The effects of increasing an audio cable's bandwidth as related to the speaker cable's ability to transport current with lowered reflection-induced noise.

by Bruce A. Brisson

MIT constantly gets questions from the field regarding the ability of a cable to transport current between the amplifier and the speaker. Normally the question is, "What gauge wire do I need to hook up my 300 Watt amplifier to a given speaker?" Or, "Do I need bigger wire if my amplifier is 20 feet from my speakers rather than 10 feet?" The purpose of this paper is to try to clarify what really happens when a music signal enters the cable, and what the cable must provide in order to properly deliver the current to the load.

All cables have a complex impedance, consisting of both a real and a reactive part. The inverse or the reciprocal of complex impedance is called admittance. Admittance is the ease with which an alternating current flows through a circuit or device; it too has a real and a reactive part. Keeping this in mind, it should be recognized that all audio cables function as low pass filters. That is, they will pass low frequencies easily while attenuating the high frequencies. Hopefully, they will not begin to attenuate the signal until well above 20kHz.

...it should be recognized that all audio cables function as low pass filters. That is, they will pass low frequencies easily while attenuating the high frequencies. Hopefully, they will not begin to attenuate the signal until well above 20kHz.

Conventional wisdom views conductor size as the only meaningful specification for connecting audio amplifiers to speaker interfaces, but this is misleading. We all understand that a cable with too small a cross-sectional area can consume the audio signal in the way a resistor does. This type of cable exhibits poor admittance in the real part, and resistively attenuates the audio signal. When the real part of the cable opposes the music's electric signal, the signal's electrical energy will be consumed and converted into thermal heat. This is similar to what occurs when you turn on a burner on the electric stove in your kitchen. Not surprisingly, this cable will also exhibit measurable thermal noise. However, as we will show further on, this is not the sole, or indeed the major, source of noise in audio cables.

We must also understand that a cable does not have to consume the audio signal to attenuate it. If a cable has poor admittance in the reactive part, it can reflect energy back to the source without consuming it at all. This does not generate heat, but it does create distortion producing noise. Energy cannot be destroyed; it must be consumed. Thus, the energy reflected back to the source does not just vanish. It is stored in the dielectrics of the cable for some period

We must also understand that a cable does not have to consume the audio signal to attenuate it. If a cable has poor admittance in the reactive part, it can reflect energy back to the source without consuming it at all.

Energy cannot be destroyed; it must be consumed.

...the energy reflected back to the source does not just vanish.

This noise, caused by the reflected energy which is re-delivered, or "flipped back," out of phase, is the distortion element we are concerned with in this paper.

This random reactive noise, or RRN, will negatively affect music reproduction in various ways during playback or recording.

of time, and is later delivered back to the cable to be transported and consumed by the load. At this later time, however, the energy will be out of phase, and will contaminate the music signal.

This noise, caused by the reflected energy which is re-delivered, or "flipped back," out of phase, is the distortion element we are concerned with in this paper. This random reactive noise, or RRN, will negatively affect music reproduction in various ways during playback or recording. A loss of clarity is the first thing that is generally noted. There are also tonality shifts, which create overly-emphasized, hard-sounding transients. The inability to produce an image of proper size between the speakers is another manifestation of this type of noise. A realistic soundstage, producing an accurate re-creation of the size of the original musical event, is not possible with even the smallest amount of RRN present in the audio cables connecting the system.

As we will see from the measurements below, provided by our MIT Laboratory, it is not the real part (the absolute size of the conductor) of the cable that produces the distortions. It is the reactive part (inductance or capacitance) of the cable which, by reflecting energy back to the source, creates the distortions.

