Speaker Cables Review

By Charles Hansen and Muse Kastanovich

The parameters of any cable are defined as a combination of electrical resistance, capacitance, and inductance. The DC resistance is a function of conductor length and cross-sectional area. It does not matter whether the total area is composed of a single conductor or multiple conductors.

As the frequency increases, the resistance of a conductor increases due to skin-effect losses. This is the phenomenon by which the alternating current in a conductor concentrates near the surface, increasing the effective resistance. Round conductors show a more pronounced skin effect than thin flat conductors.

CABLE THEORY

The voltage between two conductors produces an electric field. When an insulator is interposed between the conductors, the molecules of the insulator rotate slightly and produce a field within the insulating material that opposes the applied field. The electric field E is reduced below the equivalent free space applied field intensity E_0 by a factor equal to the insulating material's dielectric constant relative to free space, ε_r.

$$E = E_0 / \varepsilon_r$$

The lower the dielectric constant of the insulator, the less the reduction (loss) in the total electric field.

Flat wire cables form parallel plate capacitors. The capacitance can be calculated from:

$$C = (\varepsilon_0\ \varepsilon_r\ A) / d$$

where ε_0 is the permittivity of free space, and ε_r is the relative dielectric constant of the insulating material. This varies with material, temperature, and frequency. A is the area of a plate, and d is the separation between the plates.

The round wire cables form parallel wire capacitors. You can calculate the capacitance of this arrangement without a ground plane by:

$$C = \pi\ \varepsilon_0\ \varepsilon_r\ l / \log_e (d/r)$$

where e = 2.718, ε_0 is the permittivity of free space, ε_r is the relative dielectric constant of the insulating material, l is the length, d is the separation between the wires, and r is the wire radius. Note that d must be much larger than r, a condition not always met with speaker cables. Large gauge, closely spaced round conductors may more closely approximate parallel plate capacitors.

Speaker cables also have the properties of series inductors. You can determine the inductance of two rectangular strips by:

$$L=[0.4l(0.5 \log_e (2dl/(w+h)) + 0.22(w+h)/l] \quad \text{where } l>>w, h$$

where l is the length, d is the distance between the strips, w is the width of a strip, and h is the height of a strip.

To find the inductance for two parallel wires carrying equal and opposite currents, use:

$$L = [0.1 + 0.4 \log_e (d/r)]\ l \quad \text{where } (d>>r)$$

where d is the distance between the

PHOTO 1: Alpha-Core Goertz MI 2.

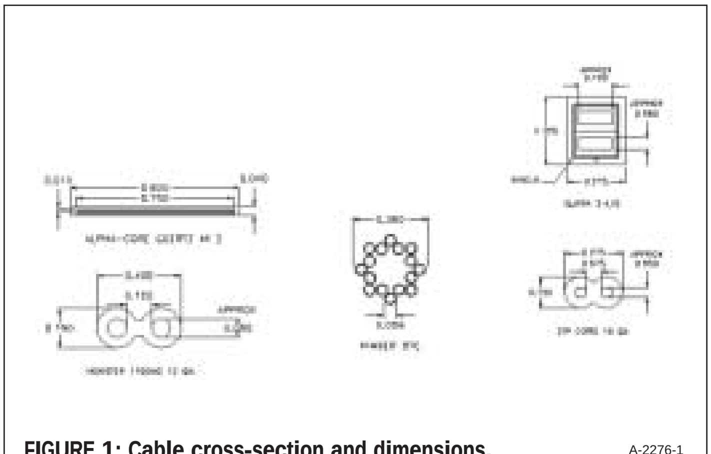

FIGURE 1: Cable cross-section and dimensions. A-2276-1

PHOTO 2: Kimber Kable 8TC and Supra 3.4/S.

wires, r is the wire radius, and *l* is the length.

Thus you can see that the impedance of a speaker cable will vary with frequency as well as the distance between conductors. Capacitance varies in proportion to distance, while inductance varies inversely with distance.

The wire resistance is in series between the amplifier and loudspeaker, and increases with frequency due to skin effect. The skin effect is essentially the same for a conventionally stranded wire as it is for a solid conductor of the same material and the same net cross-sectional area. The skin depth is the depth below the conductor surface where the current density has decreased by 1/e, and for copper at 20kHz it is about 0.5mm (0.02″).

Skin effect at 20kHz will increase the resistance by 7% to 34%, depending on the cross section profile. This presents a problem in measuring impedance at higher frequencies. As Bob Pease of National Semiconductor pointed out, when you try to measure pure inductance, you may also measure some of the skin effect. Cable capacitance tends to cancel inductance, so you may confuse inductive phase shift measurements with skin effect.

The cable inductance is also in series between the amplifier and loudspeaker. The inductive reactance in ohms is equal to 2πfL. The resistance and reactance do not add arithmetically because the reactance lags resistance by –90°, so the series impedance is the root-sum-square of the two.

Capacitance has the least effect on the performance of a speaker cable. This is because the cable capacitance is small to begin with and is shunted by the significantly lower amplifier and loudspeaker impedances. Capacitive reactance in ohms is equal to 1/(2πfC). Capacitive reactance leads resistance by +90°. The shunt capacitance will tend to cancel some of the series inductance as frequency increases.

The complex sum of these L, R, and C components determines the equivalent series impedance of a speaker cable. The phase shift introduced by a cable is proportional to its complex series impedance. The flat wire cables have higher capacitance but lower inductance than the round wire cables.

CABLE CONSTRUCTION DETAILS

There are seemingly endless processes for constructing speaker cables. The cables provided for testing include a flat-wire type, one with woven wires, one with stranded wire in a rectangular jacket, and one conventional round stranded wire cable. I also added a sample: the infamous 16-gauge zip cord. Test sample lengths varied from 3′ to 10′. The 3′ lengths may not be long enough for systems with satellites on stands. I used a vernier caliper to measure the dimensions of all the cables. The results are shown in *Fig. 1*.

The Alpha-Core Goertz MI 2 "T"-series is a bi-wire speaker cable. Each conductor is a 0.35 × 0.010″ solid band of high-purity oxygen-free copper (OFC) surrounded by a 0.005-inch (5 mil)-thick sheath of 0.8 × 0.04″ polyethylene terephthalate (PET, or polyester, same polymer as Mylar™) insulation. The stiff conductors are placed in close mutual contact inside a 5 mil clear PET jacket. PET has a fairly stable dielectric constant of about 3.2, which decreases about 3% at 1MHz. Polyester film is slightly hygroscopic—it absorbs water by a factor of 0.2% in the presence of high humidity.

