

Abstract

Part 1 -- Problems with Stereo Reproduction and How to Fix Them

Part 2 -- Installing 2-Speaker, 4-Speaker, and 6-Speaker Ambiophonic Systems

Understanding and Installing an Ambiophonic System

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Part 2: Installing 2-Speaker, 4-Speaker, and 6-Speaker Ambiophonic Systems

The basic Ambiophonics system consists of two closely-spaced front speakers driven by RACE crosstalk-reduction software. The two speakers together are called an *Ambiodipole*. Virtually any type of speaker can be used to form an Ambiodipole. Like stereophiles, Ambiophiles can have preferences for particular speakers. **There is never a need for a center speaker.** In fact, a center speaker substantially degrades performance. Ambiophonics can also be used with four or six speakers, two in front and two or four in back. The present instructions will cover 2-speaker, 4-speaker, and 6-speaker systems.

RACE can be downloaded to a PC without charge from the Ambiophonics web site or obtained as apps or as component products. Instructions for both will be provided below.

2-Speaker Systems

Speaker and Room Set Up. The two speakers forming the Ambiodipole should be located about 20-30 degrees apart measured between the midrange drivers. Audible differences will be small as speaker width is varied within this range and the user should select what sounds best. For some speakers or listeners, angles outside the range of 20-30 degrees will work well. In fact, research is actually lacking on the exact, best speaker angle. On the other hand, the usual stereo equilateral triangle speaker spread of 60 degrees will seriously degrade the sound. Wider spreads are even worse. The speakers can flank a TV monitor and a center speaker is never required. Just to get it done, simply place the speakers anywhere from 20-30 degrees apart and go on to the rest of the set up. You can always experiment later with a different speaker angle. The speakers should be the same distance to the listener measured to the nearest inch, if possible.

One easy way to measure speaker angle is to buy a cheap, plastic protractor and a legal-size manila folder or piece of cardboard. The folder/cardboard has two short and two long sides. Put a dot at the very edge of one of the short sides, halfway across the edge. With the protractor and a straight edge, draw rays radiating from the dot all the way to the far edge. The rays should be at 5-degree intervals subtending a total of 30 degrees. Sit in the listening chair, put your eye between the speakers, hold the folder/cardboard so that the dot is just under your eye, and sight the midrange drivers to measure the angle between them.

While room treatment is always a good idea, Ambiophonics is much less damaged by room reflections than conventional stereo or 5.1. One reason is that the delays involved in RACE are less than 100 microseconds whereas even a very early room reflection is delayed by milliseconds. The richness of the localization cues provided by Ambiophonics swamps the effects of most room reflections. This is similar to a concert hall, where the richer, longer-lasting hall ambience masks the clutter of short-delay reflections from seat backs and heads. So room treatment is always desirable but not critical in the case of Ambiophonics and even less so in Panambiophonics (below).

Directional speakers produce fewer room reflections than speakers with wide dispersion. So directional speakers are well suited to Ambiophonic (and stereophonic) reproduction. Nevertheless, wide-dispersion speakers can produce excellent results.

RACE Adjustment Parameters. When one of the stereo loudspeakers produces sound, the close ear hears it first and, with some time delay and attenuation, the far ear hears it as crosstalk. The amount of delay and attenuation depends on the angle to the loudspeaker and the distance between one's ear canals. Since crosstalk cancellation requires the cancellation signal to be the correct magnitude and to arrive at an ear exactly when the crosstalk does, one must be able to adjust the crosstalk canceller to the particular attenuation and delay required by the speaker angle employed and, less importantly, to the size of the listener's head.

1. Delay. Delay represents the time difference in microseconds (μ s) between a sound's arrival at the near ear and its arrival at the far ear. The usual range of adjustment in RACE is from 20 μ s to 150 μ s. A millisecond is 1/1,000 second. A microsecond is 1/1,000,000 second. There are a thousand microseconds in a millisecond. 90 μ s (.09msec) is average for most installations. Another way to view Delay is that a Delay of, say, 80 μ s means that when a speaker launches a signal to be cancelled at the far ear, the speaker near that ear will launch the cancellation signal 80 μ s later. A Delay value that is correct for a listener sitting centered will be incorrect if the listener moves off center. But there is no need to change Delay with reclining, head rotation, nodding, tilting, normal forward and back motion along the center line, or additional seating along the center line.

