IMPEDANCE MATCHING IN AUDIO

Myth or reality ?

Hervé Delétraz

1. Introduction

The objective of this article is to try to show how and if high-end cables are really better than those one can pick up from the shelf.

As an audiophile myself, I use audiophile cables in my system, and I have no doubt about the quality they bring to my hi-fi gear. As an electronic designer, however, I was always intrigued by the fact that the sound between a good cable and a bad one cannot be measured, or even "scientifically" explained.

I consequently decided to carry out some very simple measurements on a given cable, in order to better understand how the electrical signal travels into it. As we will see later, I wasn't able – yet – to *directly* correlate measurements and the sound quality, but I found that when properly used, cables tend to sound the same, whatever the kind one decided to use.

Matching impedance is the key subject of this article. As it unfortunately happens, we all link our low impedance sources to our high impedance active amplification devices. There is no real choice here, since this is the way manufacturers build their machines: low output impedance for sources like CD, tuners and so on, high input impedances for preamps and amps.

Even in the ads, low capacitance and/or inductive cables are often cited as being sonically better than cheap ones. Special dielectrics, wires' shape, twisted pairs or braided thin wires, Litz configuration and so on, all of them are described as to be better than the other ones. Are they really?

In this article I will try to keep the explanations as simple as I can, so I apologize in advance for the skilled electronic guys who will find my article a bit simplistic. This magazine being devoted to the big audiophile community worldwide, I guess that some other people will find it a bit hard to understand, but I will be glad to personally answer to their questions, if any.

Just one more thing. As I come from outside the US, I'm used to work with the metric system, also called MKSA (Meter, Kilo, Second, Ampere) notation.

So the symbol used for V(olt) is U, for A(mpere) is I, for W(att) is P, and so on.

Then, U is defined as a potential difference in volts, I is defined as the current Intensity in Amperes, and Power is defined as the electrical power in Watts.

I hope that most of you will enjoy reading the following.

2. Transmission lines

2.1. Definitions

2.1.1 Impedance

Most of us already heard about impedance, but only few really know what does it mean. The **impedance** Z is for the AC (Alternative Current) signals what the **resistance** R is for DC (Direct Current).

So speaking, if $R = U_{DC}/I_{DC}$, $Z = U_{AC}/I_{AC}$. Both R and Z are values in ohms [Ω].

The main difference between R and Z is that Z can vary versus frequency, as you certainly noted when looking, for example, at a speaker impedance curve.

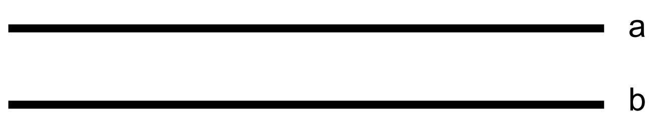
2.1.2 Transmission line

An *electrical* transmission line can be defined as being a device allowing an electric signal to travel from a point A to a point B.

In the hi-fi world, it simply means that a transmission line is in fact 2 – or more – wires, which will let pass the audio signal from a source to a receptor.

2.2. Electrical data

Let's take the simplest electrical line, say two copper wires a and b, which is characterized by :



L = Total line length in meters, where $L = L_a + L_b$	[m]
S = Section (area) of the copper wires used	[m^2]
R = Total line resistance, where R equals $R_a + R_b$	[Ω]

In this first approach, the parasitic capacitance and inductance are voluntarily omitted.

It is commonly admitted, in order to minimize the perturbation effects of the line, to match the source and the receptor as indicated in the fig. 1 :

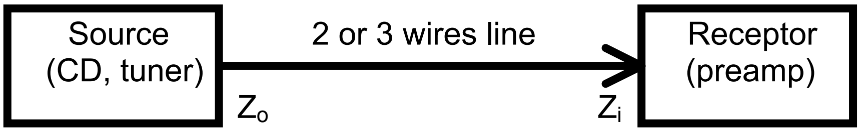


Fig. 1

With : $Z_i \;/\; Z_o \geq 10$ (1)

Most hi-fi gear is based upon this impedance scheme :

Low output impedance, high input impedance.

