HIGH RESOLUTION CABLE DESIGN THEORY

By Don Palmer, Designer, Highwire Audio

Highwire Audio cable development started in 1986. Skywire Audio cables contain the best of 20 years' continuous research, as embodied in the best Highwire designs, and in further recent development.

The major difference between our cables and other high end audio cables is in the use of Radio Frequency (RF) suppression around the cable. This is accomplished by encircling the signal conductors with an efficient electromagnetic RF absorbing material.

The purpose of this is to reduce the RF ringing and RF noise in the cables. My experience and testing indicate that properly reducing the RF in cables will give a considerable improvement in cable sonics. This was not generally appreciated when we started in 1986, but now other high end cable manufacturers have realized the benefits of reducing RF in audio cables and have incorporated RF reduction in their designs.

EFFECTS OF RF ON THE CABLE SONICS

The effect of RF energy in cables does not show up in steady state audio frequency testing such as a sine wave sweep. However it can be audible with music reproduction. I believe this is because the effects are primarily due to intermodulation distortion (IMD). Each musical instrument has fundamental frequencies and harmonics. When several instruments are playing, the number of individual frequencies increases rapidly. Even small amounts of IMD from each pair of frequencies can raise the overall noise and distortion floor to audible levels. Note that distorted music will sound louder than undistorted music and sometimes distortion can be mistaken for dynamics.

There are a number of items that one can listen for in the music that indicate RF noise and intermodulation distortion in the system:

Veiling, artificial airiness, blurring, softening, homogenization of the sound. These may give a sense of increased space and detail but do not actually increase the amount of information.

Lack of dead quiet background and loss of the room ambiance of the recording space.

Instruments not well separated and distinct from each other and in their own sound space.

"Congestion" in complex music such as orchestral and choral.

Thinness or lack of richness (lack of reproducing all the harmonics of instruments).

Chords sounding "sour" or nonmusical.

Differences in energy or dynamics at different areas in the audio frequency range. This can make certain frequency ranges sound louder or more forward or hard.

Certain notes being bright or "jumping out" (forward towards the listener).

Loud passages or voice sibilants jumping out or distorting or "overloading."

The top edge of horns smearing or "tearing" or "breaking up" or "turning to hash" or getting sharp or overly edgy.

Complex voices, such as Shirley Horn and Thomas Hampson, sounding mechanical and hard instead of warm and powerful especially when singing loudly.

NOTE: It is interesting that many of these characteristics are more present in CD reproduction with its built in RF digital pulse generators.

RESULTS OF LOWER RF ENERGY

We have found that all of these characteristics are ameliorated as we improve the efficiency of the RF suppression on the cables.

Suppressing all the cables and power cords will yield the quietest results since one cable with RF noise can raise the noise floor in the entire system. Suppressing other unrelated cables and power cords in the home will further reduce the audio system noise floor. These can include TV power cords, telephone lines, etc.

I am convinced that properly reducing the RF in cables will give sonic benefits that cannot be achieved in any other way. This conclusion has been reinforced through twenty years of research and experimentation and listening.

CABLE DESIGN THEORY

The design theory is that RF energy in a cable will reflect from the ends of the cable and will set up a sustained ringing when the wavelength of the RF energy is at odd and even multiples of the length of the cable. By reducing the sustained ringing in audio cables we can demonstrate that the cable noise is reduced and the reproduction of low level audio signals is improved.

Several conditions must be present for sustained ringing to occur. First, there has to be Radio Frequency energy present in the system and cables to initiate the ringing. Audio frequencies (20-20,000 Hz) will not have enough high frequency energy to initiate Radio Frequency (RF) ringing. However there are many sources of analog RF signals, noise, and high speed digital pulses that splatter through out the RF ranges.

There are numerous sources of RF contamination in homes. DVD players, FM tuners, TV sets, wireless telephones, digital answering machines, computers, fax machines, microwave ovens, variable light dimmers, and other household electronics produce RF both into the air and back onto the power lines.

Within the audio system itself there are the high frequency digital pulse generators in CD transports and players, S/PDIF digital cables, and in remote control circuits. Power supplies and fluorescent displays are also significant RF noise sources.

RF sources outside the home can include ham radios, commercial AM and FM stations, cell phone towers, local police and taxi communications, contamination from nearby residential and industrial equipment, and other sources.

RF noise energy can enter an audio system through the power lines, can be generated within the system itself, and can be picked up by the signal cables and power cords in the system acting as receiving antennas. As one can see there are many sources of spurious RF energy that can affect a high end audio system.

The second condition to have sustained ringing is that the cable conductor resistance must be low enough to keep the resistive losses down. If there is high resistive loss in the conductors then the ringing energy will be dissipated in heat. Most cables have relatively low resistance but there are some cables made with high resistance conductors. These can use very fine wire or high resistance materials and will reduce the ringing but can have other sonic side effects.