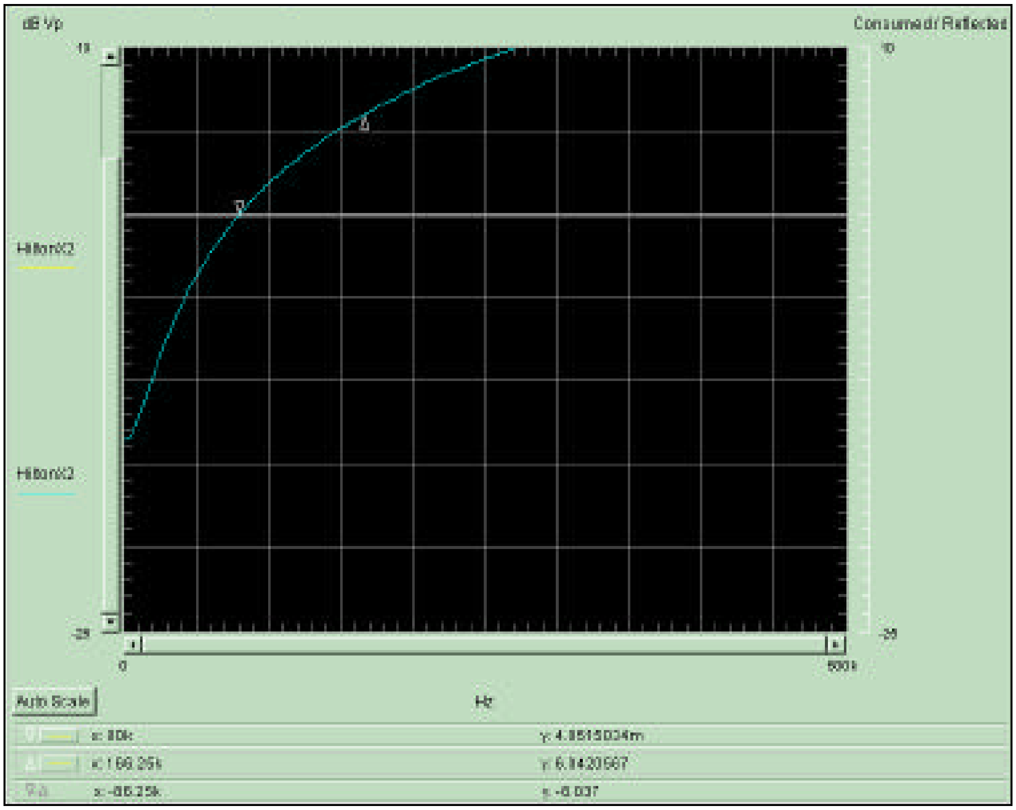
Interpreting the reflection measurement:

In each of the reflection measurement graphs, the thick black horizontal line running from left to right across the plot represents unity gain, that is, the magnitude of the signal MIT has input into the cable from the signal generator. The vertical axis is magnitude, and the horizontal axis is frequency. Any magnitude measured below the unity line represents current flow through the cable on to the load, or the speaker in the case of audio reproduction. The further below unity gain the measurement is, the more current is flowing through the cable. Any magnitude above the line represents current that is not being admitted through the cable. Since this energy cannot flow through the cable, it will be flipped back to the source, to be returned to the cable out of phase, as RRN. Note; all RRN measurement results presented in this paper have been averaged 20 times.

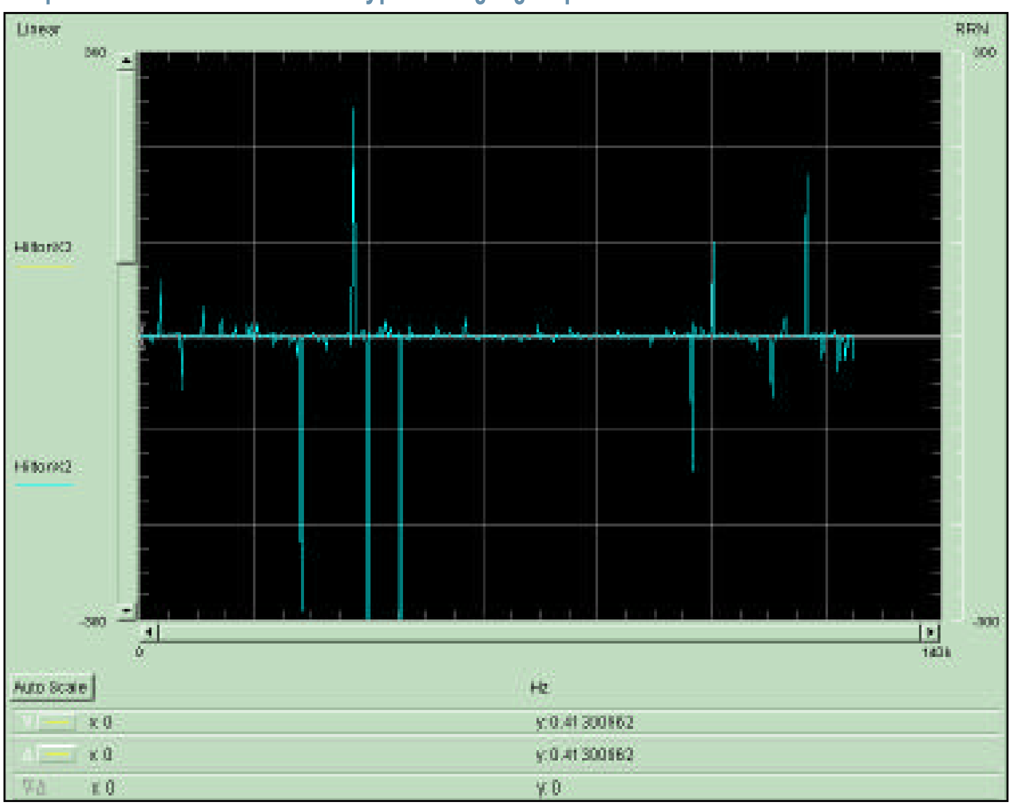
Let's examine the reflection measurement in Graph #1 of a typical 12 gauge zip cord sold and used around the world for economical amplifier to speaker interfacing.