The admitted minimal ratio for proper compatibility is 10 or higher, as stated above. In/Out impedances in tube machines are generally of bigger values than those in the transistor land, both for output and input.

Put in other words, a silicon CD output stage will easily drive a tubed preamp, but a tubed CD output could have some problem driving a professional, low input impedance amplifier, for example. Nothing new under the sun here.

This impedance ratio is worldwide used for its design simplicity, no brainstorming problem when hooking our CD from Digital-Heaven to our Straight-Wire-Gain amplifier.
This easy-to-use impedance ratio unfortunately doesn't take into account the link cables itself. Thus the reason we will soon see why this ratio is not as magical as it seems.

2.3. Perturbations due to the transmission line

When hooking two hi-fi devices together, we generally don't know much about the characteristics of the cable we use. We just know that the cable is the best on earth, that the insulation is made from very good dielectric, that the wires are made from pure copper or silver, and that we paid it a lot of buck per meter (sorry, even *foot* here in US), and that the sound is excellent.

No real indication is provided about the capacitance and or inductance per meter, expect for phono cables or few manufacturers.
After all, who really cares, if the resulting sound is good ?

At the other end, the audio pro people tend to buy the cheapest cables, given the technical belief that copper is copper, period. "Silver cables in audiophile systems? What a joke!" they say.

Whatever the cable is made of cheap copper or pure platinum, its parallel wires behave as a transmission line, in which the signal will travel step by step. In the line, the signal will then propagate from the input to the output. That kind of signal is called a **propagation wave**.

The fig. 2 shows the equivalent circuit of a real transmission line. In order to simplify the diagram, only one wire is drawn. The return wire is simply represented by the ground path. In a symmetrical line, the figure would be mirrored for the cold signal side, but the principle remains the same.

We then can easily see that a real transmission line is much more complex than the 2 wires model. In order to better understand that the signal is propagating through the line like a wave – *it's* in fact a wave – we also need to take into account the parasitic parameters of the line, say the specific capacitance and the specific inductance.

This relative complexity partially explains why most cable manufacturers don't tell too much about their products. In fact, *all* cables can be represented by the fig. 2 :

