

Understanding Loudspeaker Coupling/Decoupling

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Introduction

This is a question that I get asked a lot – what do I have to do to properly stabilize a pair of loudspeakers? Floor-standing speakers are sometimes supplied with feet and spikes already installed, or they have inserts to allow spikes to be screwed into the cabinet. How effective are spikes? With your stand-mounted monitor (bookshelf) loudspeakers, what stands do I use? What do I use to couple/decouple the loudspeaker to the stand?

This paper attempts to bring a bit more clarity to the subject.

Definitions

Couple – to “make as one” as in coupling a loudspeaker to a loudspeaker stand makes the stand and the loudspeaker as one. Coupling the loudspeaker to the floor makes like the loudspeaker is a part of the floor, and coupling the loudspeaker to the loudspeaker stand makes the stand a part of the loudspeaker – like it has suddenly grown feet.

The opposite is to de-couple – where there is absolutely no relationship. Using an anti-gravity generator to float the loudspeaker is an example of de-coupling. Even magnetic levitation has some degree of coupling. Absolute de-coupling is impossible using current technology.

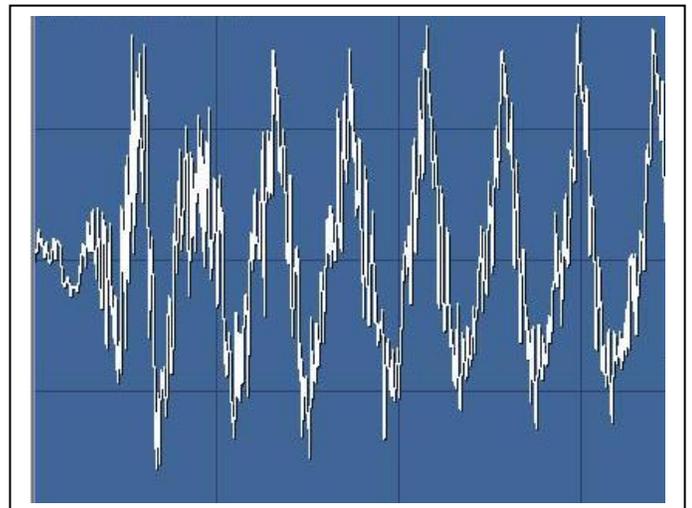
So, for the real-world purposes of understanding loudspeaker coupling/decoupling, there is no perfect coupler and there is no perfect de-coupler.

The Musical Context

We must consider that the context of our discussion to be that the loudspeaker is playing music, and not sine waves. Sine waves are symmetric. Music is never symmetric. Music is transient and chaotic.

For example, common sense tells us that a plucked guitar string, a bass drum hit, a struck piano key all have a much larger initial positive-going wave than the negative wave. Looking at the waveform of a piano note, it is easy to see that there is more energy in the positive-going wave. As the note decays, it will get more and more symmetric.

Once we understand this about music, we can design proper loudspeaker coupling/ decoupling. This fact is also important to driver design,



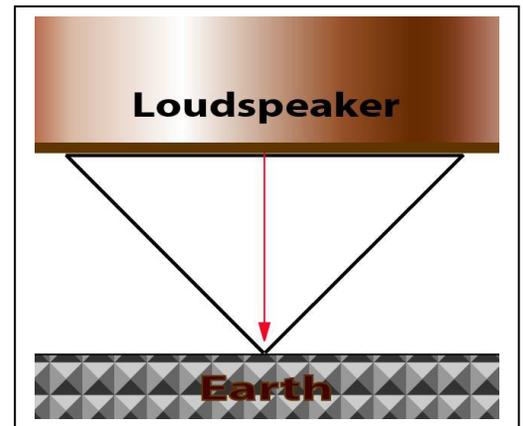
crossover design, amplifier design, power supply design, and cable design for music reproduction, but at this time we won't go there. There is net forward energy from the loudspeaker drivers, and there will be net backward energy in the loudspeaker cabinet that has to be managed.