Note the first cursor measurement, displaying 80 kHz, which represents the unity gain frequency. This is the frequency where current can no longer pass through the cable, and above which only reflections will exist. The second cursor measurement, displaying 166.25 kHz, represents the plus 6dBV frequency. The value present at this frequency represents twice the voltage applied to the input of the cable by the signal generator. Now lets look at the RRN measurement in Graph #2 and find out where that energy went after it was flipped back to the source generator, stored in the cable, and released out of phase.

Graph #1: Reflection Measurement—Typical 12 gauge zip cord



Graph #2: RRN Measurement—Typical 12 gauge zip cord



Interpreting the noise measurement:

Noise, in the broadest sense, can be defined as any unwanted disturbance that obscures or interferes with a desired signal. Noise is a totally random signal. It consists of frequency components that are random in both amplitude and phase.

Noise, in the broadest sense, can be defined as any unwanted disturbance that obscures or interferes with a desired signal. Noise is a totally random signal. It consists of frequency components that are random in both amplitude and phase. Noise in high quality audio reproduction obviously has no useful purpose. One would not want to listen to music in a room with a thin metal ceiling on a rainy day. And we certainly do not want electrical noise obscuring the music because of our audio cables. Random reactive noise, RRN, is not a stable or cyclic noise. Music for the most part is not constant or of steady state. In fact music consists largely of short bursts of information and is harmonically rich. It is therefore, mostly transient in nature. The magnitude and frequency of RRN vary with each harmonics transient.

One would not want to listen to music in a room with a thin metal ceiling on a rainy day. And we certainly do not want electrical noise obscuring the music because of our audio cables.

The noise measurement graph, like the reflection measurement graph, has a dark horizontal line running from left to right across it, representing unity gain. Anything negative to this represents a negative voltage, and anything positive to this represents a positive voltage. Again, the vertical axis is magnitude, and the horizontal axis is frequency. The results of the measurement show the magnitudes of the RRN versus frequency. This noise has been generated by the release of the energy temporarily stored within the cable's dielectrics, but not admitted or transported to the load. Note; all RRN measurement results presented in this paper have been averaged 20 times.

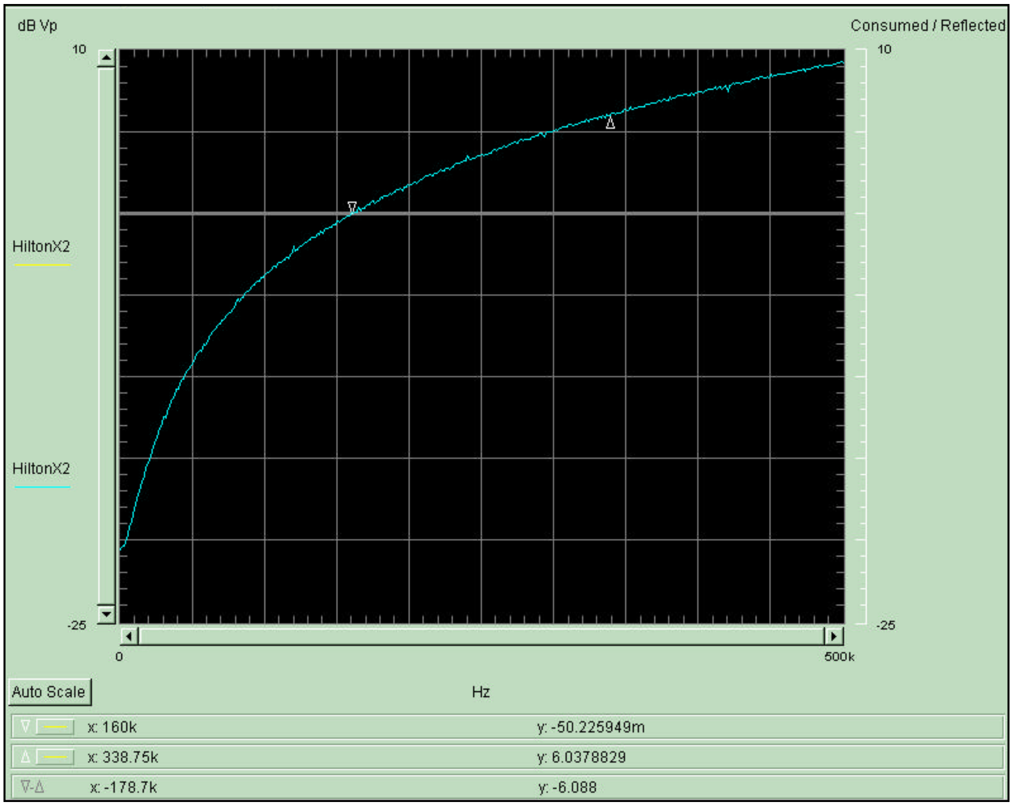
Our typical 12 gauge zip cord has generated significant RRN falling within the all-important range between 20 Hz to 140 kHz.