2. Attenuation (Spread Factor). Attenuation represents the level loss, in dB, between the near and far ears (The level loss is due to longer path and facial absorption.) RACE normally has an adjustment range from -1.5 dB to -4 dB. It is easier if one drops the minus sign and thinks of these values as positive. We will

refer to the Attenuation range as 1.5 dB to 4 dB. An Attenuation of 1.5 dB means that there is a 1.5 dB loss in level between the near and far ears.

Too low an Attenuation, 0.5-1.5 dB (Spread Factor 90-100) can produce unpredictable effects such as buzzing, abnormal localization, or even oscillation. Attenuation between 2.0-2.5 dB usually produces the best results. Another way to interpret Attenuation is that an Attenuation of, say, 2.5 dB means that when a speaker launches a signal to be cancelled at the far ear, the speaker near that ear will launch a cancellation signal that is 2.5 dB softer. The signals will have the same level but opposite polarity when they arrive at the far ear.

How to Use the Three Adjustments. Even more than stereo, Ambiophonics is a tweak-and-listen enterprise. The basic principle is this: Normally all tweaks and changes in settings will be heard only as slight changes in the width of the stage. Stage width can vary from recording to recording due to the microphone and mixing techniques used. Using recordings with the widest stage, or better yet a one-sided test signal (see below), Attenuation and Delay settings have been optimized when stage width is just under 180 degrees. Here, crosstalk cancellation is optimum. A stage wider or narrower than (just under) 180 degrees indicates incorrect settings for best cancellation. Begin with the following settings and experiment from there: Delay = 70-80µs, Attenuation = 2.3 dB. Neither Delay nor Attenuation settings are all that critical if not pursued to excess. However, you may prefer partial crosstalk reduction (less stage width) for certain recordings or to suite your taste.

Fine Tuning Attenuation. To cancel crosstalk at the far ear, the correction signal must arrive at the far ear at just the correct loudness. If Attenuation is too low, the correction signal will be louder than needed to cancel the crosstalk. Here, instead of the correction signal and the crosstalk canceling each other to zero, the far ear will hear a residue of the correction signal and it will be opposite in polarity to the signal heard by the near ear. The ear/brain appears to interpret this as an increase in ILD (interaural loudness difference) and the stage gets wider. This increased stage width results from an incorrect Attenuation setting and not from the recording. Insufficient Attenuation also affects center-stage soloists. Soloists are located at center stage when the same (or nearly the same) signal arrives at both ears at the same time. Insufficient Attenuation produces a residue of the correction signal at each far ear which is opposite in polarity to the signal at each near ear—reducing the loudness of the (almost mono) signal arriving at the near ears. The result is a reduction in loudness of center soloists compared to side sources. To avoid these problems, one can fine tune Attenuation: Use a test disc with a signal on only one channel or, with a standard stereo CD, disconnect one output channel of the CD player. You need a signal on only one of the two stereo channels. Engage XTC. Set Attenuation high at 4.0 dB. Do not change the Delay setting. Gradually decrease the Attenuation until the sound is located nearly 90 degrees to the side and then stop. To confirm the stopping point, repeat the procedure with a signal on just the other channel. The result with both channels operating should be a stage nearly 180 degrees wide with the many recordings and movies that have such stages.

RACE assumes that the sound from a speaker arrives at the far ear with a fixed delay and loss in level. These two values depend on the angle to the speaker and the size of one's head. As the speaker angle gets wider or one's head gets larger, the attenuation gets larger and the delay gets longer. With the speakers about 20- to 30-degrees apart (measured from the midrange drivers), a Delay of about 70-80µs (.07msec to .08msec) is usually correct for most people and speakers. Changing the Delay to, say, 60µs or 90µs will probably not be audible. You should experiment as described below to get the stage you like. Attenuation is usually correct when set to around 2.3 dB but again try varying it to get a stage just under 180 degrees. If you have a recording of a string quartet and the violin and cello appear to be 200 feet apart, consider changing Delay and Attenuation (Spread Factor) settings for this recording. The 200-foot wide quartet or a 70-foot wide piano indicates that the recording contains interaural loudness and/or time difference cues, picked up by the microphones, which the recording engineer could not hear while mastering because monitoring was done in conventional stereo. Nevertheless, you are hearing what the microphones heard even if the engineer did not.