Coupling by Spiking Loudspeakers

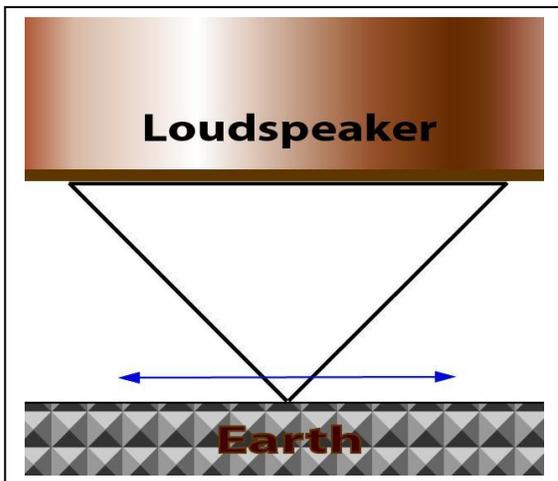
Spikes are couplers and will couple the loudspeaker to the earth – or are they? Most of what you read will tell you that a spike is a coupler – and common sense will tell you that it is, until you examine it in much greater detail.

Considering the forces vertically, the spike is a coupler. Due to the tiny contact patch, it is a low impedance path to ground for all frequencies of vibration. Considerations include the size of the contact patch at the point of the spike (how sharp is the spike), the material the spike is made of (whether the spike deforms), and the material the spike sits on (whether it dents).

If the spike deforms, and the deformation is elastic, there may be a resonant frequency at which the spike will “bounce”. In general, we would consider the spike an excellent coupler in the vertical plane.



However, what happens when we look at the spike with forces in the horizontal plane? Then, whether the spike is a coupler or a de-coupler takes a whole different complexion.



If, like skates on ice, the spike is very hard, the surface on which it sits is very hard, and there will be low friction, then spike is a decoupler. Depending on the weight of the loudspeaker and the friction of the surface the spike sits on, a sufficiently large sideways force will cause the spike to slide around on the surface.

If the spike can deform the surface in any way, there will be a whole host of new things to consider. For example, if the surface is hard stone, and the spike is steel, a large enough horizontal force could cause the spike to just scrape around on the surface, and you might get a sound like fingernails on a chalkboard (blackboard).

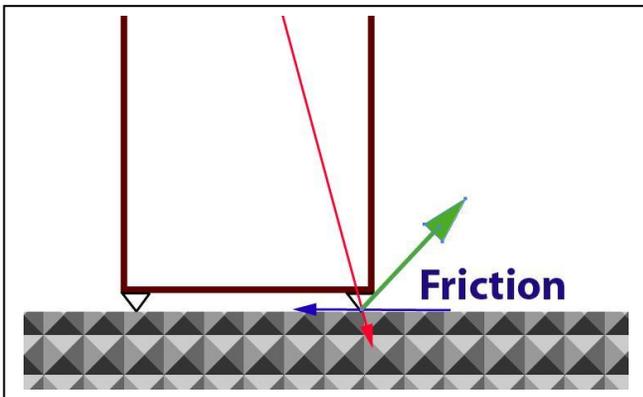
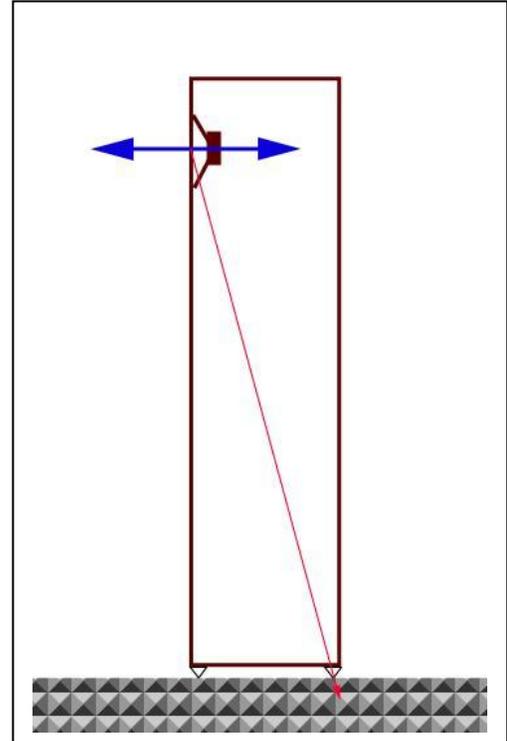
If the surface is wood, and the spike makes a hole and nails the loudspeaker to the wood, then the wood couples to the loudspeaker, and you might get a warm, woody sound that some audiophiles will find attractive.