Our typical 12 gauge zip cord has generated significant RRN falling within the all-important range between 20 Hz to 140 kHz. What cannot be shown here (unless we wanted to do a real time video) is the fact that each time the test equipment triggers and displays the one of the 20 individual measurements which were averaged for this result, that measurement contains a different set of magnitudes and frequencies. A cable such as this, which contains high magnitudes of RRN, will change the tonality of voices and instruments, lessen the clarity of the sound, and impede the imaging ability of the system. And if the frequencies dance around as these do, it is doubtful that any realistic sound stage at all will be rendered by the system.

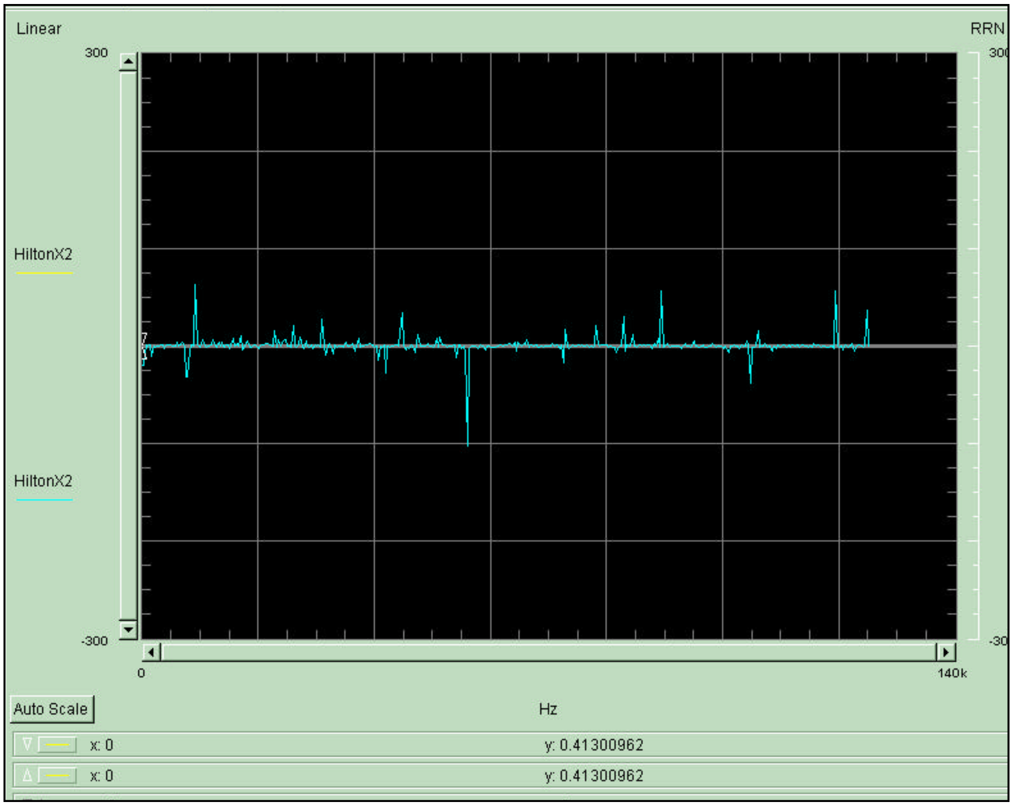
A cable such as this, which contains high magnitudes of RRN, will change the tonality of voices and instruments, lessen the clarity of the sound, and impede the imaging ability of the system.

