Let's Phase the Music: More comments on papers from the 91st AES convention

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Acoustic phase, and its audibility, has been a subject of controversy ever since Hermann von Helmholtz addressed the subject in the late 1800's. Yet, despite all we've learned about hearing since Helmholtz, and the current availability of sophisticated new research tools, the controversy lingers on. The argument is not, as one might think, simply an abstract, if sometimes heated, debate among philosophical psycho-acousticians. It has real-world consequences for the way audio signals should be recorded an audio equipment should be designed.

I've been aware ever since I built my first Williamson amplifier in the early 1950's that signal phase *shift* was a significant audio parameter—at least in power amplifiers. In its early incarnations, the Williamson suffered from marginal instability because the 20-dB negative feedback loop sometimes shifted positive at the frequency extremes. That frequently resulted in pulsing woofers at one end of the spectrum and RF oscillation at the other. But aside from such obvious instability disturbances, I've never felt that linear phase shift posed a severe threat to fidelity.

In the early 1980's, many speaker manufacturers decided that the conventional two or three drivers installed on the single vertical front panel of a system resulted in acoustic phase shifts caused by the different path lengths to the listener's ears of the woofer and tweeter signals. That was usually "solved" by stepping a cabinet's front panel so that the woofer was several inches forward of the tweeter. Aside from generating new opportunities for advertising copy writers (and some expensive pot-bellied speakers), the arrangement's audible advantages were elusive—at least to my ears. And, in any case, it seems to me that on a purely theoretical basis such "time alignment" would only hold when a listener's ears were also aligned exactly on axis with the acoustic center of the two (or more) drivers.

I once saw/heard a speaker-phase demonstration using a two-way system with a movable tweeter. A square wave was fed to the system and the speaker's output picked up by microphone and displayed on an oscilloscope. As the tweeter installed on top of the system was slowly shuttled back and forth over a five-inch distance, the square wave would visibly distort and then restore itself as its high- and low-frequency harmonic components shifted in and out of phase. I stood in front of the display for several minutes, really trying to hear the waveform distortion that was clearly evident on the scope screen. Following in the tradition of Herr von Helmholtz, I never did hear any effect. All of this is background for the latest phase controversy beautifully delineated in the following Audio Engineering Society (AES) preprint.

INTERCHANNEL SPEAKER PHASE

Most of us first encountered "phase" as an audio phenomenon when we were told to make sure that the right and left speakers of our stereo system were connected in proper polarity. That meant that when presented with, say, a positive audio pulse from both amplifier channels, the cones of both woofers would move simultaneously in the same direction. If the speakers were wired incorrectly, the cones would move in opposite directions, and bass performance would suffer. In addition, the 180-degree phase differences in the high frequencies would confuse the ear's localization system, disturbing the stereo sound-stage image and imparting a vague "phasiness" to the reproduced sound. In general, speaker polarity/phase, if correct in the original installation, remains so unless the connections are changed. R-E

Observations on the Audibility of Acoustic Polarity [Greiner and Melton (3170 K-4)].

To understand what is meant by absolute polarity, it helps to use a simple musical example, such as the sound of a kickdrum. The impact on the drum head produces an air compression that moves outward and is picked up by a recording microphone. Ultimately, it is reproduced by a forward-moving speaker cone as an air compression. However, anyone who deals with electronics knows that the original electrical signal from the microphone has had its polarity flipped probably dozens of times by the recording and reproduction electronics before it reaches the speaker. In fact, there's a 50–50 chance that the initial kickdrum impact is being reproduced by a speaker cone that is pulling at the air rather than pushing it. In other words, what reaches our ears is an air rarefaction, although the original was a compression. It follows that our eardrums are also being pulled rather than pushed. Does it make a difference? That's what Greiner and Melton set out to explicate in their paper.

The audibility—or inaudibility—of absolute inversion is a recent element in the ongoing discussion. Unlike other phase shift phenomena discussed earlier, polarity inversion does *not* change the shape of a transient signal nor shift the phase relationship among its component elements. However, as the authors state, it does present to the ear a fundamentally different signal.

A major part of the authors' research effort involved extensive, carefully controlled listening tests to determine the types of signals most sensitive to polarity inversion. It seems self evident that highly asymmetrical signals were most likely to be audibly changed by inversion. For example, note the trombone waveform shown in Fig. 1.

In general, it could be said that acoustic polarity inversion is clearly audible in some circumstances (particularly with test signals), although most of the time with real-world music it is not. It seems that even when waveforms have clear asymmetries as in Fig. 1—and not all of them do—other effects inherent in the complex nature of most musical tones tend to mask the identifying characteristics of the inversion.

The authors conclude that "while polarity inversion is not easily heard with normal complex musical program material, as our large-scale listening tests showed, it is audible in many select and simplified musical settings. Thus it would seem sensible to keep track of polarity and to play the signal back with the correct polarity to assure the most accurate reproduction of the original waveform."

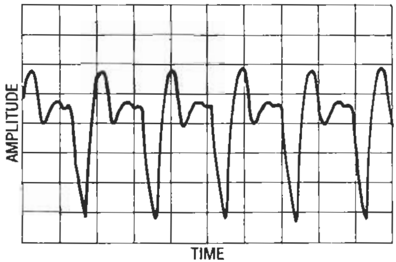

Fig. 1. Trombone waveform. In general, reed instruments show the greatest asymmetry.

No one can argue with the above as an ideal goal, but exactly how is it likely to be realized? Assuming that (1) we have a recording with all the instruments recorded in phase, that (2) our three-way speaker doesn't have its mid-range connected in inverted polarity to flatten the system's frequency response (a no longer common practice), and that (3) anyone in authority cared enough to manufacture discs and tapes with all their polarity ducks in a row, how would the consumer know when he had it right?

Next month I'll discuss one more AES paper and then call it quits for the 91st Convention. **R-E**

PHASE INSENSITIVITY

It is well known that loudspeaker cone travel is seldom equally linear in both its outward and inward excursion. In other words, the speaker cone's push on the air may not be exactly equal to its pull, even when driven by a low-distortion, highly symmetrical sinewave. It seems probable to me that most human ears are also asymmetrical in their responses to the compressions and rarefactions of an impinging acoustic waveform and therefore generate harmonic distortions. Whether any individual listener's degree of hearing asymmetry correlates with their sensitivity to absolute phase is an open question. I noted with interest that Greiner and Melton suggest at one point that a distorting sound system may increase the audibility of polarity inversion.

I know for a fact that I've always been comparatively insensitive to phase. For example, in the early days of quadrophonics I was evaluating a four-channel synthesizer that attempted to generate artificial rear channels by tapping off the front channel, "wobbulating" it at a 25-Hz rate, and feeding it to a pair of rear speakers. The four-channel effect, for better or worse, was barely perceptible to my ears. A friend dropped in unexpectedly while I was doing my listening and greeted me with, "Hi Larry ... (three-second pause) ... your rear speakers are out of phase." I sat alongside him on the couch between the wobbulated rear speakers and for the life of me couldn't hear what he had detected instantly—and claimed was giving him a headache!

I also know that some listeners are incredibly sensitive to very small percentages of tape flutter, a phase-shift phenomenon, but the numbers have to get pretty bad before I hear it. In case you are wondering, my *overall* acuity and sensitivity were (by test) pretty good in those days, so my phase insensitivity was, in effect, an independent variable. I wonder what the normal distribution of phase sensitivity is, and whether ignoring it may not skew the results of psychoacoustic studies of phase. **R-E**