Now that we understand that the spike is a coupler in the vertical plane and could be a decoupler in the horizontal, we need to consider the forces that the spike will meet. The next consideration is simple vector mechanics that we all learned in High School.

Examining the dynamic forces generated by the movement of the driver cone (blue arrow) in a loudspeaker, there will be zero vertical forces since the cone is almost directly above the front spike, but the horizontal force will equal the force generated by the driver assuming always that the spike is tightly coupled to the loudspeaker cabinet by screwing it in or glueing.

The rear spike, on the other hand will have both a vertical element as well as a horizontal element. (The red vector.) We mustn't forget that there are also static forces on the spikes due to the mass of the loudspeaker and gravity.

Since the point of force and the two spikes are rigidly coupled by the loudspeaker cabinet, the forces on the two spikes will also be related. Looking at the rear spike, the combination of the horizontal and vertical forces, and friction will result in a third force (green vector below).

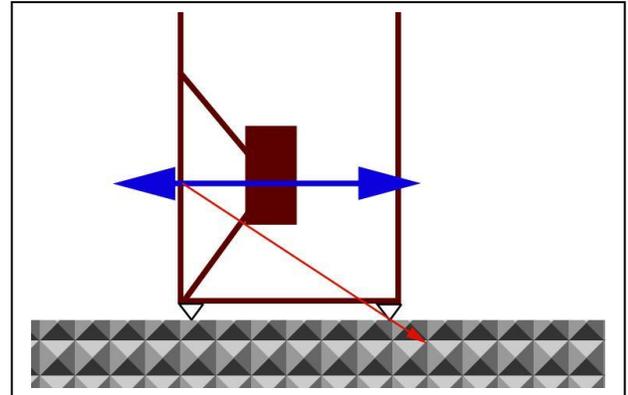


To illustrate this third force, if you push the top of a spiked loudspeaker, and if there is sufficient static force (weight) on the spikes and if there is sufficient friction, the loudspeaker will start to tilt backwards on the rear spike. If you pull the top of the loudspeaker towards the front, the loudspeaker will tilt forwards on the front spike. On a hard, slippery low-friction surface, pulling or pushing the top of the loudspeaker, even when it is on spikes, will cause the loudspeaker to slide.

Thus, although we mentioned earlier that there is zero vertical force on the front spike generated by the horizontal driver forces, the front spike's tightly coupled relationship to the rear spike plus friction at the rear spike creates some vertical forces. You will also find that due to the different vector forces, it is easier to pull the front of the speaker to tilt it forwards than it is to push the front of the speaker to tilt it backwards.

Hence, the spiked speaker will react asymmetrically to forces generated at the top of the speaker (usually the midrange – as the tweeter is usually too small and light to generate significant forces at the foot). With sufficient forces at a midrange/mid-woofer at the top of a tall loudspeaker, the front spike might *chatter* on a hard surface due to the up and down forces generated.

How about a woofer at the bottom of the cabinet? Looking at the forces created by a woofer at the bottom of the speaker, the forces on the spikes are primarily horizontal. However, as the woofer produces very much larger forces than the midrange and it is usually mounted at the bottom, most of the vibrational forces in a loudspeaker are horizontal – the plane on which a spike is **least effective** as a coupler. This is also true of the forces on a bookshelf loudspeaker on the top of a loudspeaker stand.