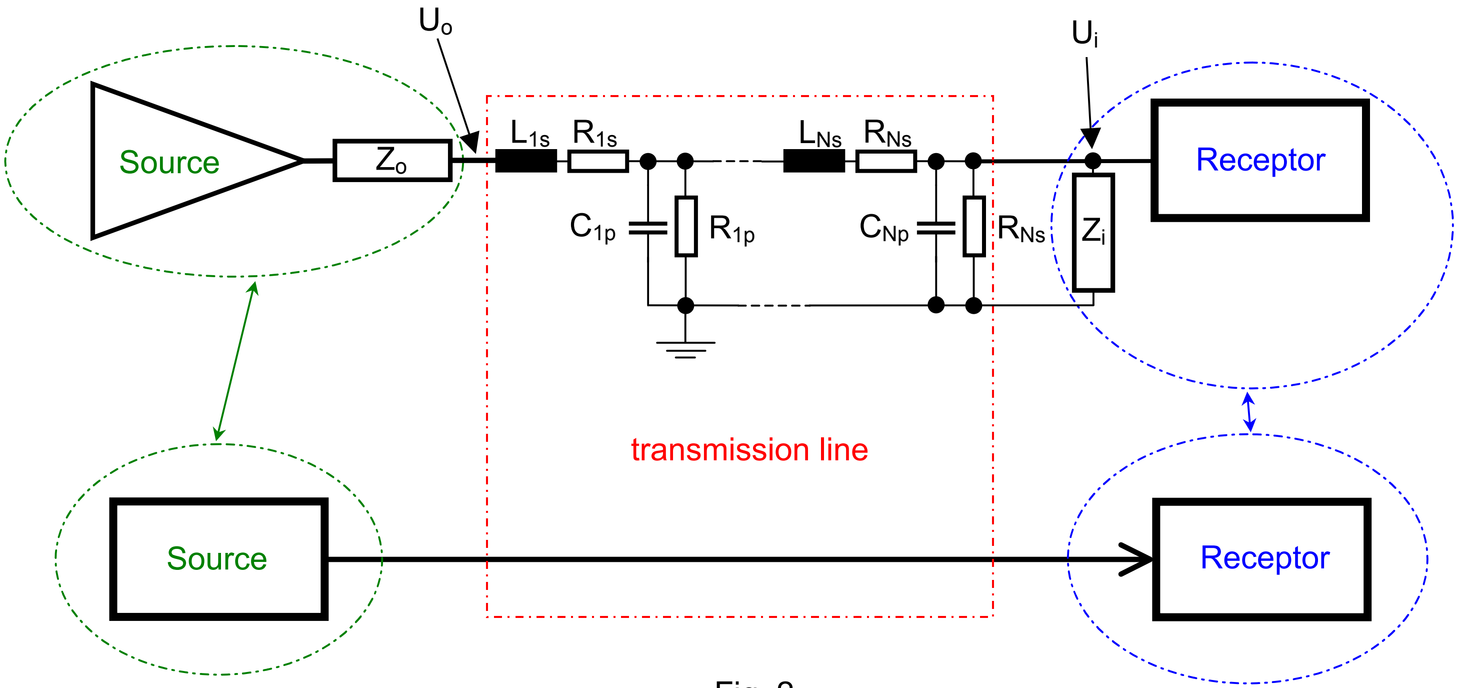


Fig. 2

First, let us consider that the cable is purely resistive. So the parasitic capacitance and inductance can be omitted, and it becomes easy to figure the signal level at the input of the receptor :

$$U_i = U_o \frac{Z_i}{R_c + Z_o + Z_i} \quad [\,V\,] \qquad (2)$$

With :

U_o = Output source voltage without load.
U_i = Input receptor voltage, when the line is connected.
R_c = Total serial resistance of the cable, negligible for $L \leq 20$ m.

A quick computation shows that if $Z_i / Z_o = 10$, the attenuation factor is about 0.83 [dB], providing that the cable resistance itself is far lower than those of the source and receptor involved.

In this particular case, if we consider the 2 wires model, the attenuation is constant throughout the entire audio frequency range, and does not affect the frequency response.

Now take a look at the real, physical parameters of the transmission line, or, simply put, at its **intrinsic impedance**.

Important notice :

*Contrary to the common belief, the frequency response **does not** depend upon the parasitic capacitance and/or parasitic inductance !*

It's well known by the audiophile community that high capacitance and/or high inductance of the cable **itself** can severely affect the signal response. Wrong !

In fact, one must consider a cable exactly like the transmission line described in the fig. 2, where each portion of length is made of a partial serial inductance L_{xs}, a partial serial resistance R_{xs}, a partial parallel capacitance C_{xp} and finally a partial parallel resistance R_{xp}, where the x term varies from 1 to N for N parts composing the entire line.

In order to avoid the mathematical development not needed here, one can imagine that each portion of the line stores the energy before releasing it in the next portion. It's exactly like a human chain extinguishing a fire by passing buckets of water from hand to hand.

If everybody takes care, no drop of water will be lost in the chain. In fig.2 this ideal situation will be obtained by omitting resistors R_{xs} and R_{xp}.

Practically, however, some losses due to imperfect materials lead to additional attenuation. But the **intrinsic** bandwidth of *any* cable is as high as several MHz (Mega Hertz), thousand times the best golden-eared audiophile capabilities.

So, then why explaining all the above if all cables can handle such high frequencies, and why care about the matching impedance, provided that $Z_i / Z_o \geq 10$?

By using the word **intrinsic** bandwidth, we touch the key point here. The cable behaves like a transmission line, thus has practically unlimited bandwidth, *only* when correctly matched in impedance. Before going further, a short intrusion in another well-known world could help.

3. Small trip in the digital world

3.1 Digital links

The confirmed audiophile perfectly knows that only true 75 ohms S/PDIF cables can offer good data – and good sound – transmission between a CD transport and its associated D/A converter. This 75 ohms figure is called the **intrinsic impedance** of the cable.

In the same manner, the networks used for linking computers together, also need the use of specific cables with determined intrinsic impedance.

