external sources. With the **ETL**[™] module the cone remains in the mode of fig 2a for all frequencies and point x is not reached.

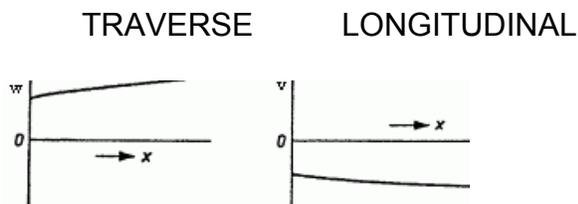


Fig 2a

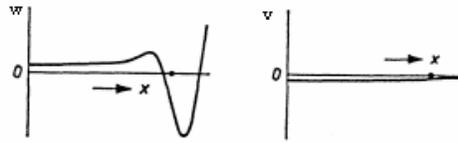


Fig 2b

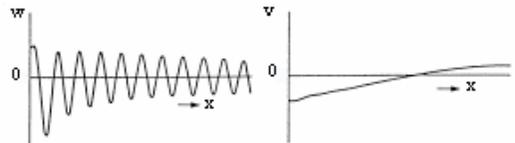


Fig 2c

ETL™ - DYNAMIC BREAKUP MODES

Beyond the problems associated with static almost predictable breakup modes, which must be damped, there are those associated with the program material itself. When the loudspeaker diaphragm is forced to heat the air mass within the enclosure the effect varies with frequency and level. The diaphragm will not exhibit the same breakup characteristics when under pressure as it does when there is less resistance to its motion. This means that mixed higher frequency breakup will be modified by the lower frequency content when pressure is created causing extremely complex and unpredictable patterns to occur on the diaphragm surface. Eliminating the pressure increase eliminates these unpredictable breakup patterns, as they can't be created when the volume is dynamically modified by the **ETL™**.

ETL™ - ROOM REFLECTIONS

The constant pressure within the **ETL™** enclosure or modular **ETL™** based driver resists the modification of its radiation resistance by external reflected signals to provide a neutral in room performance. The additional external pressure summed at the diaphragm will be dissipated in the **ETL™** at the molecular level in addition to that created internally. The recorded ambience (acoustics) of the source material will now dominate any attempt of reflections to modify the recordings character. Normally the room will create new sounds that cause the speaker to change its tone. This will be different for each user location with no consistent predictable sound quality.

ADDITIONAL BENEFITS OF THE EMBEDDED TRANSMISSION LINE

REALIZE EFFECTIVE CROSSOVER DESIGN

ETL™ technology can be introduced into existing loudspeaker enclosures in modular form to provide its benefits with dimension, thickness and shape allowing acoustic tailoring of the drivers response. Individual drivers such as full range, midrange and tweeters can have ETL™ technology as a part of their construction. A reduction of breakup modes in midrange and tweeters greatly improves the systems in room performance as their off axis contribution to total response is accurate. The application of ETL™ technology to all of the drivers in a multi-way system enhances the performance of the drivers at their frequency extremes allowing for similar dynamic mass (mass alignment) to exist at the chosen crossover frequency. The electrical crossover becomes very effective in achieving its intended purpose whether first, second or third order with the improved drivers response at the crossover point being a great contributor to its' effectiveness and simplicity. The virtual elimination of cone breakup modes provides a consistent acoustic platform to establish a reliable crossover point in multi-way systems.

IMPROVED LOW LEVEL RESPONSE

The resultant ETL™ single or multiple driver loudspeaker improves the low level response of the system in which the driver(s) typically hunts for a zero stop point due to breakup resonance and suspension non-linearity's very similar to an improperly biased push-pull amplifier which exhibits notch (crossover) distortion at low levels. Notch distortion increases inversely relative to level because at low volumes the signal induced cone excursion is small relative to the unstable zero positioning of the cone. This distortion typically has to be overcome by high volume levels to separate the observed signal from this constant low-level distortion characteristic. Cone breakup is also non-linear with its greatest effect being experienced at lower levels. The solid structure of the cone prevents the flexing from maintaining linearity at higher levels creating more distortion at lower volumes. Although the flexing will get greater at higher levels it will be relatively low compared to the much higher longitudinal motion of the cone causing it. Detail and recorded ambience suffer from cone resonance and non-linear zero crossing distortion even at higher levels.

LONG TERM LISTENING

ETL technology improves the listening experience over time, as the body is stressed by the introduction of unnatural sound when using conventional speakers. ETL technology allows the listener to enjoy music and video comfortably without feeling the need to stop.