Delay and Attenuation adjustments are useful for adjusting the width of the stage. They have the same audible effect but, when solving certain problems, both should be used. Normally, one changes the two controls about the same percentage. Imagine that Delay and Attenuation are controlled by two close knobs. You connect the knobs with a rubber band so that when you turn one, the other turns similarly. But feel free to experiment. To find the best listener location, play a test track with a signal on only one channel or, with a standard stereo CD, disconnect one of the outputs of the CD player. Engage XTC. Now move closer to and farther from the speakers along their center line until the source just begins to reach as far to the side as you can get it. This is the best listening position—the maximum crosstalk reduction on the center line—given the speaker angle, head size, and Delay and Attenuation settings used. Repeat the single-sided experiment with the other side, checking to see that the audible stage is symmetrical. A nonsymmetrical stage means that the speakers have different distances to the listening location or are not identical in level or frequency response. It may be faster to use a program source with both channels operating while you adjust settings for maximum stage width. But you are assuming, perhaps incorrectly, that the recording was mastered to have a symmetrical stage.

If you are hearing the 180-degree stage but interior decoration requires moving the listening location farther from or closer to the speakers, move the listening chair to where you want it and change the distance between the speakers to maintain the same speaker angle used at the original listening location. If the speaker angle is the same at the new listening location, you will not have to change the Delay and Attenuation settings. If you do not change the distance between the speakers, then moving the listening chair has, in effect, changed the speaker angle and you must change the Delay and Attenuation settings.

Delay/Attenuation settings and speaker angle must jive—that is, for a given speaker angle (and head size), only one Delay and one Attenuation setting will produce the nearly 180-degree stage when the recording calls for it. If you change the speaker angle, you must change Delay and Attenuation. If you change Delay and Attenuation, you must change the speaker angle. If Delay and Attenuation are correct for the speaker angle, you will have the longest sweet centerline coupled with the 180-degree stage. This means that listeners can sit in front of you and behind you and they will hear the same stage you hear. If your head suddenly shrinks to the size of a child's head, you can reduce Delay/Attenuation without moving the speakers or reduce the speaker angle without changing Delay/Attenuation. Either way, play with the adjustment until your new head hears the widest stage. Within reason, Delay/Attenuation settings are not critical.

Be careful with speaker tone controls or equalizers. When RACE calculates cancellation signals, it assumes

that the speakers have identical frequency response at the listening location. If the speakers are not identical, the cancellation signals will be incorrect. So the speakers must have the same response at the listening location and the location must be equally distant from the speakers.

As an example of using Delay and Attenuation, you might decide to flank your new TV screen with your speakers and find that the angle between the speakers is wider than before, perhaps 25-30 degrees. Adjust Delay and Attenuation, changing them by similar percentages, to obtain the 180-degree stage. For speakers 25-30 degrees apart, try the larger Delay/Attenuation settings first. On the other hand, if speakers are very closely spaced, again use Delay and Attenuation to produce the 180-degree stage. When the stage is just under 180 degrees, crosstalk cancellation is at its maximum. There is no theoretically ideal angle for the speakers within reason (within about 20-30 degrees). But the 60-degree angle used in conventional stereo is far too wide and will seriously degrade performance. RACE control settings cannot compensate for such a wide angle. Moreover, pinna errors will return.

