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Periodicity and Perception

Why speakers sound different

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Why speakers with identical specifications sound different.

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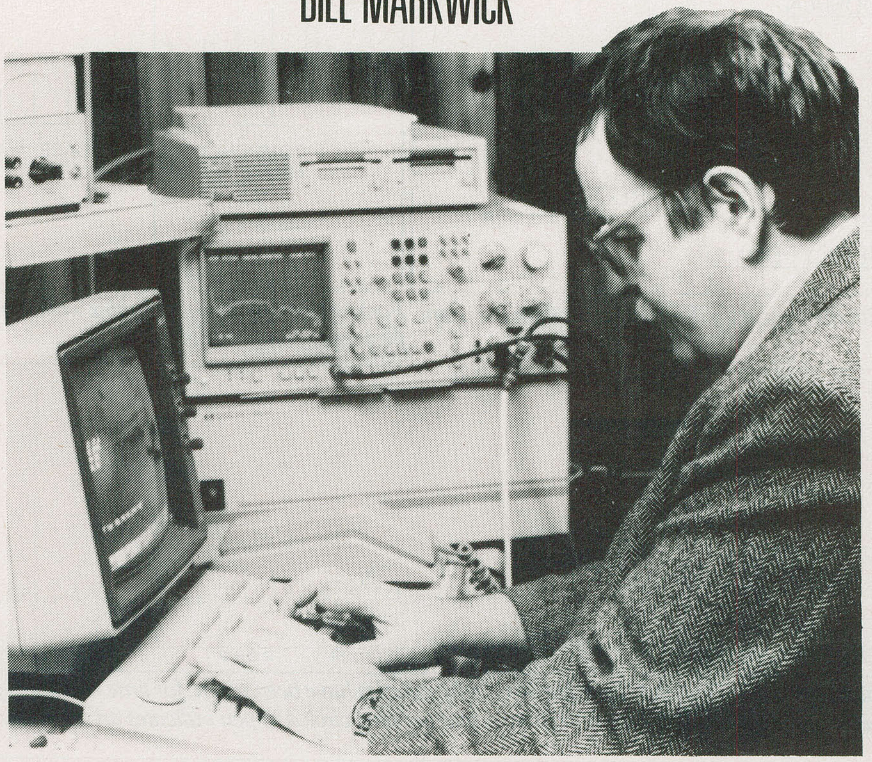
The usual methods of speaker testing yield a mystery, one that you're certain to have come across in the hifi press: if two similar speakers from different manufacturers have identical distortion, tone burst and frequency response specifications, why does each speaker have a unique sound? Writers struggle to describe these differences, coming up with such terms as strident, veiled, or muddy in an attempt to capture the subtleties of sound.

One term that seems to work is "transparent". The accepted meaning is that a transparent speaker adds nothing of its own to the sound, producing natural audio that just seems to come out of thin air. In the early years of the hifi boom, this was usually described as "an orchestra actually playing in your living room", an elusive goal for all but the best of systems. A speaker which is not transparent immediately tells you that you're listening to the music through a machine, and this is true whether or not the speaker does well in the standard tests.



Mike Wright in the Richmond Hill, Ont. lab and sound room.

Standard Testing

Before the advent of affordable computer-controlled test gear, there were a number of methods used to quantify speaker response, and despite hi-tech advances in equipment, they remain the mainstay. The most popular, and one that gives a great deal of information, is the frequency response test. A calibrated microphone is used to measure the output from the speaker as it is swept over the audio frequency range. Unless you have an anechoic chamber which prevents any reflected sound, this test is plagued with the peaks and dips of the room response itself. Some of the ways around this include the averaging of several tests from different directions and the use of rapidly swept frequencies to avoid stimulating room resonances.

Testers soon realized that steady-state frequency response wasn't telling the whole story, and the tone burst test was used in an attempt to measure the speaker's ability to respond quickly without overshoot; the test frequency is switched on and off rapidly, letting through a desired number of cycles. The difficulty comes in trying to interpret the imperfect tone burst which is picked up by the microphone. Sometimes the results have no apparent connection with the perceived sound.