In doing so, the source, the line *and* the receptor work under the very same impedance. Without taking care about that, parasitic echoes will appear and will smear the signal, introducing data errors.

Matching impedance is the only mean to avoid echoes and data loss. We will see later how and why.

3.2 The sound of digital cables

Every people, audiophile or not, who really try using different S/PDIF cables, can hear a *sound* difference. How can it be possible ? After all, ones and zeros are bits, aren't they ?

The main reason why digital cables sound different is because they aren't always perfectly matched. Cables rated at 75 $\pm$ 2 Ω, which are already tricky to manufacture, can introduce data errors. These errors can be taken as "constant jitter error", because the mismatching line introduces some echoes. Echoes smear the data stream, and lead to A/D misinterpretation during the conversion. A one can be taken for a zero, and vice-versa, and this kind of error activates the error correction system. When errors are too frequent, the system becomes less transparent.

3.3 Digital matching impedance

One good question is "why matching digital lines but not the analog ones?"
In the digital world, the frequencies involved are just in the MHz range, so even a very small echo leads to data loss.

In analog audio, the frequency range is about 500 to 1000 times lower, so the echoes problem are very low. Can the ear detect such small anomalies ?

4. Intrinsic cable impedance

4.1 Calculation according to manufacturer specifications

The intrinsic impedance mostly depends on the physical dimensions of the cable. This impedance is defined by the linear capacitance *and* the linear inductance, given in Farads per meter [F/m], and in Henrys per meter [H/m], respectively.

Once again, let us avoid the mathematical demonstration, and let us go directly to the formula giving the intrinsic impedance of a cable :

$$Z_c = \sqrt{\frac{L_l}{C_l}} \quad [\,\Omega\,] \qquad (3)$$

Where :

Z_c	=	Intrinsic impedance of the cable	[Ω]
L_l	=	Linear inductance of the cable	[H/m]
C_l	=	Linear capacitance of the cable	[F/m]

Unfortunately, It's not easy to obtain the linear parasitic values of the cable. Very few audio manufacturers give that kind of figures, simply because they are much less speaking than words like "pure", "fast", "transparent" and so on.

High frequency cables, like those used for TV or FM antennas, clearly display their intrinsic impedance. Manufacturers even give the linear capacitance, as sometimes their **propagation time** in nanosecond per meter [ns/m].

The linear figures directly act on the propagation time. The more capacitive and/or inductive a cable is, the more the propagation time is. This propagation time can be seen as a pure **delay**, so one can now better understand that the bandwidth does not depend on them, as one could have believed at first glance.

For most cables, the propagation time is around 5 [ns/m], corresponding to a **propagation speed** of $2 \cdot 10^8$ [m/s], say two thirds of the speed of light.

The propagation speed is given by the following formula :

$$V = \sqrt{\frac{1}{L_l C_l}} \quad [\text{ m/s }] \qquad (4)$$

Where :

V	= Speed of the propagation wave	[m/s]
L_l	= Linear inductance of the cable	[H/m]
C_l	= Linear capacitance of the cable	[F/m]

4.2. Calculation according to physical dimensions

As seen above, since data are often missing, one can use a different way to figure the intrinsic impedance of a cable, simply by measuring its physical geometrical dimensions.

This method requires some care if one wants to obtain accurate results, but is very useful when one needs to know the impedance of the cable one might use. The advantage is that the intrinsic impedance does not depend on the length of the cable, and consequently only a few measurements will be needed.

A) Coaxial cable :