In some versions of RACE, it is possible to restrict the range of frequencies in which crosstalk reduction operates. This is done with the Algorithms setting. At one time, it was thought necessary to restrict the frequency range of crosstalk reduction. This is no longer the case. Suppose RACE is allowed to operate at low bass frequencies, say below 90 Hz. Below 90 Hz, there is no meaningful attenuation, no meaningful bass loss, as sound travels around the head from the ear closest to the speaker to the far ear. Since both ears hear the same low bass—even in a stereo system—all low bass is mono. Hence, low bass frequencies cannot be localized by our ears and crosstalk in the low bass has no localization significance. Nevertheless, RACE will try to cancel it. While the Attenuation control may be set at a value of, say, 2 dB, the actual attenuation of low bass across the head is almost zero. The cancellation signal will be 2 dB smaller than needed to cancel the crosstalk. It is now thought that such errors average out so close to flat that their effect on low bass response is inaudible. And the change in bass is several dB less than that caused by the bass boost of the stereo triangle. Hence, what RACE does when it operates below roughly 150 Hz is acoustically meaningless. It is also acoustically meaningless when RACE operates above roughly 10 kHz. High frequency wavelengths are so small that crosstalk cancellation is essentially uncontrollable and random—resembling the randomness of concert hall reverberation but infinitely lower in level. Any narrow peaks or dips produced by RACE when operating at high frequencies are unlikely to be audible. Moreover, such peaks and dips at much lower frequencies are inherent in stereophonic reproduction and these peaks and dips are removed by RACE. So why provide an algorithm control if the full range setting is almost always the best choice? The control was provided because it was easy to create and because it might be fun to experiment with it—and it has been used in laboratory studies.

ENVELOPHONICS 4-Speaker Playback of 2.0 Media

It was noted early on that adding a pair of RACE speakers at the rear of the listening position enhanced the depth and width of the frontal stage. The use of a crosstalk cancelled pair relatively close to the listener in the rear appears to enhance the feeling of envelopment without causing any sound sources to appear as if they are coming from the rear. The effect is easily audible and there is a greater sense of being there at the recording session, of clarity, presence, spatial ambience, etc.

The reason for this enhanced sense of binaural realism is that in normal hearing there are always lots of very early reflections coming from objects close to any listener in almost any space. These early reflections of left and right frontal sound coming from the rear area are quite uncorrelated in that any such reflection from say a chair back, lamp, floor, etc. reaches each ear in turn with a distinct time and level difference. So to maintain these differences, RACE needs to be used with the rear speaker pair even if just listening to a CD, LP or other 2.0 file. The normal room reflections do not have enough variety to generate such envelopment because the front speakers stimulating such reflections are too close together to mimic the pattern that a real full width orchestra would produce. But ENVELOPHONICS does simulate such a wide rear stage with frontal sound reflections coming from an up to 180 degree rear arc.

Since the rear speakers are closer and likely to be at a somewhat wider angle than the fronts, the delay and attenuation parameters should be adjusted accordingly. More delay and more attenuation are usually required for the best result. Facing the rear speakers one just needs to get a wide stage with both a single left input and then a single right input as described above for the front speaker adjustments. Neither the angle to the rear speakers nor these settings are critical. The level of the rear speakers is not critical and is normally almost as loud as the fronts.

It is also possible to use six speakers when reproducing 2.0 media as described below in the surround sound section.

Panambiophonics-Reproducing 4-Channel (5.1)Surround Media with 4 or 6 Speakers

Panambiophonic 4.x and 6.x systems provide a 360-degree sound field for music and movie recordings that have such full circle effects. A 4.x system contains two closely-spaced front speakers and two closely-spaced rear speakers as in ENVELOPHONICS above. However when playing 4.0 files the rear speakers reproduce the rear surround pair instead of the frontal data as in ENVELOPHONICS. But this means that the envelopment effect of ENVELOPHONICS is lost. Thus one may want to use one rear pair for ENVELOPHONICS and another for the rear surround pair. Thus three different RACE programs may be used, one for the front speakers and two for the two rear speaker pairs. Again the rear speakers can be relatively close to the listening area.

One can reproduce 4.x or 5.x DVDs, BDs, or SACDs. One never needs a center speaker—front or rear. Set your player to the no-center-speaker setting for both movies and music. The result is called *Panambiophonics* or *Panambio*. If music recordings or movies are made with a direct sound, 180-degree wide rear stage, then it is possible to hear voices, instruments, or sound effects anywhere in the horizontal plane.

Imaging at the extreme sides is easy to achieve, unlike 5.1 where such localization is impossible. Normally, one can sit anywhere on the line between the two pairs of speakers and experience the full circle of sound. With four speakers going, even off-center listening is usually more enjoyable than off-center 5.1 listening since, with 4.x, it is harder to identify a speaker's location and one can still separate front sources from rear.