The reflection measurement in Graph #3 is also a 12 gauge speaker cable. However, this cable has a more sophisticated conductor geometry and also possesses Teflon dielectric. This cable sells for approximately $1,000. Note the first cursor at approximately 160 kHz representing the unity gain frequency. This is the frequency where current can no longer pass through the cable. Any frequency above this and only reflections will exist. The second cursor measurement displaying 338.75 kHz represents the plus 6dBV frequency. The value present at this frequency represents twice the voltage applied to the input of the cable by the signal generator. Both of these measurements represent clear performance increases over the 12 gauge zip cord in reflection measurement #1. Now let's look at the RRN measurements for this cable (Graph #4), showing the effect of the energy flipped back to the source generator, stored in the cable, and released out of phase.

Graph #3: Reflection Measurement: 12 gauge cable with Teflon dielectric



Graph #4: RRN Measurement: 12 gauge cable with Teflon dielectric



Our common 14 x 2 in-wall cable has generated about as much RRN as the 12 gauge zip cord. Much of it also falls within the all-important range between 20 Hz. to 140 kHz.

Like the 12 gauge zip cord, this cable contains such high magnitudes of RRN it will change the tonality of voices and instruments.

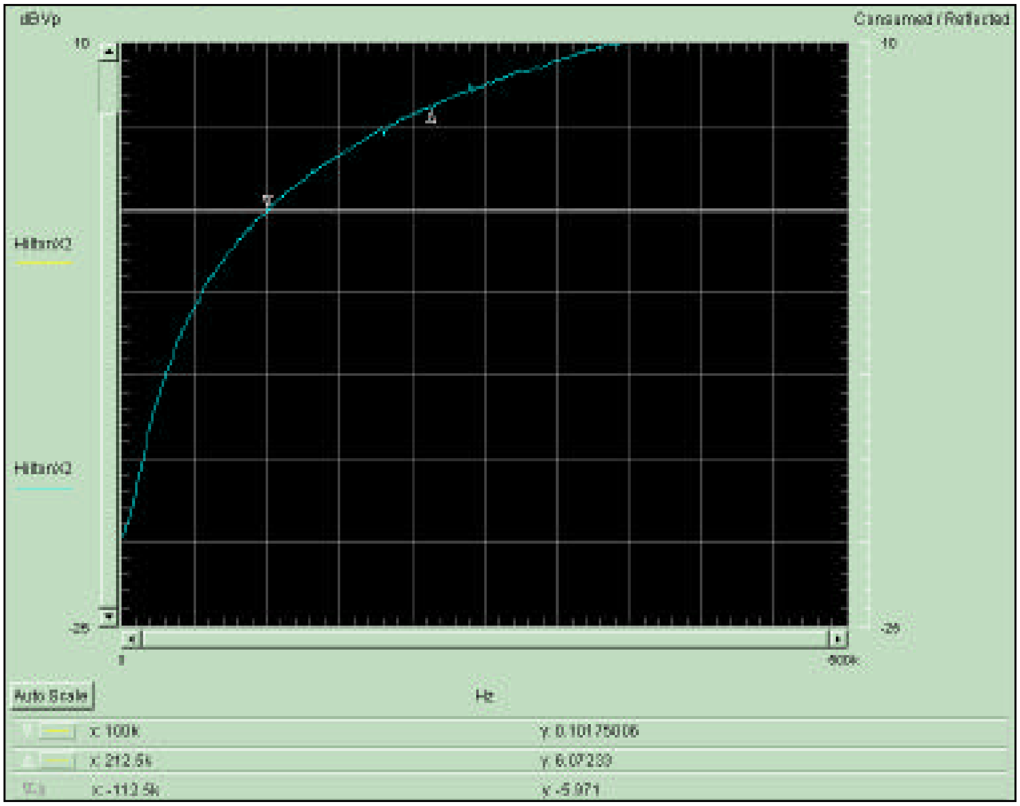
This cable, just like the 12 gauge zip cord, will not be able to create even the beginnings of a accurate or lifelike soundstage.

