SPEAKER

measurements V

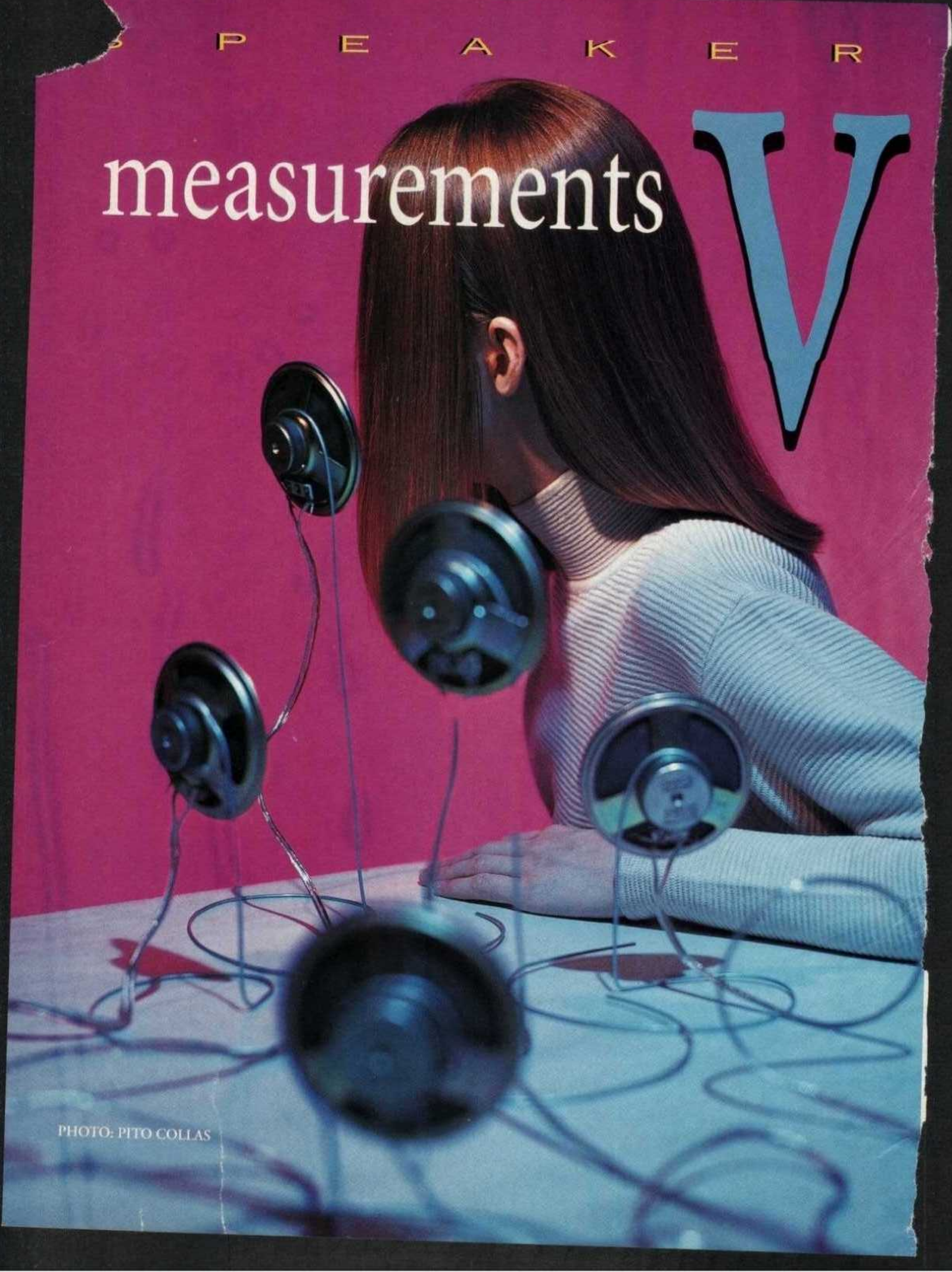

PHOTO: PITO COLLAS

CABLES

S psychoacoustic data

EDGAR VILLCHUR

The current controversy about loudspeaker cables is not new, although in previous years the arguments were somewhat different. In the '50s and '60s, the arguments had to do with the d.c. resistance of the speaker cable (and of chokes in the crossover network, which typically have more d.c. resistance than the cable); it was claimed this resistance interfered with the amplifier's control of the speaker. The low output impedance of a good amplifier brakes the speaker voice-coil after the signal has stopped, and excessive resistance between the amplifier and speaker would impede this damping action. The solution to this supposed problem was to eliminate the crossover network by using separate amplifiers for each component of the speaker system, and to use short, heavy speaker cables.