The mutual distance between the conductors is 0.003 inches, and the overall cross-section is approximately

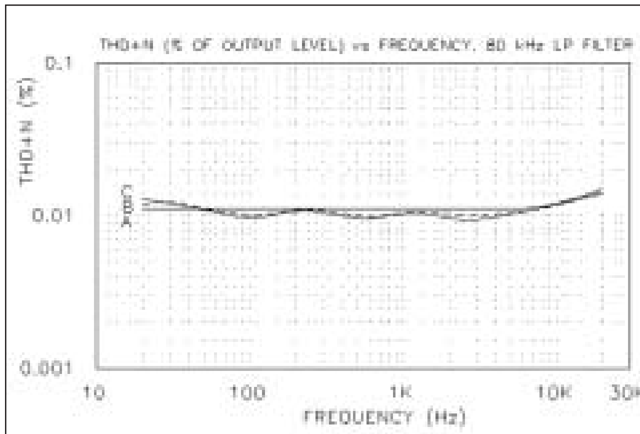

FIGURE 2: THD+N versus frequency, 3′ Goertz MI 2. A-2276-2

0.8 by 0.040″. The space ratio is close to 50%. The conductor cross-section approximates AWG 10. Rhodium-plated connectors are available to terminate the cable. *Photo 1* shows the amplifier end of the MI 2 cable test sample.

R/C Match Links are provided with the MI 2 cables. The Match Links consist of a pair of Zobel networks, 100nF in series with 10Ω. They are intended to be placed across the speaker terminals in systems with high GBW solid-state amplifiers and loudspeakers with high impedance at high frequencies to prevent oscillation. “Chances are you’ll not need these,” it says on the package.

The Kimber 8TC consists of 16 individual VariStrand™ PTFE (Teflon™) insulated wires (eight wires for each channel) arranged in a hollow, large format braid. PTFE is the most stable of the dielectric materials, with a low dielectric constant of 2.1. The aggregate wire gauge size is equivalent to two nine-gauge conductors. The tightly braided configuration and the Teflon™ insulation make these cables a bit stiff.

Various terminations are available: spades, angled and straight banana plugs, even plain ends. The test cables had WBT–0144 angled banana plugs. *Photo 2* shows the Kimber 8TC (top) and the Supra 3.4/S (bottom).

The Supra 3.4/S uses tin-plated copper wire strands arranged in a rectangular cross-section. The slash-S designation identifies the screened ply by which the two main conductors are surrounded by a braided shield with a drain wire at the amplifier end of the cable. This drain wire is intended to be connected to the amplifier chassis, to limit the EMI radiated from the cables. The shield and the ion-stabilized polyvinyl chloride (PVC) double jacketing make this cable rather stiff. The terminations are Supra Fork XL gold-plated spade plugs.

The conductors in the Monster 1190MC 12-gauge speaker cable are concentric rope lay stranded wire with eight individual helical wound members. The rope lay construction makes this cable very flexible. The insulation material is

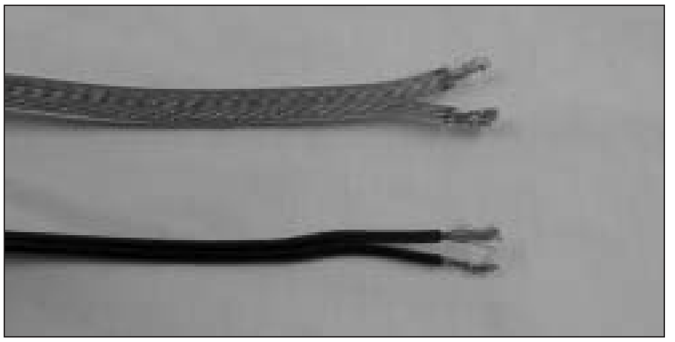

PHOTO 3: Monster 1190MC cable and 16-gauge zip cord.

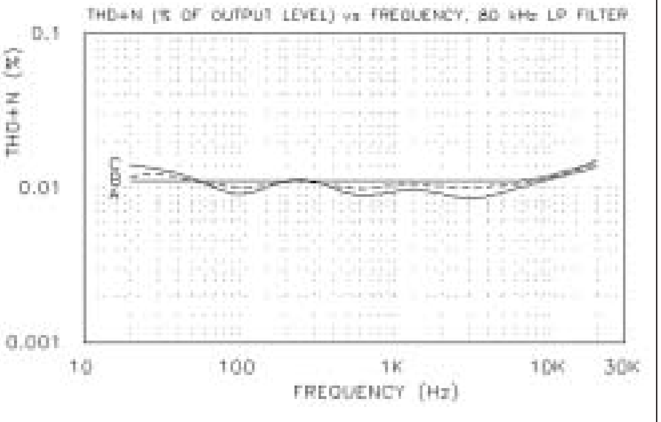

FIGURE 3: THD+N versus frequency, 8′ Kimber 8TC. A-2276-3

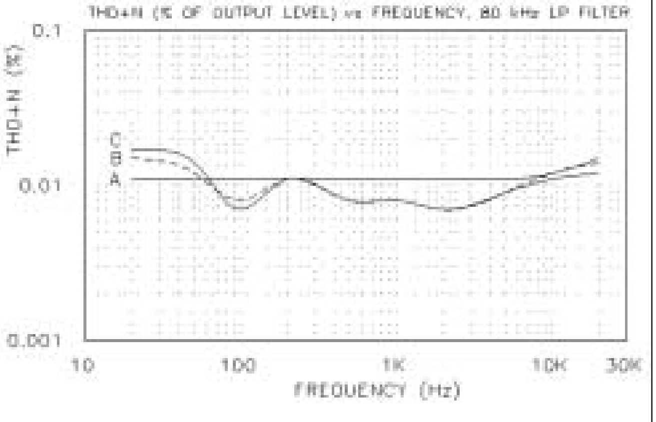

FIGURE 5: THD+N versus frequency, 10′ Monster 1190MC. A-2276-5

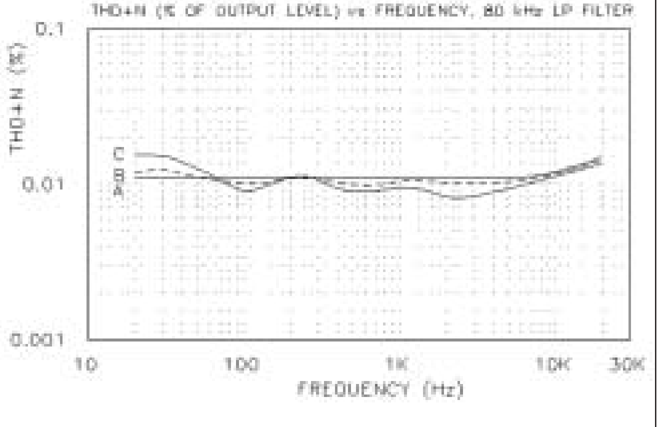

FIGURE 4: THD+N versus frequency, 8′ Supra 3.4/S. A-2276-4

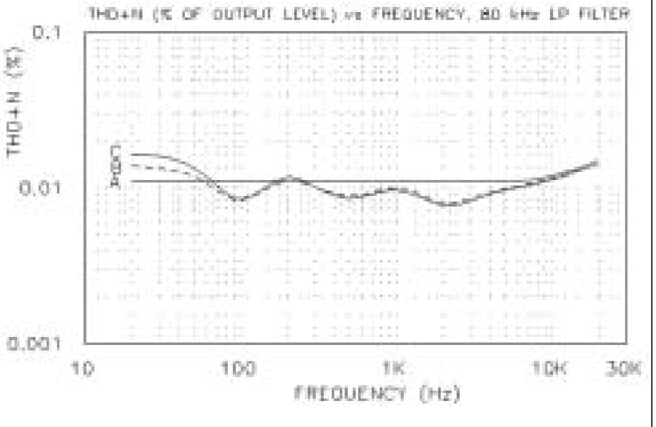

FIGURE 6: THD+N versus frequency, 8′ zip cord 16. A-2276-6

linear polyethylene, which has a stable dielectric constant of about 2.3, changing less than 1% at 1MHz. The 1190MC is Monster's original cable design.