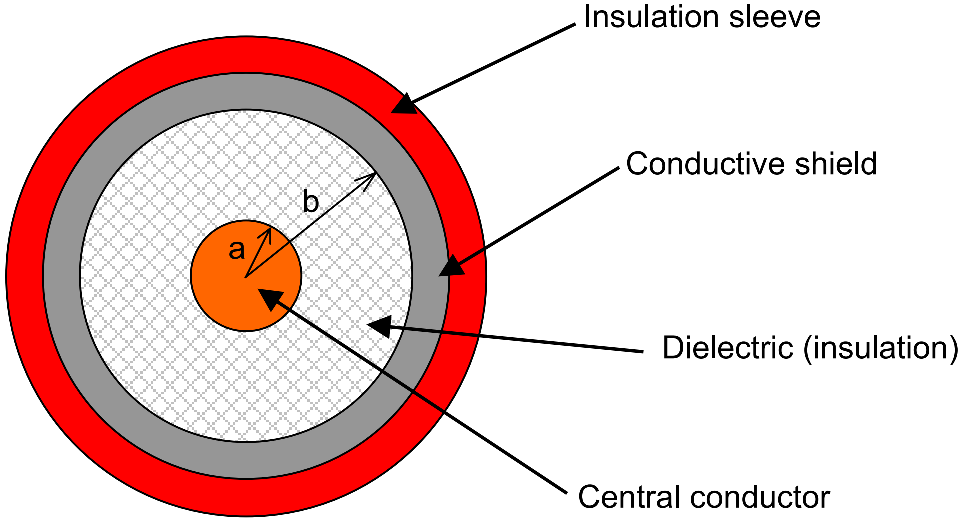


Fig. 3

$$Z_c = \frac{1}{2\Pi} \sqrt{\frac{\mu_o \cdot \mu_r}{\varepsilon_o \cdot \varepsilon_r}} \; \ell n \left(\frac{b}{a} \right) \quad [\Omega] \qquad (5)$$

With :

Z_c	=	Intrinsic impedance of cable	$[\Omega]$
μ_o	=	Inductance constant = $1.256 \cdot 10^{-6}$	$[(A \cdot s)/(V \cdot m)]$
μ_r	=	Relative permittivity, here $\mu_r = 1$	
ε_o	=	Influence constant = $8.859 \cdot 10^{-12}$	$[(V \cdot s)/(A \cdot m)]$
ε_r	=	Relative dielectric factor, here $\varepsilon_r = 2$ (PVC, plastic, Teflon)	
a	=	Central conductor radius	[m]
b	=	**Internal** shield radius	[m]

It is possible to observe that the impedance is directly dependent of the b/a ratio. A small diameter cable could have the same impedance than a thicker one, provided that the central conductor is proportionally thinner, thus keeping the same b/a ratio.

If only small power is involved, a very thin cable could be used, without performance degradation.

B) Bifilar cable :

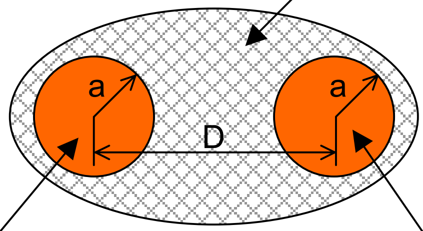


Fig. 4

$$Z_c = \frac{1}{\Pi} \sqrt{\frac{\mu_o \cdot \mu_r}{\varepsilon_o \cdot \varepsilon_r}} \; \ell n \left(\frac{D}{a} \right) \quad [\,\Omega\,] \qquad (6)$$

With :

Z_c	=	Intrinsic impedance of the cable	[Ω]
μ_o	=	Inductance constant = $1.256 \cdot 10^{-6}$	[(A·s)/(V·m)]
μ_r	=	Relative permittivity, here $\mu_r = 1$	
ε_o	=	Influence constant = $8.859 \cdot 10^{-12}$	[(V·s)/(A·m)]
ε_r	=	Relative dielectric factor, here $\varepsilon_r = 2$ (PVC, plastic, Teflon)	
a	=	Conductor radius	[m]
D	=	Distance between the wires	[m]

Once again, it is possible to see that the impedance depends on the physical distance between the wires.

Intrinsic impedance of few cables :

Coaxial cable RJ58	50	[Ω]
Coaxial cable RJ59 (S/PDIF linking)	75	[Ω]
DNM speaker cable	288	[Ω]
Typical speaker Monster cable	117	[Ω]
Ocos (coaxial) speaker cable	60	[Ω]
Typical Klotz microphone cable	150	[Ω]

Important notice :

The theoretical lower limit for a bifilar cable is approx. 60 ohms, since that is the value reached when the 2 wires are touching together.

A coaxial cable, however, can have impedance as low as 0 (zero) ohm, provided its dielectric insulation is made of infinitely thin material. This limit is of course theoretical too.