Interest in the biamp system faded, although it has been renewed recently. One reason for the loss of interest was that articles were published—including mine in 1957 in *Audio* [1]—showing that the fraction of an ohm inserted by the cable and crossover network between the amplifier and speaker had

TABLE I—*High-frequency losses, in dB, of the best cable designed specifically for loudspeakers, and of a relatively inexpensive ribbon cable for digital data transmission, compared to the losses of #18 zip cord. Loss data from Davis [2], difference data at 20 feet extrapolated.*

Best Speaker Cable, 10 Ft.		#18 Zip Cord, 10 Ft.		Difference, 10 Ft.		Difference, 20 Ft.	
10 kHz	20 kHz	10 kHz	20 kHz	10 kHz	20 kHz	10 kHz	20 kHz
–0.3 dB	–0.9 dB	–0.5 dB	–1.45 dB	–0.2 dB	–0.55 dB	–0.4 dB	–1.1 dB

Best Ribbon Cable, 10 Ft.		#18 Zip Cord, 10 Ft.		Difference, 10 Ft.		Difference, 20 Ft.	
10 kHz	20 kHz	10 kHz	20 kHz	10 kHz	20 kHz	10 kHz	20 kHz
–0.25 dB	–0.8 dB	–0.5 dB	–1.45 dB	–0.25 dB	–0.65 dB	–0.5 dB	–1.3 dB

TABLE II—*Just noticeable differences, in dB, for unmasked pure tones.*

	1 to 4 kHz	10 kHz	16 kHz
Average jnd	1.72 dB	2.12 dB	3.05 dB
Minimum jnd	0.51 dB	0.47 dB	1.01 dB

no significant effect on speaker damping, which was controlled by the total mechanical, acoustical, and electrical resistance in the rest of the system. The d.c. resistance of the voice-coil of a typical 8-ohm speaker, for example, is about 6 ohms, 23 times the resistance of 20 feet of #18 zip cord for the two legs of the speaker cable, and this resistance has exactly the same effect on the damping of the system as the resistance of a 460-foot cable of #18 zip cord. Another reason interest in the biamp system faded was that no one was able to demonstrate an audible difference between that system and a standard one.

Fred E. Davis swept away some of the cobwebs of the current debate about speaker cables last year. He made rigorous measurements of the total frequency response of an amplifier/cable/speaker system with different cables, from the exotic and expensive to #18 zip cord [2]. The present article examines whether we can expect the differences in frequency response measured by Davis to be audible. Davis' data is compared to data in the psychoacoustic literature on just noticeable differences (jnd's) for intensity in the frequency range in which there were response differences between the different cables.

Edgar Villchur developed the acoustic suspension woofer and the dome tweeter; these designs were first described in his disclosure articles in Audio *in October 1954 and October 1958. The AR-3 speaker, which embodies both designs, is on permanent exhibition at the Smithsonian Institution. Villchur is president of the Foundation for Hearing Aid Research, a nonprofit research organization, and a vice president of RDL Acoustics, a manufacturer of loudspeakers.*

The Davis Measurements

Davis plotted total system response between 30 Hz and 20 kHz with each of 12 cables, and with two amplifiers and two speakers. There were no measurable differences in the response of any of the systems at low frequencies, confirming that cable resistance does not affect speaker damping.

Table I shows Davis' data for high-frequency losses caused by different cables in the speaker/amplifier combination that exhibited the greatest cable effect. The first column shows the losses, in dB, at 10 and 20 kHz of the system with the two best cables (those which produced the least high-frequency loss). One of the cables was designed specifically for loudspeakers and the other for transmitting digital data. The second column shows the losses of the system with #18 zip cord. The third column shows the increase in loss for a 10-foot length of #18 zip cord; losses below 10 kHz are not shown because the increases were less than 0.2 dB. It is of interest that the best of the 12 cables was a relatively inexpensive ($4.00/foot) ribbon cable designed for d ital interconnections, and that two of the exotic speaker cables measured by Davis, not represented in Table I, showed a greater loss at 20 kHz than the #18 zip cord. The Davis measurements were made with 10 feet of speaker cable, but since it is not unusual to place loudspeakers 20 feet from the amplifier, the fourth column of Table I shows response differences for 20-foot cables.

The difference in system response created by substituting 20 feet of #18 zip cord for 20 feet of the best speaker cable is a loss of 1.1 dB at 20 kHz and of 0.4 dB at 10 kHz. When the #18 zip cord is compared with the best ribbon cable, the difference at 20 kHz becomes 1.3 dB.

Psychoacoustic Studies of Just Noticeable Differences

A study of jnd's (also called difference limens, or DL's) for the intensity of pure tones was done in 1987 by Florentine et al. [3]. Their findings were consistent with the findings of previous studies, but they extended the frequency range of their study to 16 kHz. The size of the reported jnd's varied with frequency, level, and the individual subject.

The smallest detectable differences were in the octaves between 1 and 4 kHz: The jnd in this frequency range, averaged over all subjects and intensity levels (using the standard of 70.7% certainty of response), was 1.72 dB. The lowest jnd in the group—for the most sensitive subject at the intensity level that gave the subject's lowest jnd—was 0.51 dB. The subjects were between 20 and 24 years old and had normal hearing to 20 kHz.