The Radio Shack Megacable and Phoenix Gold cables appear to be similar in construction. My unofficial wire count is that each of the eight helical members contains 33 strands of AWG-37 wire. These individual strands are not insulated, so this construction is not the same as Litz wire[1]. *Photo 3* shows the Monster cable (top) and the zip cord (bottom).

The 16-gauge zip cord is intended for lower current household appliances. My sample consisted of 40 strands of 32-gauge wire, with plain PVC insulation. Ordinary PVC has a rather high dielectric coefficient of 4.7 compared with other polymers. The dielectric coefficient also decreases by 46% at 1MHz.

MEASUREMENTS

The cable samples vary from three feet to ten feet long. I measured the total capacitance, inductance, and resistance of each sample with two types of digital LCR meters. The HP 4261A performs measurements at 120Hz and 1kHz. The AADE L/C IIB uses a resonance measurement method with a variable frequency signal.

I also measured the DC leakage current of the dielectric using a Keithley 480 picoammeter as a measure of insulation quality. A 12V DC gel cell battery biased the cables. I made all measurements with the samples laid out in a straight line.

The MI 2 is quite stiff, so I needed to clamp it down to hold it flat and straight. Capacitance is measured between the two open circuit conductors (four in the case of the MI 2). The HP 4261A also measures capacitance dissipation factor (DF), which is an expression of the power loss in the dielectric. DF is the ratio of the equivalent series resistance (ESR) to the capacitive reactance (Xc), and is a measure of the insulator's ability to store energy at a given frequency. A lower dissipation factor is better.

The capacitance of the Supra 3.4/S dropped from 944pF to 328pF when I attached the shield drain wire to the guard terminal of the HP 4261A. This is because an adjacent ground plane reduces the mutual capacitance. Were the ground plane to be in between the conductors (a Faraday shield), the capacitance drop would be even greater.

Inductance is measured by short-circuiting one end of the cable and connecting the LCR meter to the open end. Resistance is measured the same way, so the L and R per foot is the sum of both conductors. The inductance measurements for the MI 2 were a bit erratic because of the bi-wire pair parallel cables. I ended up shorting the amplifier end, then measuring each of the pairs independently. Then I computed the equivalent parallel inductance Lp=La*Lb/(La+Lb).

This measured inductance of 18nH/ft for the MI 2 turned out to be higher than the specified 6nH/ft. This caused the calculated characteristic impedance, which is equal to √(L/C) and is independent of length, to also be higher than specified.

I also took a 10′ length of the flexible Monster 1190MC wire and measured its parameters first as a straight run of cable, and then coiled its full length on the floor in 8″ diameter loops. The total capacitance increased by 7% while the

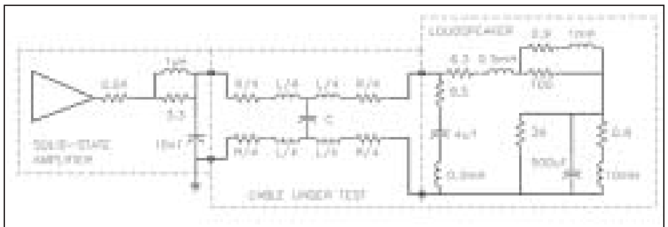

FIGURE 7: Solid-state amplifier system SPICE model. A-2276-7

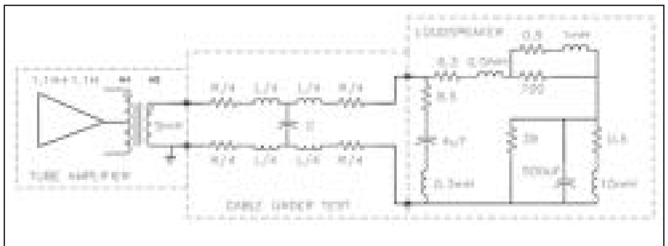

FIGURE 8: Tube amplifier system SPICE model. A-2276-8

inductance remained the same.

The standard 25°C resistance for one-foot pairs of wires is 1.58mΩ for 9-gauge, 2mΩ for 10-gauge, 3.18mΩ for 12-gauge, and 8.03mΩ for 16- gauge.

Using the measured data, I calculated the C, L, and R per foot, the characteristic impedance (Zo), the insulation resistance (Rp), and the cable resonant frequency. Using the physical measurements of the cables, I calculated Rac/Rdc ratio and the effective skin effect resistance at 20kHz. This varied from 107% of the DC resistance (Goertz) to 132% (zip cord). The data is summarized in *Table 1*.

The Goertz, Kimber, and Supra cables came with characteristic data. I compare this specification data with my measured data in *Table 2*.

TESTS

With my audio system warmed up, I first measured the THD+N versus frequency with 2V RMS across an 8Ω resistor connected directly to my Parasound HCA-1000A solid-state amplifier output terminals. Next, I connected each of the test cables in series with the 8Ω resistor and measured the THD+N at the resistor. There was essentially no difference in the readings with or without the cable. Unfortunately, I did not have a tube power amplifier available for these tests.

I repeated the THD+N vs. frequency test with each cable connected between the amplifier and one of my satellite loudspeakers, an NHT Super-One. I held 2V RMS at the amplifier terminals. Now there was some measurable difference compared to the THD+N that I measured with the 8Ω resistive load alone. The three curves on each graph represent (A) the 8Ω resistive load from

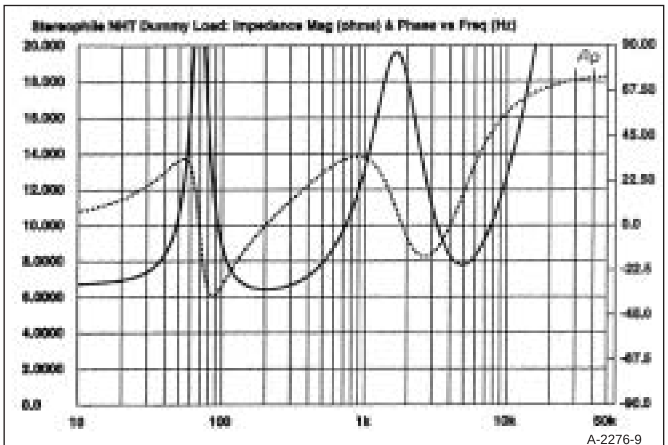

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FIGURE 9: Kantor speaker simulator impedance/phase plot.