It is possible to make a four-channel music recording that records a 180-degree rear circle of hall ambience for the rear surround speakers and a 180-degree front circle of direct and ambient sound for the front two speakers. Such a recording can be reproduced Panambiophonically to create a domestic concert hall which lacks only ceiling reflections to mimic fully the hall in which the performance was recorded. The rear channels can include rear instruments for unusual musical effects or sound effects if the recording is a movie soundtrack.

If you do use six speakers for surround, then when you play 2.0 files there is no rear surround signal going to one of the rear pairs. But these speakers can be used to stimulate the ears with some extra pinna cues and provide a better head shadow when a far side source is reproduced. Note that these speakers produce only a very small improvement in side imaging over a ENVELOPHONICS system. If you are engrossed in a 2.0 music or film, you may not notice the improvement. It is for perfectionists and to make use of the otherwise idle speakers. It is also possible to pass the front pair through a Prologic (SQ) decoder and use the frontal output to drive the second rear pair. Tell the Prologic unit that five full-range speakers will be used. That way, only side signals (labeled front left and front right) will be sent to the rear pair. Feel free to experiment with this sort of arrangement. Each recording may sound different.

The four speakers in a 4.x Panambiophonics system will clearly outperform a 5.1 surround system. The 4 speaker system will provide seamless surround without hot spots, without sonic gaps between surround speakers, without localization to surround speakers, and with precise imaging at all angles including at the sides and rear. Again, even though Pamambio does not use side speakers, **it provides better side imaging than 5.1, 7.1, or 10.2 systems.** 6 speaker Panambiophonics combined with ENVELOPHONICS is better the ultimate in imaging and envelopment. Both 4.x and 6.x with the front speakers flanking a TV screen, provide a fine center image for dialogue without needing a center speaker. But you do need to set the CD/DVD player to the no-center-speaker setting. The player will then split the center signal and add it to the main left and main right speakers. Similarly, if DTS or Dolby decoding is done in a processor, set it to divide the center channel equally between the left and right front channels.

Review- Playing Two-Channel Media with 4 or 6 Speakers

When playing two-channel media such as CDs or LPs, feeding a RACE signal to the rear speakers noticeably enhances stage width and depth—and makes all the various adjustments seem less critical. The front and rear RACE signals should be similar but not identical in order to avoid audible peaks and dips. Using the rear speakers on two-channel media insures that not all hall ambience comes unrealistically from the front. For a side source, rear speakers provide a second, quite different rearward pinna pattern that combines with the same-side frontal pinna pattern. This allows the brain to localize more easily to the extreme side. The exact mechanism of why this works is unknown. One possibility is that the final pattern that reaches the ear canal averages out relatively flat and therefore seems to come from a direction where the ear canal has a direct view of the sound source which, of course, is at the side. Another possibility is that this novel pattern is unknown to the brain and thus is ignored. With two-channel media, using two speakers directly behind the listening position (ENVELOPHONICS) increases stage width roughly 15 degrees and enhances the feeling of depth and spaciousness

Speaker and Room Set Up

The preferred room set up for 2-, 4-, and 6-speaker Ambiphonics is the same. The rear speakers need not be the same brand or type as the front speakers. Delay and Attenuation must be set for the rear speakers and with the same criteria used for the front speakers. The rear stage should have the same width as the front stage. A purist should face the rear speakers when making the adjustments. Compared to the front speakers, the rear speakers should not have the same angle and be about one fifth closer to the listener. The reason is that, when you set Delay and Attenuation for front and rear to create the same front and rear stage width, the rear settings will be different from the front settings. If everything is too symmetrical, some averaging potential is lost. Moreover, there is a remote risk that, if everything front and rear is exactly identical, audible peaks and dips can occur with slight head motions. Normally, the level of the rears should be about the same as the level of the fronts. But feel free to experiment with all the variables. The goal is to produce a front stage of nearly 180 degrees for music or for movies with sound effects at the sides and a rear stage with the same width. When front and rear settings produce the same stage width, nearly 180 degrees, crosstalk reduction is optimum for front and rear speakers. Once you know the optimum settings, feel free to back off the settings to reduce the stage width to suit your taste or the recording. Whether you back off the settings or not, if you rotate to face the rear speakers—keeping your head in the same spot—you should hear the same stage width but reversed for two channel material.