5. True impedance matching of an audio line

5.1 Concept

We are here reaching the heart of this article. As described earlier in chapter 1, the term "true impedance matching" is in fact referring to the **power** impedance matching.

Then in chapter 2 we saw that the ratio between source and receptor is generally $Z_i / Z_o \geq 10$.

When applying the power matching concept, the following principle is used :

$$Z_i = Z_o = Z_{cable} \quad (7)$$

Note :

In using such a ratio, the signal attenuation will be 6 dB, and not the 0.83 dB figured at point (2.3). This – small – caveat is the price to pay with this kind of linking. The solution is to slightly turn up the volume control.

5.2 Propagation wave reflections

When the impedance is mismatched, a part of the outgoing signal from the source is reflected by the receptor.

In order to better show this phenomenon, we conducted all the following measurements using a 75 ohms coaxial cable, 100 meters long. This cable has a propagation time of 5 ns/m, say 500 nanoseconds for the signal to travel from the source to the receptor.

The reflection ratio of the generated propagation wave is given as follows :

$$\delta = \frac{Z_L - Z_c}{Z_L + Z_c} \qquad (8)$$

Where : δ = Reflection coefficient (ratio)
Z_L = Receptor load impedance [Ω]
Z_c = Intrinsic impedance of the cable [Ω]

It is worth to note that the source impedance is not taken in account, since a source mismatch will rather act on the signal attenuation than on the reflections themselves.

The equation (8) shows that even slight deviation already generates reflections, also called echoes. So it will be of primary importance to keep the nominal values as tight as possible, in order to maintain the deviation within 1 to 3 %.

Furthermore, a symmetrical deviation leads to asymmetrical reflection ratios. Thus, +3% in the receptor impedance corresponds to +1.4 % reflection, while -3% leads to -1.5 % of reflection.

The impedance of high-end digital S/PDIF cables is generally of 75 ± 2 ohms, representing a tolerance of 2.7 %, then a reflection factor of around 1.35 %.

In analog audio, the almost total mismatch gives very high reflection ratios, close to 1, or 100 % of reflection !
This is the worst case, but you and me are listening to such mismatched system every day with great pleasure anyway. So what ?

We will now see which – bad – effects a mismatched line induces.