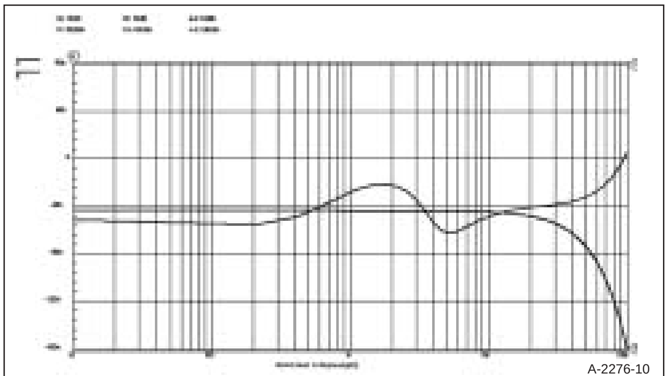

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FIGURE 10: Frequency response, 8Ω resistor versus Goertz MI 2 (S-S).

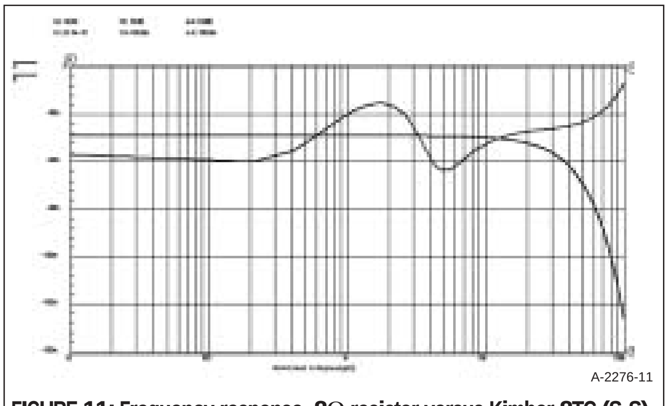

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FIGURE 11: Frequency response, 8Ω resistor versus Kimber 8TC (S-S).

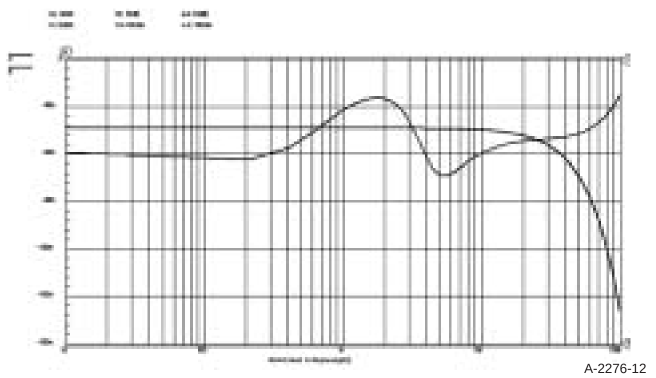

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FIGURE 12: Frequency response, 8Ω resistor versus Supra 3.4/S (S-S).

TABLE 1

MEASURED AND CALCULATED PARAMETERS

Cable	Goertz (MI 2)	Kimber (8TC)	Supra (3.4/S)	Monster (12)	Zip (16)	Units
Measured C	2,090.0	836.0	944.0	61.7	66.5	pF
Dissipation Factor	0.002	0.001	0.069	0.056	0.063	%
Measured L	54.0	86.0	694.0	580.0	606.0	nH
Measured R	4.80	21.00	27.00	12.00	23.90	mΩ
Length	3	8	8	3	3	ft
AWG equivalent	10	9	12	12	16	
Insulation	PET	TFE	Stabil.PVC	Linear PE	PVC	
Leakage current	0.3	0.6	1.1	1.1	0.7	pA
Rparallel	38.1	190.5	2.4	46.1	38.0	MΩ
C per ft	696.7	104.5	118.0	20.6	22.2	pF/ft
L per ft	18.00	10.75	86.75	193.3	202.0	nH/ft
R per ft	1.60	2.63	3.38	4.00	7.97	mΩ/ft
Characteristic Zo	5.1	10.1	27.1	97.0	95.5	Ω
Lkg per ft.	0.1	0.1	0.1	0.4	0.2	pA
Resonant Frequency	47	59	20	84	79	MHz

TABLE 2

MANUFACTURER'S SPECIFICATIONS VERSUS MEASUREMENTS

Parameter	Goertz spec	measured	Kimber spec	measured	Supra spec	measured
C per ft	950pF	697pF	100pF	105pF		
L per ft	6.0nH	18nH	50nH	10.8nH	61nH	87nH
R per ft	2.2mΩ	1.60Ω	2.2mΩ	2.63mΩ	1.55mΩ	3.38mΩ
Zo	2.5Ω	5.1Ω				

the initial tests, (B) the THD+N at the amplifier terminals with the cable connected to the speaker, and (C) the THD+N at the speaker terminals.

Figure 2 shows the THD+N versus frequency for the Goertz MI-2, *Fig. 3* the Kimber 8TC, *Fig. 4* the Supra 3.4/S, *Fig. 5* the Monster 1190MC, and *Fig. 6* the 16-gauge zip cord. Bear in mind the varying lengths here.

I intended to measure voltage drop and phase shift with each cable installed in one channel of my audio system. However, with 2V RMS at the amplifier terminals, the voltage drop at the speaker end of the worst-performing cable (8′ zip cord) was 71mV at 20Hz, 76mV at 211Hz, 37mV at 1kHz, 87mV at 5kHz, and 63mV at 20kHz. At 5kHz this is a –0.4dB loss with a phase shift of 0.3°. The attenuation and phase shift in the 3′ lengths of test cable were much smaller. In order to obtain graphical information on comparative 8′ lengths, I decided to model the cables as part of an audio system in SPICE.

SPICE SIMULATIONS

Using the measured parameters, I modeled each cable as part of a SPICE model audio system in order to determine its effect on magnitude and phase. I used both solid-state and tube amp models. The cable models are T-section equivalents based on my actual measurements. The loudspeaker model is the one proposed by Ken Kantor[2] with a nominal impedance of 8Ω.

Caveat: SPICE does not model the back-emf of the driver or the many low-level mechanical resonances present in a real loudspeaker. You should consider these simulations comparative rather than absolute.

Figure 7 shows the solid-state system model, based on an NAD-214 amplifier, for which I have the service manual and thus the schematic. The closed-loop output impedance is 0.04Ω at 1kHz, increasing to 0.16Ω at 20kHz.

Figure 8 shows the tube amp system model, based on the high-frequency model proposed by Scott Reynolds[3]. It has an output impedance of about 0.6Ω at 1kHz. Other tube amp SPICE models are available on the web if you want to experiment[4].

Each amplifier model is set for an open-circuit output voltage of 2V RMS at 1kHz. I ran simulations with an 8Ω resistor directly across the amplifier terminals, and with each cable in series with the loudspeaker model. I used two identical amplifier channels in the simulations to avoid interaction between the 8Ω resistor and the cable/loudspeaker models. The vertical scale is in dB relative to 2V RMS.