Room Correction

Correction of speaker and room deficiencies has always been part of Ambiphonic theory. Devices intended for speaker and room correction have been commercially available from TacT, Lyngdorf, DEQX, and so on.

Typically, the function is simply called *room correction*. Those running RACE crosstalk cancellation on a PC will likely find compatible room correction software available in the near future.

When assembling a system with both room correction and RACE crosstalk reduction, one must decide which should come first in the signal path. If the speakers and the room are identical for both channels, then it does not matter whether room correction is done before or after RACE crosstalk cancellation—as long as room correction is the same for both channels, which would be normal for this case. If the speakers and room are not identical for both channels, we believe that RACE crosstalk reduction should come first. The signal path

would be:

program source --> crosstalk reduction --> room correction --> amplification --> speakers

Consider what would happen if the room were dissimilar for the two channels and room correction were done first. Suppose, when measuring a 500Hz signal at the listening chair, the left channel has a 7dB peak and the right channel has a 4dB valley. The correction logic will therefore cut the signal to the left speaker by 7dB and boost the signal to the right speaker by 4dB so that the direct sound from the speakers sounds flat. Again, before the left signal even gets to the crosstalk canceller, room correction for the left channel will cut the 500Hz level by 7dB. The left channel of the crosstalk canceller will create a cancellation signal for the right speaker by inverting the polarity of the left signal, but the 7dB cut at 500Hz remains in this cancellation signal. This cancellation signal is intended for the right ear and when the right speaker launches it, it will be 7dB too low. Additionally, the cancellation signal fed to the right speaker was subjected to left channel room correction but not right channel room correction. Since the uncorrected right speaker has a 4dB dip, the total cancellation signal will be 11dB below what is required to cancel the original acoustically flat signal coming from the left speaker to the right ear. (This ignores head shadow and the corresponding attenuation setting). Thus, doing room/speaker correction or any asymmetric equalization before RACE is not a good idea.

If crosstalk cancellation is done first, the subsequent room correction ideally makes both speakers identical in level and timing when measured at the listening chair and thus there will be no problem. Indeed, RACE will function at its best. The result will be a wider stage, cleaner localization, and a better sense of depth. When effective room correction follows RACE, one can think of the room correction as part of the circuitry of the speakers making them appear perfectly matched to RACE.

For almost all conventional home speaker systems, room correction will make a clearly audible improvement in Ambiophonic performance—even more so than with standard stereo. But if one is lucky enough to have excellent speakers properly located in an excellent room, one might not hear an important difference from room correction. In fact, if one is not careful, room correction can make the sound worse. For example, if the microphone is not equidistant from the speakers when measuring the room, then room correction might introduce time delay differences for the two channels that will degrade crosstalk cancellation. In a problem room, a broad, high amplitude peak in measured response might fool some room correction software into thinking that not only must the peak be reduced but also the overall level.

If one hears a loss of stage width, or if the stage gets one-sided, when room correction is turned on, then the room measurement should be repeated or the impulse response and correction filter parameters should be examined for anomalies. A nearly foolproof technique for room correction is to apply the same correction filters to both speakers. In Ambiophonics, the front speakers are so close together that the room response is likely to be very similar for both speakers and, if the speaker frequency responses are reasonably similar, a single correction curve for both channels is likely to yield excellent crosstalk reduction.

Whether or not room correction has been engaged, one can use channel level and delay controls to fine tune the width and symmetry of the stage. Thus, if the correction curves are not quite identical in level, one can adjust the channel level controls to compensate. Similarly, if the delay from each speaker to the listener is not identical, the left or right channel delays can be tweaked to compensate—thus optimizing stage width and symmetry. This is easily done by feeding the left channel music or test signal to both speakers and then feeding the right channel music or test signal to both speakers. In each case, one should adjust controls to achieve maximum stage width and symmetry.

Additional Reading

Additional reading on these topics can be found on this web site:

<http://www.ambiophonics.org/TechnicalPapers.html>