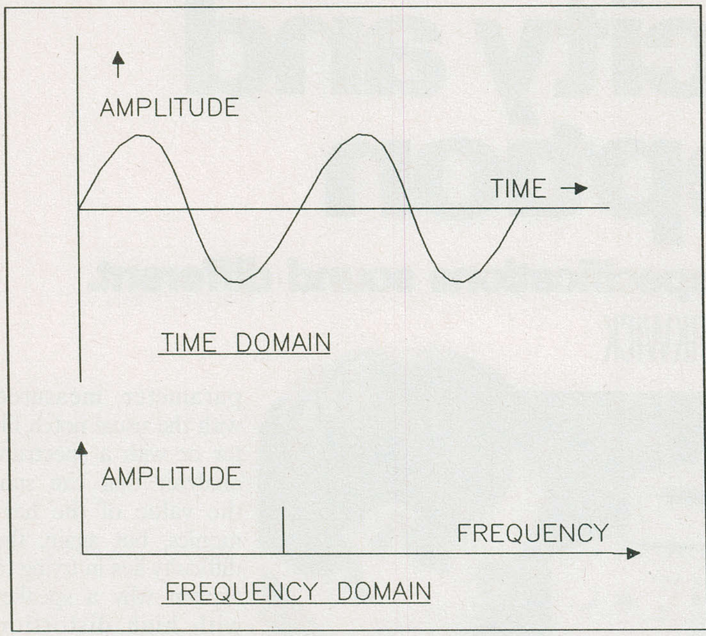
Distortion seems to be an important parameter, measured with the usual notch filter or with a spectrum analyzer that can sum the value of the harmonics, but again, the difficulty lies in trying to explain why a speaker with high distortion sounds better than one with impeccable specifications.

Adding to the technical difficulty is the processing of the sound by the listener, a subjective variable which we'll come to in a later section.

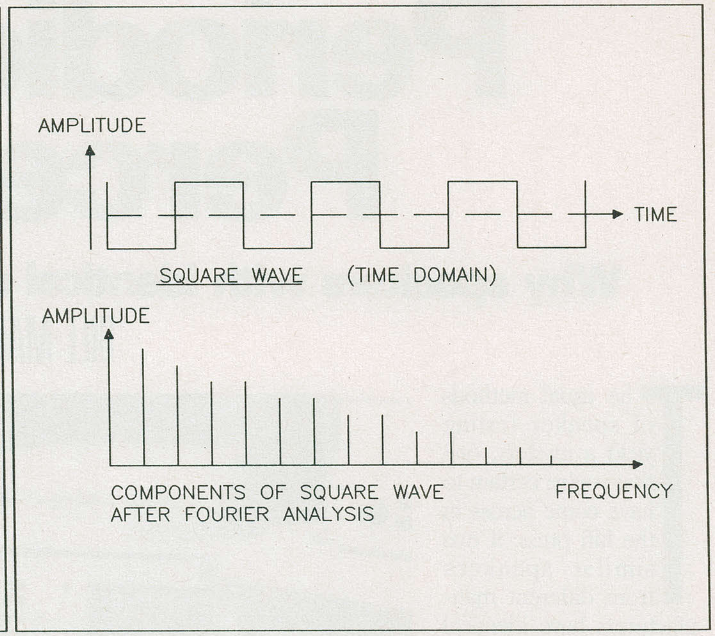
Periodicity

In the mid-1970s, Bell Laboratories published papers on the use of the Fourier transform in sound analysis. The Fourier analysis is a mathematical tool used to find the various components that make up a complex waveform; a spectrum analyzer displaying the harmonics of a sound is doing a Fast Fourier Transform (FFT). By doing another transform on the new-found components, you can find the *periodicity*; such anomalies as reflections or speaker shortcomings show up clearly.

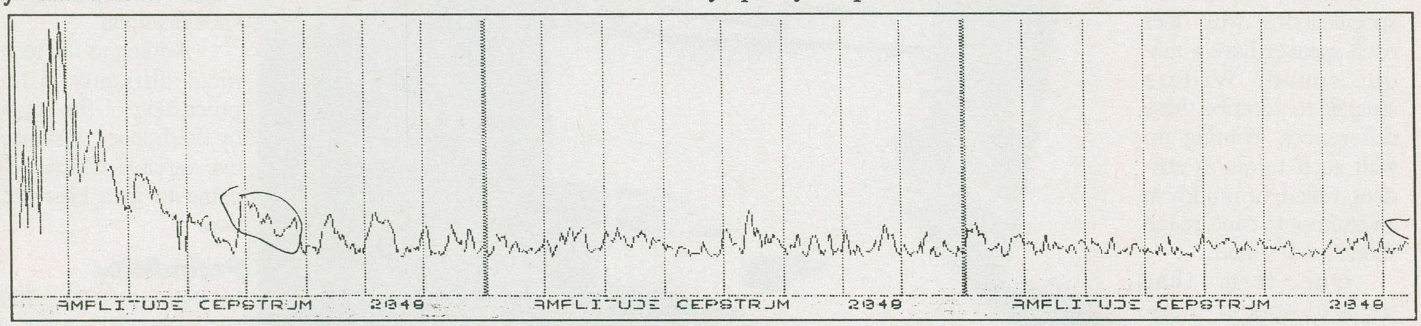
The method of analysis was used to analyze the noise signature from Concorde jet engines; previously, the tests had been affected by sound reflections from the runway, but the periodicity tests allowed engineers to separate pure engine noise from the total sound. The method was later used by Bruel & Kjaer in their industrial failure-prediction equipment to separate undesired machinery noise from the total sound, allowing detection of impending faults without the necessity of shutdown.