The nominal 8Ω speaker impedance has peaks of >20Ω at 70Hz and above 15kHz, 18Ω at 1.5kHz, and reaches down to 6.5Ω at 200Hz. *Figure 9* displays the impedance/phase graph.

Figure 10 shows the modeled response of the Goertz MI 2 as a composite (not bi-wired) 8′ cable. The top line at 100Hz is the response across the 8Ω resistor directly across the amplifier terminals. The output is a flat –0.043dB over the audio band (1.99V at the resistor), until it drops due to the increasing impedance of the amplifier's RLC network outside the feedback loop. This network is designed to make the amplifier inherently stable with all speaker loads.

The MI 2 cable shows the peaks and dips as a result of the complex impedance of the loudspeaker model. These excursions vary from –0.021dB at 1.8kHz to –0.062dB at 5.2kHz, representing voltages of 1.996V to 1.986V, respectively, at the speaker terminals. The phase shift at the loudspeaker terminals over the audio band (not shown)

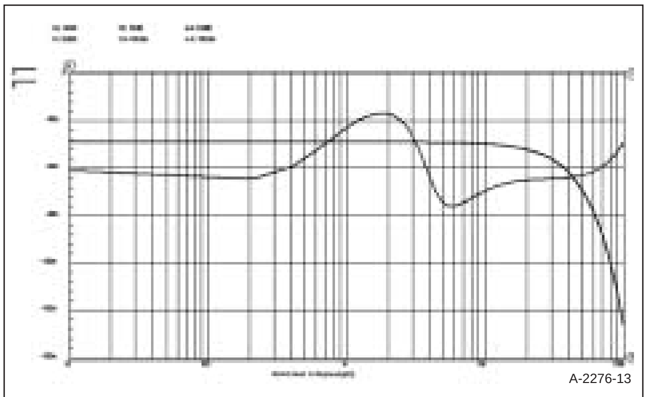

FIGURE 13: Frequency response, 8Ω resistor vs. Monster 1190MC (S-S).

varies from +0.099° at 639Hz to –0.182° at 3.5kHz, using the phase shift across the 8Ω resistor as a 0° reference.

In order to determine phase shift at 20kHz as accurately as possible, I substituted the skin effect resistance for the DC resistance in the cable model. The rise in response above 30kHz is due to the increasing impedance of the loudspeaker, which rises faster than that of the amplifier. Note that if the values of L, R, and C specified by Alpha-Core for the M-1 are used in the cable model, the excursions are –0.018dB to –0.059dB with the phase shift varying between +0.092° and –0.180°. This is a negligible difference.

Figure 11 is the response model for the 8′ Kimber 8TC. The peaks and dips as a result of the complex impedance of the loudspeaker model vary from –0.023dB to –0.065dB. The phase shift at the loudspeaker terminals varies from +0.111° to –0.180°.

Figure 12 depicts the response model for the 8′ Supra 3.4/S. The peaks and dips as a result of the complex impedance of the loudspeaker model vary from –0.024dB to –0.073dB. The phase shift at the loudspeaker terminals varies from +0.111° to –0.224°.

The next 8′ modeled cable is the Monster 1190MC 12 gauge cable. *Figure 13* shows the peaks and dips as a result of the complex impedance of the loudspeaker model, which vary from –0.025dB to –0.084dB. The phase shift at the loudspeaker terminals varies from +0.107° to –0.286°.

Finally we come to the 16-gauge zip cord (*Fig. 14*). The peaks and dips as a result of the complex impedance of the loudspeaker model vary from –0.032dB to –0.098dB. The phase shift at the loudspeaker terminals varies from +0.150° to –0.297°.

I took the zip cord and loaded it with the 8Ω resistor rather than the speaker model (*Fig. 15*). The response across the resistor, which was –0.043dB at the amplifier terminals, is –0.056dB at the end of the 8′ zip cord (bottom trace at 2kHz), with a slightly greater –.062° lagging phase shift at 1kHz. Compare this linear response to the rises and dips for that of the cable terminated with the speaker model.

I summarize the SPICE simulation magnitude and phase shift data for the solid-state amplifier models in *Table 3*.

Figure 16 shows the Goertz MI 2 (L, R, and C as measured) feeding the tube amp model, compared with an 8Ω resistor at the output terminals of the tube amp. Again, I used two separate amplifier channels to prevent interaction. You can see the greater degree of interaction between the amplifier and the complex impedance of the loudspeaker. The flat portion of the 8Ω resistor load is down to 1.862V or –0.63dB. The combination of cable and loudspeaker varies from –0.041dB at 34kHz to –0.694dB at 211Hz. The phase shift at the loudspeaker terminals varies from +1.77° at 6.5kHz to –1.04° at 2.8kHz.

The combination of the 8′ Kimber 8TC cable and loudspeaker models (*Fig. 17*) varies from –0.041dB to –0.700dB. The phase shift at the loudspeaker terminals varies from +1.80° to –1.04°.

The combination of the 8′ Supra 3.4/S cable and loudspeaker models (*Fig. 18*) varies from 0.052dB to –0.702dB. The phase shift at the loudspeaker terminals varies from +1.76° to –1.06°.

The combination of the 3′ Monster 1190MC cable and loudspeaker (*Fig.*

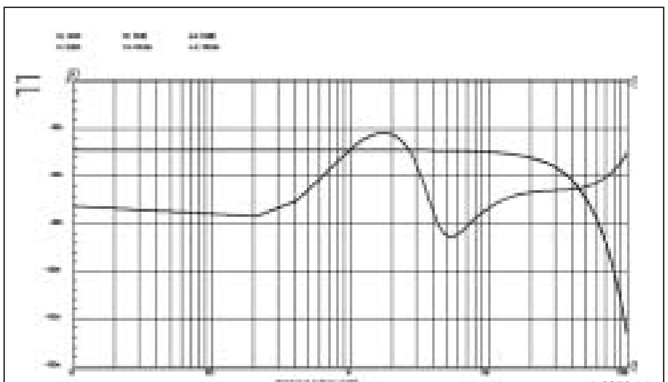

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FIGURE 14: Frequency response, 8Ω resistor versus zip cord 16 (S-S).

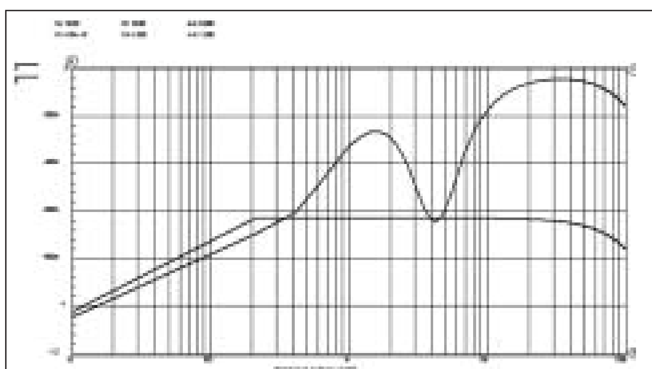

FIGURE 16: Frequency response, 8Ω resistor versus Goertz MI 2 (tube).