A pair of spiked loudspeakers on a very low friction surface (steel spike on a diamond surface for example) might well be launched backwards with a single very loud drum kick. With sufficient friction on the other hand, the forces around the moment of the front and rear spike will generate vertical forces in the other spike – resulting in the subwoofer rocking on the spikes and hopping around the room.

Effectiveness of Spikes

When a loudspeaker is sufficiently massive, the spike is an effective coupler. The large static forces in the vertical plane are difficult to be overcome by the vibrational forces in the horizontal plane. However, it may not be efficient enough as a coupler to sink the vibrations generated by the drivers to the earth depending on the scale of difference.

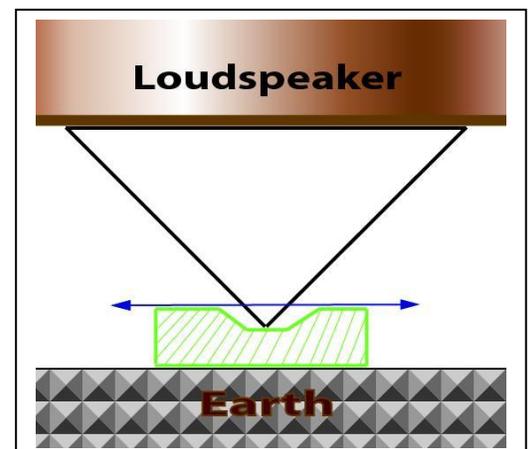
As a result, most spiked loudspeakers will sound different depending on the surface upon which they are placed. It may sound “harsh and brittle” if the spike is just barely scratching the surface of a stone or tile floor, or “warm and inviting” if the spike has nailed the loudspeaker into a wooden suspended floor that is now booming along with the loudspeaker.

Band-aids for Spiked Loudspeakers

Enter the “spike cup”.

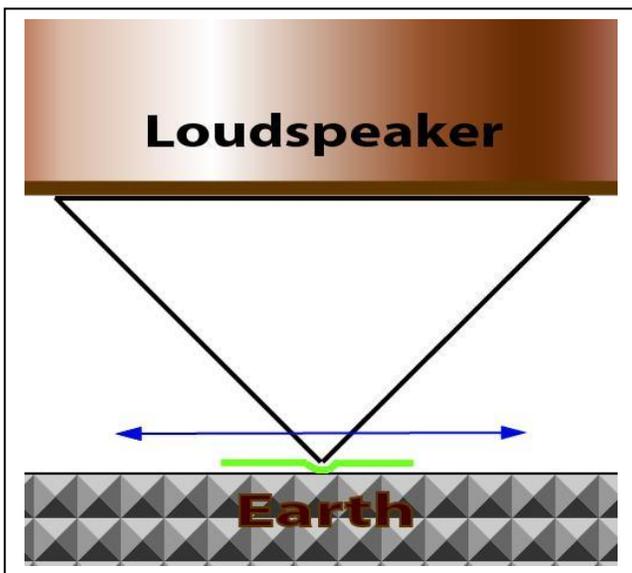
For many reasons, including to protect a valuable hardwood floor, and to “improve” the sound of a spiked loudspeaker, the spike cup was invented.

With stone and ceramic floors, the spike cup (usually made of a metal) solved the problem of a hard, scratchy sound caused by the spike scratching the surface of the stone, or a warm, muddy sound when the floor is made of wood. A cup is also often used to protect a hardwood floor from being marked by the sharp spike.



Remembering that there are more vibration forces in the horizontal plane due to driver movement in the loudspeaker, and due to the mass of the loudspeaker, there are more static forces in the vertical plane, the cup couples well vertically to the earth, and friction between the cup and the surface helps couple to dissipate horizontal vibration forces.