As we might expect, the 12 gauge speaker cable with Teflon dielectric exhibits reduced RRN as compared with that from the 12 gauge zip cord shown in the RRN measurement in Graph #2. However, it is still significant enough that the music will lack clarity, and there will be a negative effect on the system's ability to create a rock solid image or accurate size of sound stage. One would expect more for approximately $1,000.

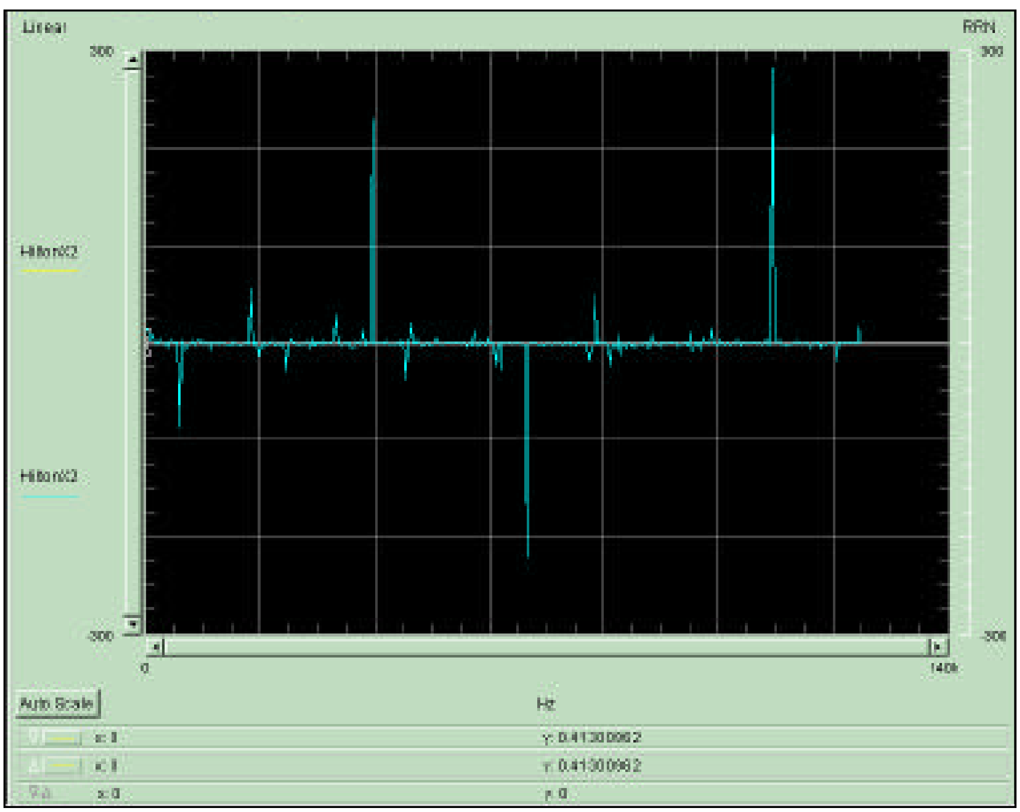
The reflection measurement shown in Graph #5 are the results from a popular 14 x 2 in-wall cable used by custom installers around the world. Note the first cursor displayed at 100 kHz. This is the frequency where current can no longer pass through the cable. Any frequency above this and only reflections will exist. The second cursor displayed at 212.5 kHz represents the plus 6dBV frequency. The value present at this frequency represents twice the voltage applied to the input of the cable by the signal generator. The RRN measurement shown in Graph #6 shows us where that energy went after it was flipped back to the source generator, stored in the cable, and released out of phase.

Our common 14 x 2 in-wall cable has generated about as much RRN as the 12 gauge zip cord. Much of it also falls within the all-important range between 20 Hz. to 140 kHz. Again, what can not be shown here (unless we wanted to do a real time video) is the fact that each time the test equipment triggers, and displays the last measurement, the measurement contains a different set of magnitudes and frequencies. Like the 12 gauge zip cord, this cable contains such high magnitudes of RRN it will change the tonality of voices and instruments. And when the frequencies dance around as these do, the image will wander around between the speakers. This cable, just like the 12 gauge zip cord, will not be able to create even the beginnings of a accurate or lifelike soundstage.

Graph #5: Reflection Measurement: 14X2 In-Wall cable



Graph #6 RRN Measurement: 14X2 In-Wall cable



MIT's One Wire T-Max Super is virtually noise free!

...MIT has been providing speaker cables and interconnects with wide bandwidth, minimal reflections, low RRN, and more useable current vs. bandwidth than ordinary cables for many years.