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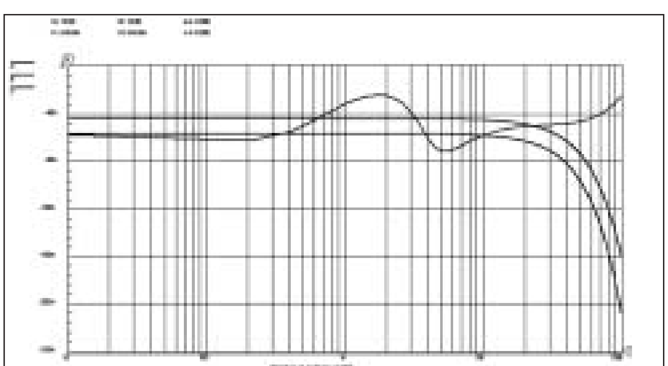

FIGURE 15: Frequency response, 8Ω resistor versus zip cord 16 with 8Ω load, speaker load (S-S).

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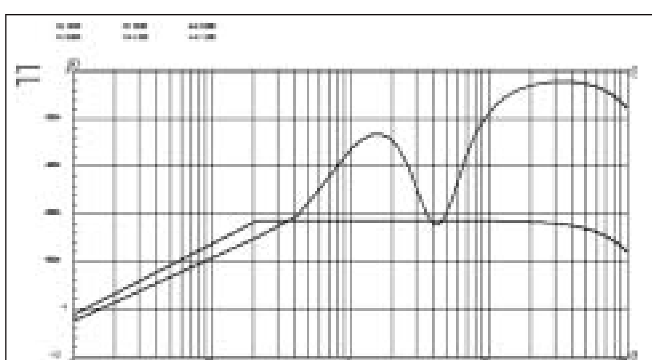

FIGURE 17: Frequency response, 8Ω resistor versus Kimber 8TC (tube).

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19) varies from –0.068dB to –0.705dB. The phase shift at the loudspeaker terminals varies from +1.69° to –1.10°.

Using the 16-gauge zip cord in the same tube amp simulation setting (*Fig. 20*) shows the response varying from –0.070dB to –0.720dB. The phase shift varies from +1.73° to –1.12°.

The SPICE simulation magnitude and phase shift data for the tube amplifier models are summarized in *Table 4*.

The increase in skin effect resistance at 20kHz seems to have less consequence than you might imagine. The increase in inductive reactance from 1kHz to 20kHz has a much greater effect on the series impedance than does skin effect. The increase in the RL series impedance component of the six cables from 1kHz to 20kHz is listed in *Table 5*. Note the much higher percent increases for the last three stranded cables, with their higher inductance. The first two cables have a double advantage due to their geometry: low inductance and low skin effect.

CONCLUSIONS . . . SORT OF

Looking at *Figs. 2* through *6*, you can see the distortion levels decrease in every case at the peaks of the loudspeaker impedance when compared with the essentially flat distortion curve for the 8Ω resistor. At the high-frequency end of the curve, where you might expect the rising cable impedance to have an effect, the distortion is essentially identical to that of the resistor alone. The more pronounced rise in distortion at the low frequencies, where the cable is essentially a resistor, may be due to woofer distortion in the satellite speaker, whose –3dB point is 57Hz.

The distortion excursions are lowest with the short 3′ flat wire cable, and highest with the 10′ length of Monster cable and 8′ length of 16-gauge zip cord. In the mid-range the measured distortion is lowest with the 10′ Monster cable than with the other cables, but its low-frequency distortion is also one of the highest. Of the three 8′ cables, the Kimber has the lowest overall distortion excursions. This suggests that short lengths of low resistance, low inductance cable are going to be the most accurate.

There is no question that there are also measurable LRC differences between these three speaker cables. However, the 1kHz impedance of even the 10′ length of Monster cable is less than the 40mΩ source impedance of the solid-state amp and far less than the impedances of the tube amp and

TABLE 3

SPICE SIMULATION RESULTS—SOLID-STATE AMPLIFIER

	Goertz MI 2	Kimber 8TC	Supra 3.4/S	Monster 12	Zip 16	Units
min attenuation	–0.021	–0.023	–0.024	–0.025	–0.032	dB
at Freq =	1.8	1.7	1.7	1.8	1.8	kHz
max attenuation	–0.062	–0.065	–0.073	–0.084	–0.098	dB
at Freq =	5.2	5.1	5.4	5.8	5.3	kHz
max + phase shift	0.099	0.111	0.111	0.107	0.150	degrees
at Freq =	639	623	623	631	631	Hz
max – phase shift	–0.182	–0.180	–0.224	–0.286	–0.297	degrees
at Freq =	3.5	3.3	3.5	3.6	3.5	kHz

TABLE 4

SPICE SIMULATION RESULTS—TUBE AMPLIFIER

Cable:	Goertz MI 2	Kimber 8TC	Supra 3.4/S	Monster 12	Zip16	Units
VT min atten	–0.041	–0.041	–0.052	–0.068	–0.070	dB
at freq =	34	34	34	34	34	kHz
VT max atten	–0.694	–0.700	–0.702	–0.705	–0.720	dB
at freq =	211	211	211	211	211	Hz
VT max + phase shift	1.77	1.80	1.76	1.69	1.73	deg
at Freq =	6.5	6.4	6.5	6.5	6.5	kHz
VT max – phase shift	–1.04	–1.04	–1.06	–1.10	–1.12	deg
at Freq =	2.8	2.8	2.8	2.8	2.8	kHz

loudspeaker, especially the loudspeaker. Only the 16-gauge zip cord impedance is higher than the solid-state amplifier source impedance. At 20kHz, the zip cord and the long Monster cable impedances are both higher than the solid-state amplifier source impedance. In all cases, the variations in speaker impedance across the audio band result in voltages at the speaker terminals that vary above and below those across the fixed 8Ω load alone.

CHARACTERISTIC IMPEDANCE

Any transmission line exhibits a certain amount of loss due to the conductor resistance and dielectric leakage current loss in the insulation. Line loss increases when the line termination is not equal to the line characteristic impedance. At frequencies where the transmission line length is an appreciable fraction of the wavelength, a mismatch in line termination from the line's characteristic impedance will produce reflections from the mismatched termination back to the source of the signal. The phase and amplitude of the reflected energy will vary with the degree of mismatch in impedance. The sum of the voltage vectors flowing toward the load is called the incident wave, and the sum of the voltage vectors flowing back to the source is called the reflected wave.

Note that one important consideration here is the ratio of line length *l* to wavelength λ. For audio signals, even the longest practical speaker cables are an infinitesimal fraction of the signal wavelength. The wavelength of a 20kHz audio signal, even after accounting for the drop in signal velocity propagation factor due to the cable configuration, is over 39 kilometers.

The flat wire cable characteristic impedance comes closest to the nominal loudspeaker impedance. However, irrespective of the extremely small *l*/λ ratio, any attempt to match the characteristic impedance of the speaker cable to the system components is also thwarted by the large excursions in speaker impedance over the audio band.