When the cup is made of soft metal like copper or bronze, a steel spike deforms the surface and then couples the spike better to the cup. Due to the much larger contact area between the cup and the ground, vertical coupling is not as good, but since most of the vertical forces are static, the degree of coupling is not critical.



A soft metal is also likely to have higher friction against a smooth floor like granite or marble. An excellent substitute for a spike cup is a pre-1982 US penny. We use a pre-1982 penny because they were 95% copper, whereas post-1982 pennies were zinc with a thin copper plating. For whatever reason, we find copper pennies to sound far better than zinc pennies (and most spike cups we have encountered.)

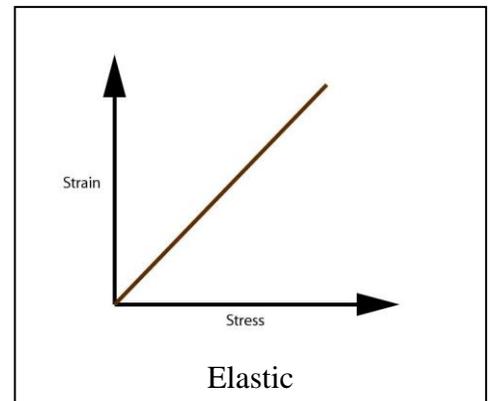
If you have pre-1964 US dimes in your pocket, they are even better than pre-1983 pennies as they are made of silver, silver being softer than copper.

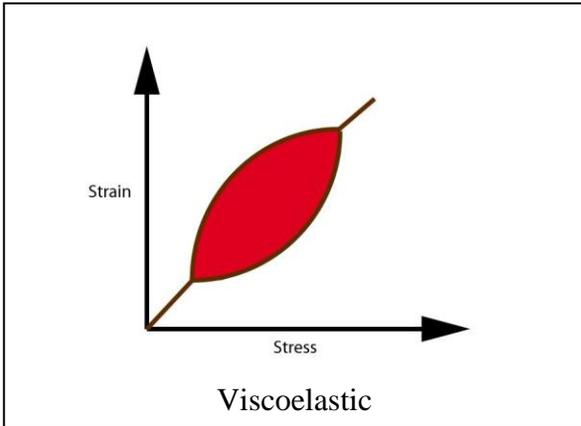
Due to the weight of the loudspeaker, the spike is likely to put a dimple on one side of the coin, and push out a nipple on the other side. This serves to better couple the spike to the coin in the horizontal plane, and also better couple the coin to the floor.

Decoupling Loudspeakers with Viscoelastic Materials

The other school of thought is that the loudspeaker needs to be de-coupled from the surface it sits on. Hence, decoupling pucks of various materials and design – the most common of which are viscoelastic materials. These are materials with both elastic properties as well as viscous properties.

An elastic material is like a spring. It has a constant stress-strain relationship. When the stress is applied, it instantly deforms, and when the stress is removed, it will quickly return to the same state it was in before the stress was applied. A viscous material (like honey) on the other hand, will first resist the stress, and then will strain linearly with time as long as the stress is applied, and it will not return to its pre-stressed state.

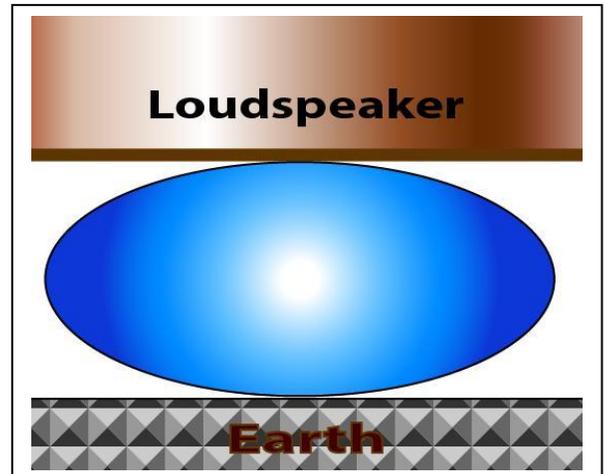




A viscoelastic material combines the properties of both. At low levels of stress, it behaves as an elastic, deforms under the stress and will “bounce back” when the stress is removed. At a higher level of stress, it may then flow and deform more with time at the same level of stress. When the stress is removed, it may take some time to return to its pre-stressed state. The stress-strain graph looks like this. The red area is where the material behaves as a viscoelastic – and where there is a loss of energy, seen as a generation of heat in the material.