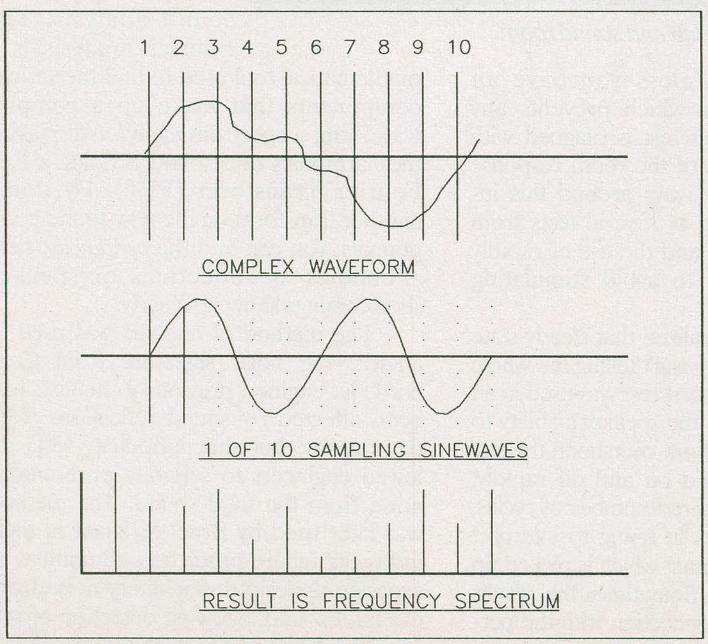
Fourier analysis deals with the frequency domain rather than the more familiar time domain.



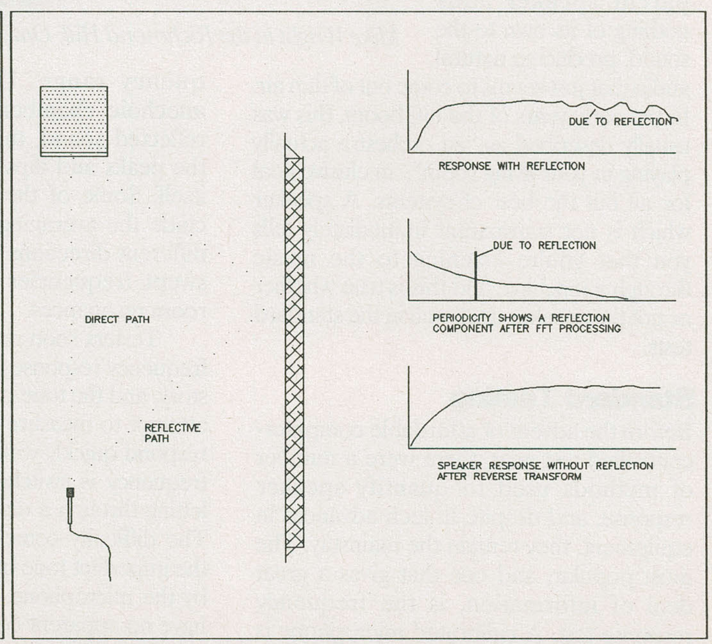
Fourier analysis allows complex waveforms to be separated into their frequency components.



Part of a cepstrum response plot of a Dayton Wright speaker. 2048 samples have been taken for time constants from .5 to 133 milliseconds. The large spikes at the right indicate room response, and the area circled in pen indicates an anomaly.



The sampling sinewave is multiplied by the element in each window of the sampled waveform, and is then repeated a a higher frequency.



Because of differences in the two pathlengths, the periodicity will have a component due to the reflection.

Here in Canada, the method was adapted to speaker analysis by Mike Wright, developer of the Dayton Wright loudspeakers and Stabilant 22, a liquid semiconductor used as a contact enhancer (see the review in our October issue). Periodicity testing offered the possibility of easy removal of room effects from a response plot, as well as the detection of unwanted reflections from the speaker construction itself.

Perceptions

One year during a large trade show, Mike noticed that his awareness of speaker quality was seriously affected by the noise and associated fatigue of maintaining the display booth. Speakers which had previously sounded fine were becoming a chore to listen to, a phenomenon which was easily interpreted as the brain's reluctance to accept any more input.