The third condition for sustained ringing is an RF impedance mismatch between the cable and the connectors and loads at the ends of the cable. At radio frequencies the impedance is equal to the voltage divided by the current. The cable, the connectors, the source, and the load will each have an RF impedance.

The impedance for a steady state Direct Current (DC) is the same as the resistance. For Alternating Current (AC) and RF the impedance can have resistive, capacitive, and inductive components. An audio cable can have a fraction of an ohm DC resistance but might have a 75 ohm impedance at RF.

The impedance determines the flow of energy. Where RF encounters an impedance mismatch (change), some energy is reflected. A cable with mismatches at both ends is like two mirrors set up to reflect each other: any disturbance bounces back and forth many times.

In an audio cable the impedances of the wire and connectors are not designed to match the RF impedances of the equipment at the input and the output, and the most common methods of optimizing for audio result in mismatches at RF wavelengths. The following sections describe the way electrical waves travel through a cable and electrical differences between designing for audio and RF wavelengths.

AUDIO CABLES

The audio signals are the desired signals and the fidelity must be preserved. A low source impedance and a high load impedance with low cable resistance is the generally accepted method. This is the worst case for the RF in the system as these conditions cause RF impedance mismatches at both ends of the cable. The resulting RF ringing is spurious noise to the audio signal and will raise the noise floor in the cable. The increased noise floor will veil and degrade the audio signal.

There are many ways to reduce RF noise and ringing in cables. Some methods include impedance matching, the use of ferrite RF absorbers, the use of multiple parallel sections of wire of differing windings, and various methods of low pass filtering. The goal of all these methods is to reduce the RF without causing distortion of the audio frequencies. Each method is more or less effective and has its own side effects and its own sonic character.

We have found that our method of electromagnetic suppression gives a greater reduction in RF ringing than the other methods that we have seen. We also think that its side effects are less damaging to the audio fidelity than most of the other methods, and its sonic character is better. It is this combination of the greatest reduction in ringing and the least negative side effects that give our cables their distinct qualities.

MAGNETIC FIELD

The current flowing in a cable generates the magnetic field around the cable. The magnetic field is circumferential to the cable. The maximum magnetic field in the standing wave will be in the middle of the cable coincident with the maximum standing wave currents. It is the circumferential magnetic field that we suppress with our electromagnetic suppression material. If the magnetic energy around the cable is absorbed and dissipated then the current energy and the voltage energy in the standing waves will also be dissipated.

STANDING WAVE MODES IN CABLES

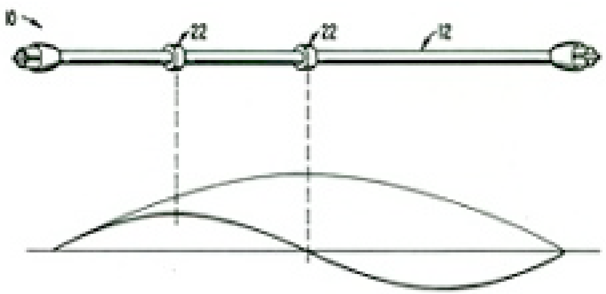
A standing wave mode is a frequency where the wavelength in the cable has maximum voltage amplitude at both ends of the cable and one or more current peaks along the length of the cable. These are the frequencies which will give maximum voltage reflections from both ends and will cause sustained end to end ringing. There are numerous possible standing wave modes in cables.

The lowest frequency for which the voltage amplitude can be a maximum at both ends will be the one where the cable length is one-half of the full wavelength. This fundamental mode will occur where the transit time of the wave is equal to the period of a half wave of the frequency. We call this fundamental ringing mode the first mode. Most audio cables have fundamental ringing frequencies in the 10 to 100 Mhz Radio Frequency range.

The harmonics of the fundamental ringing frequency occur at whole-number multiples of the fundamental ringing frequency in the cable. Therefore a series of standing waves will occur at discrete RF frequencies at the fundamental and at even and odd integer multiples of the fundamental ringing frequency.

The fundamental half wave mode will have one magnetic standing wave peak at the center of the cable at a frequency of approximately 50 MHz for a 1 meter cable. The second mode will be at the frequency where the cable contains a full wave AC cycle and is twice the frequency of the fundamental.

MAGNETIC WAVES AND MODES



The suppression material absorbs magnetic waves and therefore is most efficient on the magnetic wave peaks. We do not locate the suppression only on the magnetic standing wave peaks. We have found that the cable sonics are improved with contiguous suppression coils (i.e. no spaces between coil turns). As the total length of suppression coils increases, the higher frequency modes are more completely suppressed. Therefore we can describe the different cable designs as first mode cables, second mode cables, etc. When we call a design a third mode cable we mean that we suppress all three of the third mode magnetic standing wave peaks in the cable. Suppressing more modes is like suppressing higher harmonics of the fundamental ringing.