The flat wire cable and the open weave Kimber cable, with their low series inductance and resistance, have lower losses and phase shift than the stranded cables. This is most evident in the simulations with the solid-state amplifier. The closest comparison of the measurable inductance differences between the various cable configurations is with the two 12-gauge cables (Supra 87nH/ft, and Monster 193nH/ft).

Still, the maximum attenuations for the five 8′ cable models differ by less than 0.036dB, and the difference in total phase shift is less than 0.054°. The higher capacitance of the flat wire cable should not cause instability in a well-designed solid-state amplifier. If it does, the problem lies with the amplifier design, not the cable (Goertz does supply those Match Links).

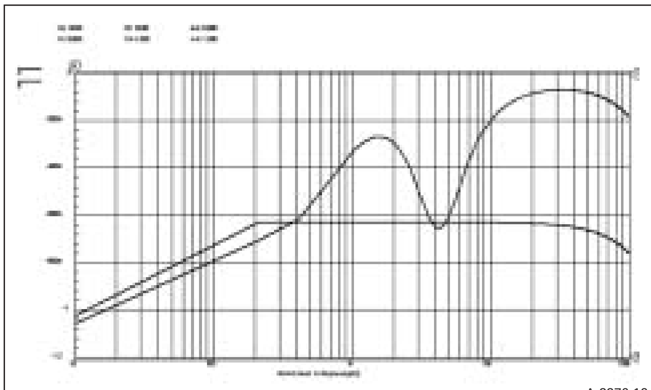
With the tube amp model, the situation is more complicated. Here the interaction of the higher output impedance of the tube amplifier (i.e., lower damping factor) interacts with the complex speaker impedance, producing greater voltage excursions across the loudspeaker than those of the solid-state amplifier. However, the cables just seem to be going along for the ride. There are again negligible differences in the attenuation (0.026dB) or phase shift (0.060°) across the cables, from the amplifier to the speaker terminals, regardless of the cable model used.

Finally, with respect to the differences in insulation materials, there will be a much greater variation in shunt capacitance with the plain PVC zip cord

TABLE 5

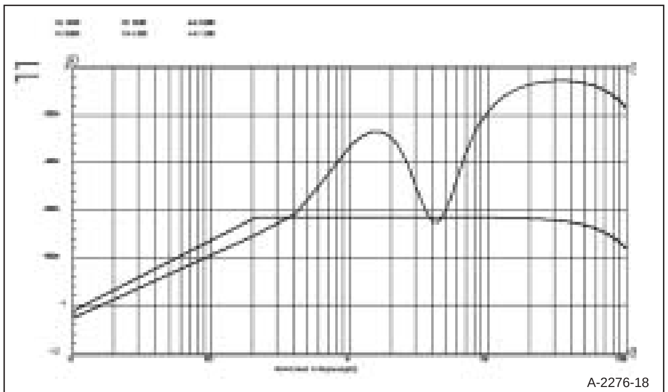
RL SERIES IMPEDANCE VERSUS FREQUENCY

Cable:	Goertz	Kimber	Supra	Monster	Zip 16
RL impedance at 1kHz	12.8mΩ	21.0mΩ	27.3mΩ	33.4mΩ	64.5mΩ
RL impedance at 20kHz	22.7mΩ	27.0mΩ	94.0mΩ	199mΩ	220mΩ



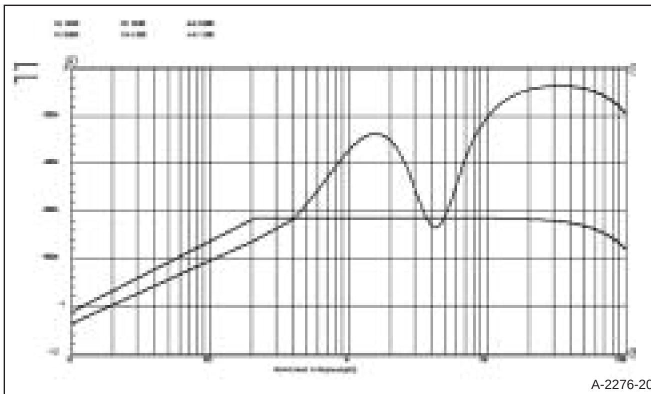
A-2276-19

FIGURE 19: Frequency response, 8Ω resistor versus Monster 1190MC (tube).



A-2276-18

FIGURE 18: Frequency response, 8Ω resistor versus Supra 3.4/S (tube).



A-2276-20

FIGURE 20: Frequency response, 8Ω resistor versus zip cord 16 (tube).

because of its higher dielectric constant and large variation of dielectric constant with frequency and temperature. The highly stable Teflon insulation should give the best electrical performance. All the cables have sufficient insulation thickness to withstand normal handling. ❖

Manufacturer's response:
We have found that it is hard to measure inductance in a short cable due to the inevitability of loops at the hook-up point. Also, because all cable interaction is relative to length, we would have proposed testing a more representative run of 10–15 ft. 3 ½ ft. is a very short speaker cable.

We were happy to see in print that "the capacitance of the flat cable should not cause instability in a well-designed solid-state amp." We share the conclusion that if it does, the problem lies with the amplifier, not the cable. Unfortunately a few designers still violate Nyquist's criteria on allowable amount of negative feedback. A good solid-state amp supply should not oscillate.

Ulrik Poulsen
Alpha-Core, Inc.

First, my compliments on a technically well-carried-out and well-explained test, giving a scientific impression.

Supra Ply is of a sandwich design for low inductance, and we know that even a lower inductance can be achieved with the ribbon design. In fact, we used aluminum tape, flat to flat, for conductors for the measurements of the Ply design concept during the R & D. However, once the theory of low inductance = low transient loss was confirmed, we began working on a user friendly design, which also was a compromise regarding the capacitance not to be too high to risk oscillations in sensitive amplifiers. Furthermore, as we have our own in-house production (different from most produced in China), we made a production friendly solution to ensure value for the money.

The final result was the braided flat conductors of Supra Ply. That was in 1993 when "high-end" speaker cables still were of wide-spaced design. Supra was first with speaker cables in 1976 and first with low-inductance design in 1993.

Tommy Jenving
President
Supra

REFERENCES

1. In order to minimize the skin effect at high frequency, a special stranded wire called Litz wire is employed. Litz wire was designed to minimize the losses in high frequency, high current applications. Litz is an abbreviation for litzendraht, which is German for stranded-wire. Litz wire is composed of separately insulated strands of very fine wire. It is wound so that every strand occupies, to the same extent, every possible position in the cross section of the wire. It is this special construction and the insulated strands that differentiate Litz wire from conventionally stranded wire.

Litz stranding is designed to equalize the flux linkages, and therefore the inductive reactance, of each strand in the wire. This results in the current being distributed evenly among all the strands. Litz wire is typically designed for a specific frequency range. AWG–28 strands may be used for frequencies below 1kHz, while strands as small as AWG–48 are used for frequencies in the megahertz region. The goal of the Litz wire designer is to make the resistance and reactance equal at the design frequency in order to maximize the Q of the cable. Sufficient strands of the selected size are then used to carry the maximum design current.