However, that night he went to a symphony concert and discovered that the live sound had none of the expected shortcomings. The conclusion he arrived at was that all speakers were introducing small oddities of their own, anomalies that the brain filtered out. This extremely complex filtering allows you to listen to desired sounds in the middle of a noisy party, and lack of it is why tape recordings of that party will later sound incredibly clattery and jumbled, since the required important information (phase relationships, visual cues, etc) is not present.

The periodicity tests seemed like the best way to analyze speaker output and find whatever faults were occupying so much of the brain's audio processing.

Testing

The present test setup in the Richmond Hill plant consists of a soundproof room which is finished inside to represent a typical listening environment, and even includes easy chairs. A calibrated AKG microphone picks up the speaker output, which is a swept-frequency pulse train. The signals are processed by a Hewlett-Packard spectrum analyzer can be displayed on its CRT as a standard frequency response plot, or as a spectrum of components (using the FFT). It also has a 16-bit output which is captured by an HP 68000-based computer.

The software, which consists of 17,000 lines in HP Basic, can then process the information to plot response, phase, and periodicity (the advantage in the spectrum analyzer lies in its speed—the computer takes much longer to derive the FFT).

When Bell Labs published their ideas on using Fourier analysis, someone whimsically labelled the various parameters using anagrams of familiar terms, and so the periodicity chart, which looks something like a frequency spectrum, becomes a *cepstrum*. The periodicity is formally defined as the inverse FFT of the log power spectrum of the components of the sound, and the cepstrum is a plot of the ripple in a waveform for each time constant of the components causing the ripple.

For instance, if the cepstrum reveals a spike with a time constant of about 2ms, then some two surfaces in the speaker environment are causing a reflection, and they'll be about 2 feet apart (taking the velocity of sound as 1ft/ms). As to why this information is not revealed in standard speaker testing: the information is there, but the test format may not be ideal for displaying it, just as a scope display of a squarewave gives no hint that it's the sum of a long series of odd harmonics.

The process can be used to detect small reflections in drivers and cabinets. For example, speakers often sound better with the grill cloth removed; it's not just a case of sound absorption by the cloth—reflections from the frame itself can cause audible effects. The speaker on the cover is being tested with a fibreglass pad to eliminate surface effects; in production this would be replaced by acoustical foam, and the speaker is constructed so that there's no frame protruding past the front surface.

Standard speaker testing in combination with periodicity plots allows rapid analysis of the speaker drivers, enclosure, crossover, and listening environment. The result of investigating and correcting is a speaker that approaches the ideal of transparency, one that never lets you know it's there.

AB/Testing

The above discussion on speaker improvements is somewhat oversimplified, since there's a great deal more to speaker analysis than watching a plot and tinkering here and there. The tester may use periodicity to discover some small ripple in the response, but the decision as to whether or not this is affecting the sound depends on the listener, and most listeners are almost unbelievably flexible in their perception of sound. In most cases, they're unaware of how their own mental processing is fooling them.

Mike Wright held a speaker listening test in which listeners came into the room while a set of speakers were playing. Then noises behind the curtain indicated that the speakers had been changed, and the test was repeated. The listeners liked the first set, and said that the second set were inferior to it. In fact, the speakers were never touched. What had happened is that the room acoustics dominated the sound environment when the people first entered for the first test. By the time of the second test, they were used to the room and began to judge differently. There's also the fact that novelty affects perception; musicians often prefer someone else's instrument—for a while. When the novelty wears off, they're more objective about deciding.

The curtain in the above tests is also used in other testing because visual cues are so important to sound perception, particularly the localizing of a sound. Mike said that additional speakers placed at either side of the listener will cause them to swear that the stereo image is much wider, even though the side speakers are not even connected.

Level settings are extremely important during comparison testing of speakers. The usual wisdom is that one dB is the minimum sound level difference we can detect, but the ear is much more sensitive to change in the midrange area; if speakers are tested with a level difference of about 0.5dB, the higher level gives the vague impression of brighter response. If the speakers are switched using the same amplifier, the more efficient speaker sounds louder and brighter.

There's also evidence that the right ear perceives high frequencies in a different manner than the left, a fact which may be due to the partitioning of the brain.

The speakers under test cannot occupy the same space, so room acoustics will cause a different sound response even if the speakers are identical. If the test is interrupted and the speakers are interchanged, the delay may not let the listener retain accurate impressions of the sound.

To sum up, the A/B test must be done under extremely well- controlled circumstances in order to reveal anything meaningful. Like statistics, they can be made to prove anything you want.

And how well did this research benefit the Dayton Wright line of speakers? They can definitely have a right to the claim of transparency; their sound indicates meticulous care in design, so much so that Stereo/Video guide of October, 1987 rated them as the number-one speaker. ■

Special thanks to Mike Wright for the time spent explaining speaker testing.