The red area is the hysteresis loop, and shows where the material loses energy in a load/unload cycle. Since viscosity gives a strain rate that is dependent on time, different materials react differently to music. Some materials (like blu-tac) react so slowly that they are effectively a solid at musical frequencies and hence must be considered a coupler.

A viscoelastic puck placed under a loudspeaker can be considered to be a decoupler because it allows the loudspeaker to “float” above the surface it sits on. However, that is again too simplistic once we consider the forces (and hence stresses) placed on the puck.



Specifically, viscoelasticity is a molecular-level rearrangement of long polymer chains. When a stress is applied, parts of the polymer chains rearrange and the material *creeps* – and exhibits the viscosity property. When the stress is removed, the polymer chains gradually rearrange themselves to regain their original shape – and exhibits the elastic property.

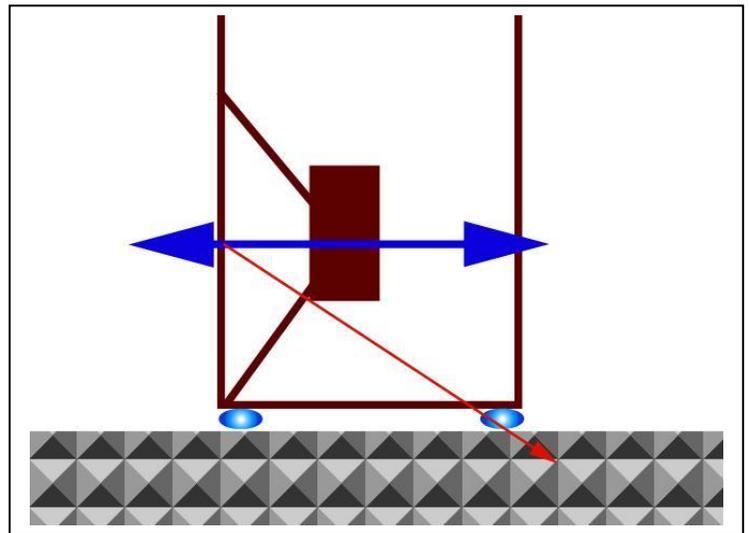
When we examine again the forces through the viscoelastic puck, we again come to the massive static vertical force generated by the mass of the loudspeaker, and the small horizontal vibrations resulting from driver cone movement. If the horizontal vibrations have time period and stress within the red viscoelastic area of the stress-strain curve, the puck will be a very effective decoupler. All vibrations are absorbed and dissipated as heat. If they fall outside (or some fall inside and others fall outside) the viscoelastic area, then we again have an elastic

The problem is the relationship of the vertical stress to the horizontal forces. Because the puck is squished and deformed by the large vertical force, the long chain molecules may already have been stressed to the point above the viscoelastic area. Then, the puck begins

to behave as a solid elastic material again – and it is no longer effective as a decoupler and performs as a coupler.

This gives rise to yet another question – how many pucks to use? If insufficient numbers of pucks are used, then the pucks couple the loudspeaker vertically, and act as an elastic spring horizontally. If sufficient numbers of pucks are used so that the vertical force plus the vertical vibration forces stay within the area of viscoelasticity, then the puck will be a decoupler in both the horizontal and the vertical planes. If so many pucks are used that the stresses in the horizontal plane are below the red hysteresis loop, then again the pucks act as an elastic spring horizontally.