2. J. Atkinson, "Real-Life Measurements", *Stereophile*, August 1995, Figs. 1, 2. The full text of the original article can be found at www.sterephile.com/showarchives.cgi?60.

3. S. Reynold, "Vacuum-Tube Models for SPICE Simulations," *Glass Audio*, Vol. 5, No. 4, 1993.

4. LTSpice and vacuum tube models, www.duncanamps.com/technical/ltspice.html.

SOURCES

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FAX (203) 384-8120
e-mail: sales@alphacore.com
Goertz MI-2 MSRP $21.50/ft pair single, $43.00/ft pair bi-wire.
Terminations: Rhodium spades/banana plugs/pins $48 single, $63 bi-wire. Silver spades $58 single, $85 bi-wire.

Kimber Kable
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Kimber 8TC MSRP $420/pair with angled WBT 0645S banana plugs
Terminations: PostMaster spades, WBT straight or angled bananas

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SPEAKER CABLE LISTENING TESTS

By Muse Kastanovich

Cable is the purist-audiophile's favorite tool for manipulating the frequency balance and other qualities of his/her system. Active equalizers/tone controls are just not transparent-sounding enough for many listeners to be considered as part of a high-quality system. What is left to balance the response and sound of the system in the audiophile's listening room is choice of components, especially cables, which are less expensive than components, and so are easier to switch when you need a change. Cables interact with components to at least some degree, so their sound is always context-sensitive, which is why most outlets allow you to audition them with your own equipment.

For this review I first listened to a selection of high-end cables from the US company Kimber and the Supra company out of Sweden. Both are well-established, reputable audio companies. A comparative study lets you test many different qualities in different models, and also allows the ear to hone in on the exact characteristic sound of individual favorites.

LISTENING TEST

I listened to the Supra Ply 3.4/S in comparison with my reference Goertz MI 2 Veracity 3′ biwire pair. The Supra's treble was just a little grainy, and its transients were a touch rolled off. The midrange and lower treble were more prominent, and the bass sounded rich but a little flabby. The soundstage was more vague than that of the Goertz, and reverb was not as pleasantly noticeable. Overall, the Supra was darker and less involving.

After changing back to the Goertz for more reference listening, I then switched to the Kimber 8TC speaker cables. The Kimber's midrange was a bit less meaty, but the bass was more solid. Dynamics sounded equally good, though transients were not quite as coherent. The soundstage was very vivid, with good depth but not quite as much width. The top octave was not as present nor as clean as with the Goertz, but the treble was more prominent.

WRAP-UP

I found the Supra Ply 3.4/S was not the best match for my system. It sounded too veiled and soft for me to recommend it as a competitor to the others. However, it is more affordable than the others and may be a decent choice at entry-level. All of the Supra cables have a pastel "ice blue" color jacket that is absolutely delicious to the eye. It's unfortunate that they were not as delicious to my ears, because I really wanted to like them.

I found the Kimber 8TC, which has been available for many years, to still be a good choice in its price range. Its very dynamic, alive, solid sound made me quite happy when I used it to connect my 804s. It is positioned in a medium price range, and you would be hard-pressed to find a better overall value. I recommend taking a listen to this speaker cable, which should match well with many different systems.

UPGRADE

For about three years, I have been using a bi-wire pair of Goertz MI-2 flat speaker cables, made by Alpha-Core, as the reference wires in my system. So you might imagine I was excited when I heard some months back that they had introduced a new Teflon insulated version called the T-series.

My long-term reference cables are an unterminated (bare-wire ends), 3.5′ long, bi-wire pair of Goertz MI-2 Veracity, insulated with a mix of Teflon and polyester terepthalate. Each pair of flat OFC copper foils is sandwiched together to make a ribbon about ¾″ wide and only about 1/16″ thick, and has the same conductor cross-section as 10 AWG wire. Of course, there are two ribbons per speaker in a bi-wire setup like mine, though only one is needed per speaker in a normal setup.

The new Goertz MI-2 T-series ($136) cables reviewed here are identical to the older version, except that they are 3′ long and have only pure Teflon insulation around them. They are also terminated with what Goertz calls integral spaces, though this is not an important difference because the spades are made from the bare copper foil of the wire, meaning they are actually unterminated like my older pair.

TEST SETUP

My system consisted of a Rotel RDD-980 CD transport and Assemblage DAC-3 D/A processor connected with a Sound & Video Digiflex Plus BNC cable. Analog interconnects were Kimber Hero unbalanced. Amplification was provided by my home-built STAMINA single-ended MOSFET integrated monoblock amps (based on the Pass Zen/Bride of Zen circuits, output impedance 0.8Ω). Speakers were my modified pair of B&W Matrix 804 (nominal impedance 8Ω, minimum 4Ω).

Alpha-Core included a pair of free R/C Match Links to prevent oscillation in certain amplifiers when using their high capacitance cables. I did not need these with my amps because the ultra simple Zen is rock stable into any impedance.

LISTENING IMPRESSIONS

The new Goertz T-series MI-2 wires appear identical to my old favorites, except for the color of the translucent insulating jacket. A change of insulating dielectric material can theoretically change the sound, considering that a good portion of the electromagnetic signal travels on the surface of the wire at audio frequencies. Indeed, I was pleasantly surprised by the improvements that greeted me when switching from my old MI-2 cables.

Listening to "Achtung Baby" by U2, I noted the T-series had a slightly brighter sound, and was a little crisper and clearer sounding. Transients sounded a little faster, and there seemed to be a greater number of different layers of sound apparent. Its soundstage was slightly wider, and images were a bit more vivid. The midrange was just a touch recessed, and the bass was deeper. Overall, I preferred the faster, more dynamic sound of the new T-series.

ASSESSMENT

I very much enjoyed my time with the Goertz MI-2 Veracity T-series flat speaker cables. I found them to be very detailed, transparent, and dynamic sounding. I highly value these main qualities, which make a system sound closer to live music.

I am purchasing the new T-series review samples, which I will use as my new reference. My old reference Goertz wire seemed just too uninvolving after becoming accustomed to what the new ones could do for the music. This is not to say that the "standard version" Goertz wire is no good (it is still being manufactured); on the contrary I still recommend it, but only for systems that are too bright and need a very mellow-sounding wire. For everyone else, the T-series represents a more involving choice that will keep the excitement level high.

RESPONSE:

We are disappointed that Muse Kastanovich didn't find the Supra speaker cable to work as needed in his system. In my experience with B&W speakers, while wonderful sounding, they tend to be rolled off on top and wanting more power than less. The Zen amplifier is a respected amplifier, but along with its minimalistic design, the power, in my experience, is less than desirable for that speaker. If the Alpha-Goertz cables are a little brighter on top, that would explain their more desired results in Mr. Kastanovich's review, andgiven the Supra's flatter response, a less desired result. As with many things in audio, system matching plays a key, and insufficiently acknowledged, role in listening satisfaction.

Tony Minasian
Tonian Labs
U.S. Distributor (Supra)