The smallest detectable difference at 10 kHz, averaged over subjects and intensity levels as above, was 2.12 dB, and the smallest individual jnd was 0.47 dB. The smallest average detectable difference at 16 kHz was 3.05 dB, and the smallest individual jnd was 1.31 dB. These subject responses are represented in Table II.

The values in Table II are for single pure tones in quiet. In music the frequency range between 10 and 20 kHz contains many partials at a given moment; further, the sound in this range is strongly masked by the sound below 10 kHz, a phenomenon called the upward spread of masking.

hough studies in the psychoacoustic literature do not match these musical conditions exactly, they are close enough to provide guidelines. It can be predicted that at a given level the jnd for a band of sound between 10 and 20 kHz will be decreased from that for a pure tone, but that this jnd will be increased by a significantly greater amount by the masking effect of musical sound below 10 kHz [4].

Davis said that the differences in frequency response he measured between cables were "at the threshold of audibility." The data on just noticeable differences cited here predicts that the differences in frequency response created by different cables are almost always below the threshold of audibility. To predict from indirect data, of course, is not the same as to prove from direct experimental data: Controlled, double-blind tests with groups of listeners, actual cables, and varied musical program material—in which everything remains the same except the cable—will show whether the differences between cables are audible to most listeners, to a favored few, or to none.

Lipshitz and Vanderkooy [5] estimated that when level differences occurred over a wide band, they were detectable down to 0.2 dB. Lipshitz agreed with me (in a phone conversation) that this figure is not applicable to speaker cables, where the level differences are all in the highest audio octave.

If at least some people can hear differences in frequency response caused by different speaker cables, it would be a trivial design problem to correct the small high-frequency loss by electronic equalization in the amplifier. The cost would also be trivial, but the high-frequency loss could be eliminated entirely, something the best of the cables tested by Davis did not accomplish.

Cable Effects Other Than High-Frequency Loss

Claims have been made that the purity of the copper in the wire affects sound purity; that the cable introduces nonlinear effects; that the cable needs to be "broken in" for several days; that the sound of the system can be improved dramatically by submitting the cable to special field treatments; that keeping the cable away from room surfaces, or tuning the distances between cable and room surfaces, will improve the sound; that cables work better when wired in one direction than the other; that the characteristic impedance of the cable ought to match its termination; that measurements of the cable's d.c. resistance are inaccurate because they do not allow for skin effect at high frequencies, etc.

Skin effect (the increase of resistance with frequency that occurs when the flow of alternating current is concentrated toward the outer surface of the cable) varies directly with the square root of the frequency and with the cable diameter; the change of resistance under particular conditions can be looked up in engineering handbooks. The d.c. resistance of 20 feet of #18 zip cord is approximately 0.26 ohm; the increase of resistance at 20 kHz because of skin effect is a negligible 0.013 ohm.

Interest in the characteristic impedance of speaker cable is probably derived from a misleading analogy between speaker cable and TV or FM antenna cable. The analogy is a tempting one because audio wavelengths (in air) are comparable to TV and FM wavelengths, the lengths of the cables are comparable, and we know that TV and FM cable is designed to have a characteristic impedance that matches the antenna to the receiver and avoids signal reflections. What makes the analogy break down is the difference between the speed of sound in air and of the audio signal in the wire, and the difference between audio frequencies and TV or FM frequencies. Audio wavelengths *in the wire* are measured in miles, while the distributed impedance of "300-ohm" TV cable is a fraction of an ohm at audio frequencies. Reflections caused by an impedance mismatch at audio frequencies become a problem only when the cable length is in units of miles rather than feet.

As for the other effects attributed to cables, I will digress a bit. Scientific method allows investigators to form a hypothesis in any way they please, out of a cold assembly of facts, intuition, or a drunken haze. The hypothesis does not need to seem reasonable; it didn't seem reasonable when Newton proposed that things don't fall but are attracted to one another because of their mass. Once the hypothesis is proposed, however, it must be demonstrated rigorously. I have never seen any of the hypotheses about speaker cables listed above put to a controlled test. For those who think some of these hypotheses are likely to hit pay dirt, there is still time. A

References

1. Villchur, E., "Loudspeaker Damping," *Audio*, October 1957.

2. Davis, F. E., "Speaker Cables: Testing for Audibility," *Audio*, July 1993.

3. Florentine, M., S. Buus, and C. R. Mason, "Level Discrimination As a Function of Level for Tones from 0.25 to 16 kHz," *Journal of the Acoustical Society of America*, Vol. 81, No. 5 (May 1987).

4. Viemeister, N. F., "Auditory Intensity Discrimination at High Frequencies in the Presence of Noise," *Science*, Vol. 221, pp. 1206-1208 (1983).

5. Lipshitz, S. P. and J. Vanderkooy, "The Great Debate: Subjective Evaluation," *Journal of the Audio Engineering Society*, Vol. 29, No. 7/8 (July/August 1981).

NUANCES BETWEEN SPEAKER CABLES CAN BE MEASURED, BUT CAN THEY BE HEARD?