So, is that a problem? We need to understand then what this puck does to the loudspeaker cabinet. For this, we turn to dynamic mechanical analysis (another high-school topic of interest) of small oscillatory forces. In a purely elastic material, stress and strain are in phase – i.e. the response of one caused by the other is immediate. In a purely viscous material, the strain lags stress by 90deg. Viscoelastic materials exhibit behavior somewhere between these two, and depending on the stress applied, the strain will lag stress by anywhere from 0deg to 90deg.



Now, this is where things get really fun and interesting! If you again consider both the vertical and the horizontal forces, there are several scenarios:

- 1) A few pucks are used and the loudspeaker squishes the pucks down so hard that they are elastic vertically and horizontally;
- 2) More pucks are used so that the pucks are elastic vertically but viscoelastic horizontally;
- 3) Even more pucks are used so that the pucks are viscoelastic vertically and horizontally;
- 4) Yet more pucks are used so that the pucks are viscoelastic vertically but elastic horizontally.

Let's consider the implications of the effect of decoupling pucks.

- 1) When the pucks behave elastically both vertically and horizontally, it is likely that they are squished so hard that they become a solid vertically – and hence become an excellent coupler. An example is a small blob of blu-tac used to secure a loudspeaker to its stand. If there is elasticity in the horizontal direction, the strain is in phase with the stress, and thus reduces cleanly nett horizontal forces. An

impulse at the loudspeaker causes the loudspeaker to bounce backwards (you have to remember that the loudspeaker is many times the mass of the driver cone) but when it is elastic, the bounce is clean and you get undistorted but reduced impact.

If there is any rocking movement of the loudspeaker it is also reduced in magnitude. As we understand that music is not symmetric and not a sinewave, with elastic behavior, we are not so concerned about oscillation that will be excited by opposite, in-phase behavior.

So, paradoxically, while elastic mounting like this may be bad for loudspeakers that are only expected to produce sinewaves, for music, it may not be too bad.

- 2) When there is viscoelastic behavior horizontally, the reaction of the suspension lags the strain by up to 90 deg. Hence, the reaction is no longer clean. An impulse from the woofer may be returned by the loudspeaker cabinet suspended on the viscoelastic pucks out of absolute phase with the impulse, resulting in the impulse being smeared in time.

The effect combines the impulse signal (cone going forwards) with an attenuated, inverted signal (speaker cabinet going backwards) chaotically resulting in a muddy sound.

- 3) When there is viscoelastic behavior vertically, the speaker will rock forwards and backwards out of phase, lagging the impulse signal. Again, the effect combines the impulse signal with an attenuated, inverted signal chaotically, but the response signal has an angular direction that is not coherent with the original signal. (Going back to our vector mechanics, we see that there is no pure up and down movement.)

The relationship between drivers that are arrayed vertically will suffer, smearing the imaging and soundstage.

Once we consider the above, it becomes clear why three pucks, four pucks, five pucks sound different under the loudspeaker. Where you put those pucks also makes a difference.

Two pucks in front, and one puck at the back may make the one puck behind elastic in the vertical and horizontal planes, but the two pucks in front viscoelastic in the horizontal plane but elastic in the vertical plane. Once you get enough pucks under the loudspeaker, it may be sufficient that there is low enough stress on each puck for it to exhibit elastic behavior.

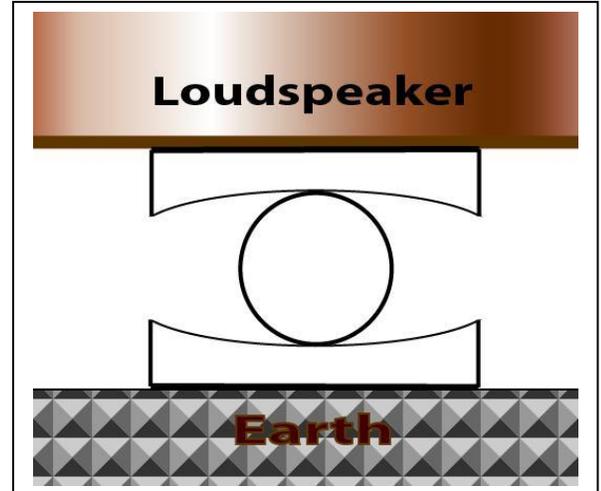
I am not a fan of viscoelastic pucks because of the out-of-phase response. Elastic pucks (on the other hand), carefully applied can be extremely effective.