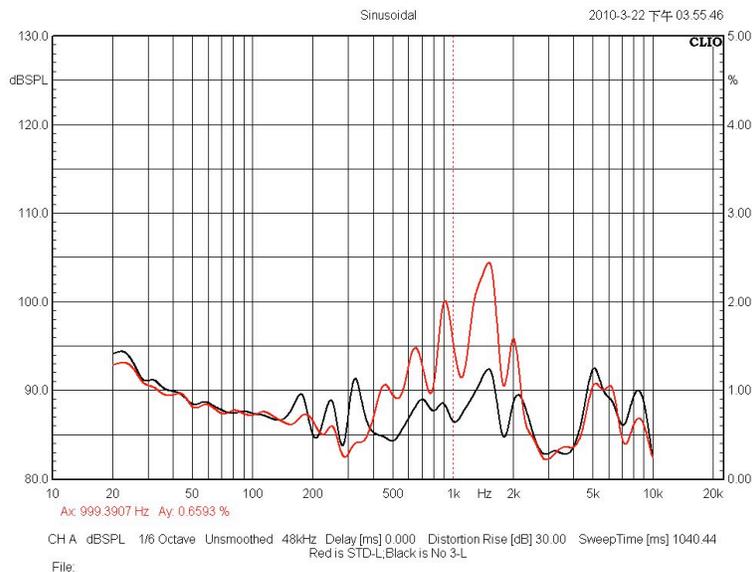
MORE WONDERFUL LIFE WITH ETL TECHNOLOGY

The ETL-technology at lower cost produce Natural, Real, and Clear sound quality, which is unprecedented and previously unattainable. Below listed items are the different in between ETL and conventional enclosure system.

ETL compare to Conventional enclosure system

Items	ETL-Technology	Conventional
1	clear	very Clear & can hear more detail sound
2	fatigue	no fatigue(good for long term listening)
3	human vocal	natural and clear
4	life	natural as life sound
5	airy	wide range and clear
6	lower volume	clear and comfortable
7	human face	relax
8	vibration	less

It is the goal of TBI to offer its ETL technology to all audio products while raising the threshold of sound quality. Life will be more wonderful with ETL technology.

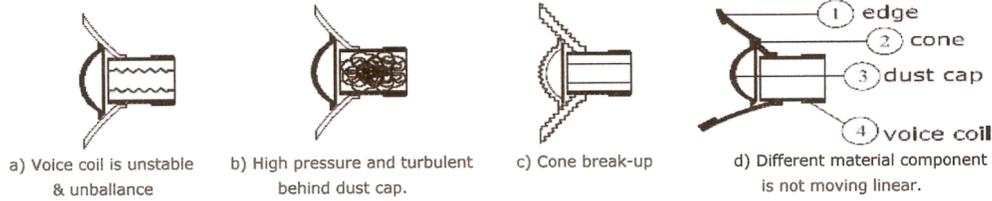


ETL (black) Distortion Reduction In Normal Earphone



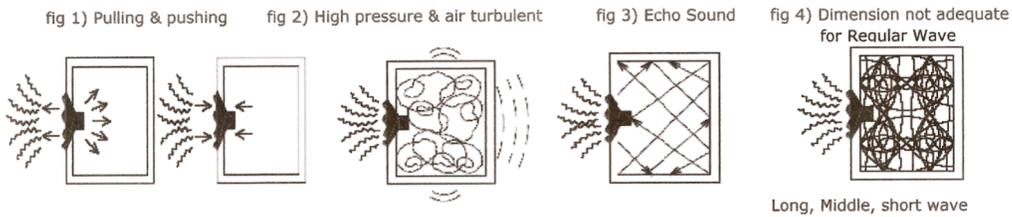
Distortion Prevention Technology

A) Reasons for distortion from speaker driver



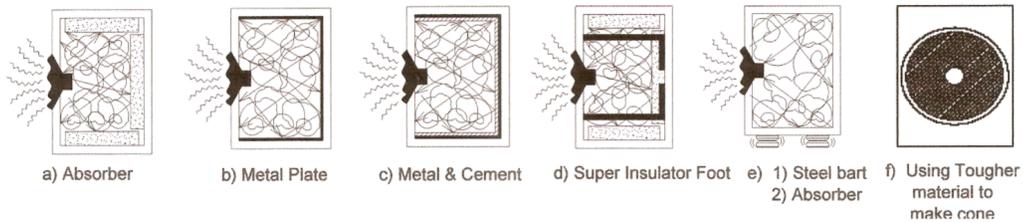
B) Reasons for distortion from conventional loudspeaker System

- Outside enclosure sound is poor, because cone is crippled by internal pulling and pushing from air pressure.(fig 1).
- Internal enclosure sound (fig 2,3,4) is fighting with outside enclosure sound.



C) Method by conventional way but no solution

- Below listed methods are taken to reduce air-pressure by traditional way but no solution.



C) ETL TECHNOLOGY- Reorganization as a pistonic motion