...MIT One Wire T-Max Super cable outperforms ... not only the 12 gauge zip cord and the 14 x 2 cable, but also the thousand dollar Teflon-coated cable. Yet its price is only 10% of that of the Teflon-coated cable.

Reflection Measurement: MIT One Wire and T-Max Super Modules

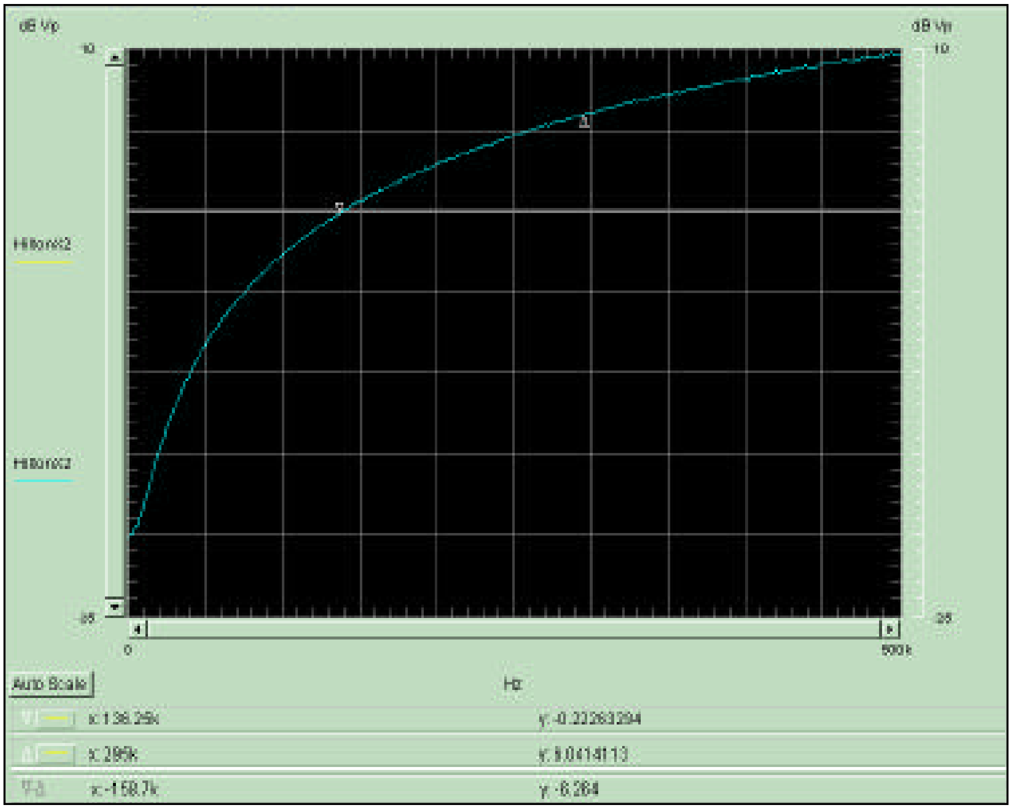
MIT's One Wire T-Max Super is shown in Reflection Measurement #7. Note the first cursor displaying 136.25 kHz representing the unity gain frequency. This is the frequency where current can longer pass through the cable. Any frequency above this and only reflections will exist. The second cursor display at 295 kHz represents the plus 6dBV frequency. The value present at this frequency represents twice the voltage applied to the input of the cable by the signal generator. Now let's look at the RRN measurement in Graph #8 and compare it to the results from the other cables examined.

MIT's One Wire T-Max Super is virtually noise free! Using our patented technologies, MIT has been providing speaker cables and interconnects with wide bandwidth, minimal reflections, low RRN, and more useable current vs. bandwidth than ordinary cables for many years. However, until the major breakthrough of One Wire and the T-Max modules, these technologies were very expensive and only available in our High End or Reference cables.

Summary of Performance Tests:

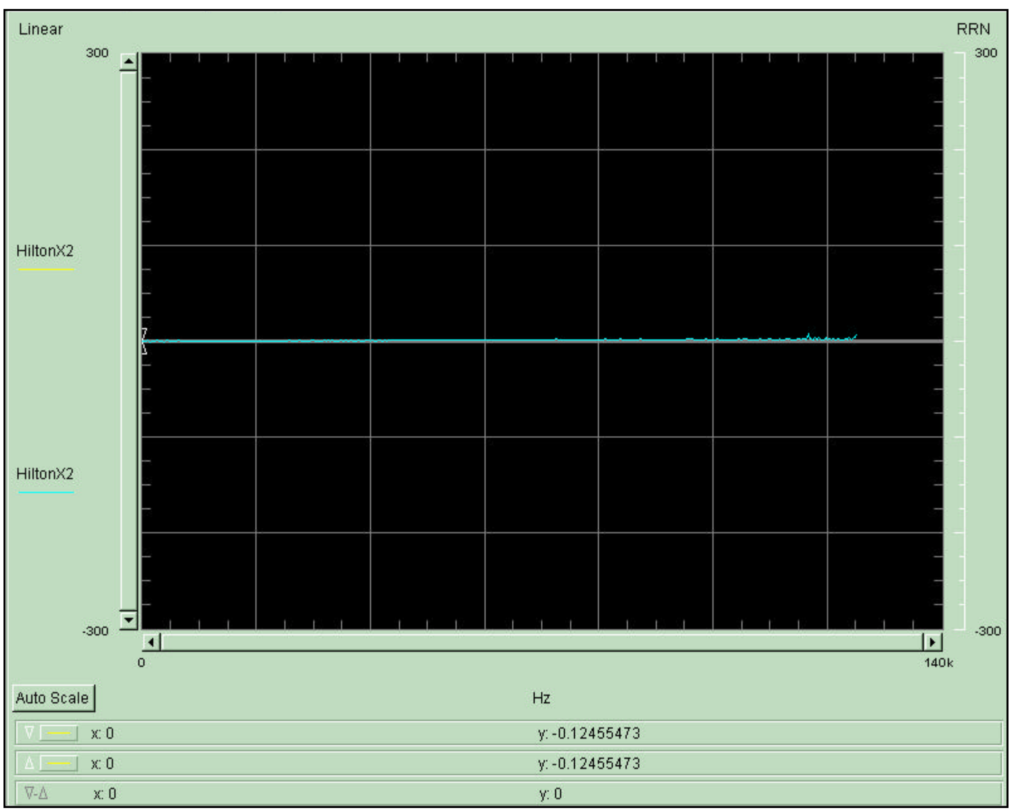
From these measurements, it is apparent that the thousand dollar 12 gauge cable with Teflon dielectric outperforms the other three cables in terms of bandwidth versus reflections. Nevertheless, the MIT One Wire T-Max Super cable significantly outperforms both the 14 x 2 cable commonly utilized for in-wall installations and the 12 gauge zip cord in this area. More importantly, in regard to damaging RRN, the MIT One Wire T-Max Super cable outperforms all three of the others: not only the 12 gauge zip cord and the 14 x 2 cable, but also the thousand dollar Teflon-coated cable.

Graph #7: Reflection Measurement: MIT OneWire T-Max Super



MIT One Wire T-Max Super cable outperforms all three of the other cables tested: not only the 12 gauge zip cord and the 14 x 2 cable, but also the thousand dollar Teflon-coated cable. Yet its price is only 10% of that of the Teflon-coated cable and sells for approximately the same price as the 12 gauge zip or 14X2 cable. The MIT One Wire T-Max system now affords everyone the same sonic benefits that professional recording studios and film studios have been using for over 15 years.

Graph #8: RRN Measurement: MIT OneWire T-Max Super



Conclusion:

It is well understood that conductor size is an important component of cable specifications: a cable with too small a cross section will attenuate the signal through resistance, creating heat and exhibiting thermal noise. However, the complex impedance of a cable, and its inverse, admittance (the ease with which current flows through the cable), also has a reactive part. This reactive part also attenuates current, but instead of consuming it as thermal noise it is flipped back as RRN to the source and adds to the music at some time later. The damage done by this type of attenuation resulting in RRN is much more damaging than thermal noise.

A cable with low admittance in the reactive part reflects part of the music signal's energy back to the source, where it is stored and then re-delivered to the cable at a later point in time. This energy is now out of phase, and contaminates the music signal with random reactive noise (RRN), as shown in the graphs above. This results in tonality changes, a hardness or edginess added to the music, and an inability to produce precise images or a realistic soundstage.

Furthermore, reactive noise can be much more damaging than thermal noise. This is because the reflected energy has not been attenuated by resistance. In fact, the noise output of such a cable can be as high as, or even higher than, the source's output.

MIT®

MUSIC INTERFACE TECHNOLOGIES™

www.mitcables.com
916/625/0129
fax 916/625/0149

MIT Products are Manufactured & Sold by CVTL, Inc.
4130 Citrus Avenue, Suite. 9
Rocklin, CA 95677