A Special Class of Viscoelastic Decouplers

This may come as a surprise, but the highly popular captive ball in two cups device is actually viscoelastic.

In the vertical plane, the ball and cup is a very effective coupler. The small contact patches providing an almost spike-like contact area.

In the horizontal plane, however, it moves almost freely. However, because of the action of gravity, the ball will always return to the lowest point on the bottom cup, and the top cup will always center on the ball. The gravity is the “spring” that centers the device – and hence confers elastic properties depending on the diameter of the ball, and the profile of the cups.



Considering the forces in the horizontal plane, as the ball rolls, there is friction between the ball and the cup. This results in a loss of energy, a generation of heat, and a viscous property. Depending on the material of the ball, and the material of the cup, you will have different coefficients of friction. The hardness also matters as elastic deformation can occur on both the ball and cup. Hence, different balls will make these devices sound different. With sufficient hardness and low enough friction (think ruby ball on a ceramic cup) they can also be elastic in the horizontal plane.

Hence, the ball and cup and related ball and race devices are a special class of viscoelastic coupler/decoupler, with almost perfect coupling in the vertical plane, and viscoelastic properties in the horizontal plane.

Monitor Speakers and Speaker Stands

The above on couplers/decouplers all also apply to placing monitor loudspeakers on stands. However, the loudspeaker stands have to be considered an integral element to how the loudspeaker sounds. Unfortunately, the stand also complicates matters tremendously.

When the loudspeaker is firmly coupled to the loudspeaker stand, the stand will form a part of the loudspeaker. There is no “standard formula” for pairing loudspeakers to stands. Some loudspeakers may require coupling to a massive stand, others may work better de-coupled from the massive stand, or work better coupled to a light stand.

There are as many designs of monitor loudspeakers as there are loudspeaker stands. Let's explore a couple of designs.

- 1) The light, resonant metal stand. Sometimes, it may make sense to use a light resonant stand as the stand does not store much energy. You might consider this if the loudspeaker is fairly massive, and vibrations in the cabinet are already fairly well damped. A metal stand will resonate at a single frequency. The level of this resonance can be very high, but it will be in a very narrow band. Hence, if the loudspeaker does not demonstrate a resonance in the same frequency band, the light resonant stand will not ring. In this case, tightly couple the stand to the loudspeaker.
- 2) The heavy, massive, sand-filled metal stand. In this case, you should look at the stand as part of the Earth, and spike the stand. When you do this, you do not want to transfer horizontal forces to the stand so that the stand is well-coupled to the ground. A good solution might then be the ball-and-cup decoupling device to decouple the speaker horizontally.
- 3) Multi-material stand. There are many stands made out of a combination of metal, wood, acrylic and stone. In this case, you will have to experiment. In most cases, the designer of the stand might have used several loudspeakers in his arsenal to design the stand to achieve a desired result. I generally find these stands to be euphonic, and have a characteristic sound that may be pleasant to some.

Conclusion

Coupling/decoupling a loudspeaker is not as simple as putting three or four spikes or pucks under the loudspeaker cabinet. Depending on the design of the loudspeaker and the floor upon which it sits, different designs of couplers/decouplers are required. However, knowing the properties and principles will help you to determine and experiment in your own set-up.

Most of these ideas were developed during the design of the acoustic suspension systems on Genesis loudspeakers. This white paper is provided for owners of older Genesis loudspeakers, and also other brands of loudspeakers, to help with solving speaker set-up and tuning problems.

Questions and comments can be posted to the Understanding Coupling/Decoupling thread in www.whatsbestforum.com and I will do my best to answer them.