Note that a first mode cable will suppress the magnetic standing wave peak of the third mode wave that is located in the center of the cable. A third mode cable will have sufficient length of suppression coils to suppress all three of the magnetic wave peaks in the cable and will also suppress all of the first and second mode peaks. A fourth mode cable will suppress all four of the magnetic wave peaks in the cable.

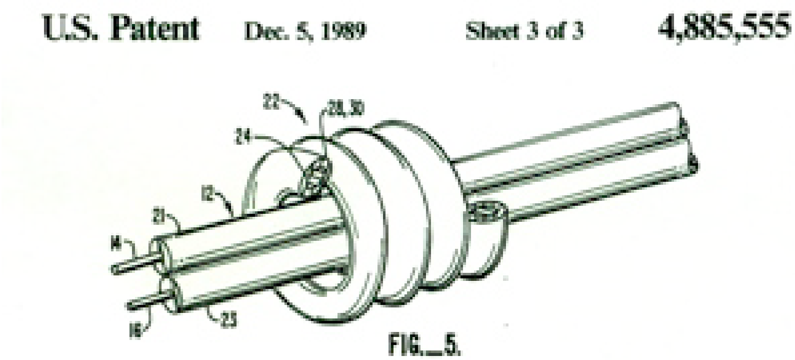
METHOD OF RF SUPPRESSION

The technique used to suppress this ringing in our audio cables is to absorb the magnetic energy in the RF standing wave. The technique was first tested using a magnetically permeable toroidal core with several shorting conductor straps.

When this core was moved along the audio cables, we could hear changes in the sound when the core was on the standing wave nodes (especially on the midpoint of the cable).

FERROMAGNETIC CORE WITH SHORTING STRAPS

In the production design we wrap the cable with a patented suppression wire. The suppression wire consists of a magnetically permeable core to couple the magnetic wave from the primary (the signal conductor) through the magnetic core to a conductive secondary (a conductive material around the magnetic core). The conductive secondary is a short circuit and resistively dissipates the voltage generated by the magnetic flux in the core. The core cross sectional area is so small that it does not couple the audio frequency waves into the secondary. Our measurements indicate that it is only effective above one megahertz.



When wound circumferentially around the cable this material acts like a transformer with a shorted secondary at radio frequencies. This dissipates the RF energy as heat and substantially reduces the amplitude of the RF ringing in the cable.

To verify our theory a comparison test was made between a 1 meter cable with the RF suppression material and an identical cable except without the suppression material. These two were both tested on an HP Analyzer with an RF signal swept from 10 MHz to 100 MHz. The suppressed cable showed significant reduction in RF amplitude at the primary (half wave mode) ringing frequency (around 50 MHz).

ELECTROSTATIC AND ELECTROMAGNETIC NOISE REDUCTION

Our current cable designs use two levels of noise reduction. The first level uses an electrostatic shield. This shield is terminated to a ground point on the connector to reduce the amount of airborne noise impinging on the signal conductors.

The second level of noise reduction uses the electromagnetic RF suppression provided by the suppression coils around the cable. Each individual coil acts as a transformer core with a completely shorted secondary. The termination of the RF energy is in the short circuit itself. This does not require the coils to be separately terminated to ground to efficiently absorb the electromagnetic energy.

AUDIO, PHONO, AND DIGITAL CABLE DESIGNS

Our cables were originally designed for audio signals. As we realized that the benefits of the design were more widely applicable we now make them for audio, phono, and digital.

OTHER SONIC ISSUES

There are numerous other design issues in addition to RF suppression that we address in our cables. Aside from the obvious effects of wire size and type, insulation, and shielding on the cable, there are some more subtle but important issues that create audible artifacts.

The effects of these items become more important as the inherent noise level of the cable is lowered. Some levels of distortion that are masked in regular cables will stand out in our cables because they are not covered up by RF noise and distortion. For these cables we had to address all the sources of noise and distortion that were above the level of the RF generated noise.

USE OF SUPPRESSION COILS

The sonic signature of our cables is a result of the wire selection, the suppression material, the length of the suppression coil, and the exact placement of the suppression coil on the wire.

Increasing the total amount of suppression on the cable will determine how well low level information is revealed. Also as the length of the suppression material is increased it will suppress higher harmonics of the standing wave modes. A short coil near the middle of the wire will suppress primarily the fundamental mode. As the total coil length is increased it will start to suppress the second mode, then the third, and so on. Each one of these has its own sonic signature as follows:

1200 The second mode cable will have a musical midrange balance.
1400 The fourth mode cable will have a smooth midbass through treble range (the vocal range) and good top and bottom extension.
2020 The 2020 gives a very neutral presentation from top to bottom with the best extension.

The cables that have more suppression will have a lower noise floor. This significantly affects the resulting overall presentation.