5.3.1 Perfect matching

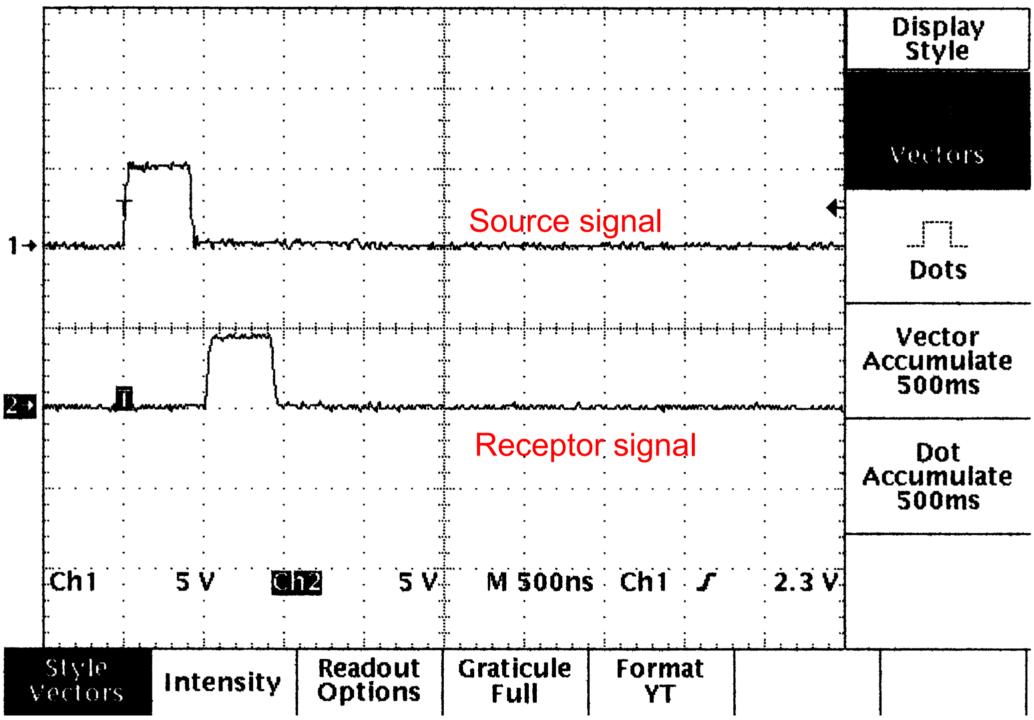


Fig. 5

In fig. 5, a 500ns pulse width is applied to the 75 ohms coaxial cable. Both source and receptor also have an impedance of 75 ohms.

The signal at the receptor is exactly the same as the one from the source, excepted the very slight attenuation due to the pure line resistance. No deformation here, even after 100 meters of travel.

The time delay of 500 nanoseconds between source and receptor perfectly corresponds to the propagation time of 5 ns/m times 100 meters.

The non-perfectly smooth traces are artifacts due to the oscilloscope input ADC, thus are not to be interpreted as noise or cable problem.

5.3.2 Source/cable matching only

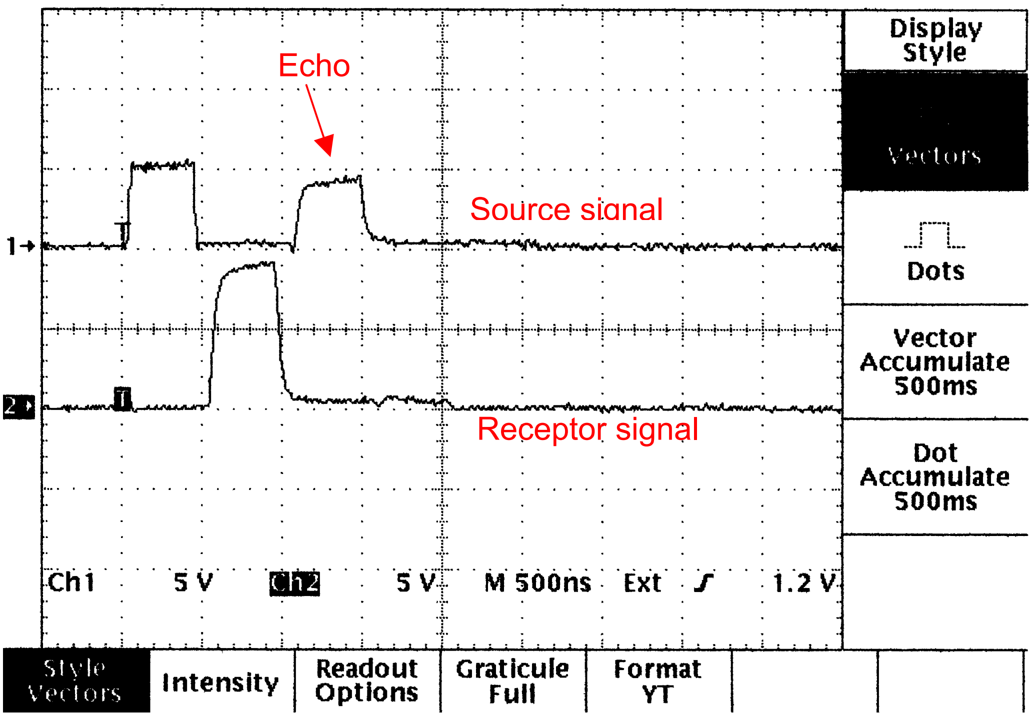


Fig. 6

Out = 75 Ω, In = 1 MΩ

Here we can clearly see that when the receptor has much higher impedance than required, the source signal is totally reflected by the receptor. The total delay of the echo to the source is 1 µs as expected, the signal having traveled forth and back, say 200 meters at 5 ns/m.

The signal arriving at the receptor is doubled, and its shape is altered, with slower rise time and tilted plateau.

When using digital cables, it is now more than evident that the choice of the cable *will* determine the sounding result.

Since fig. 5 and 6 show the 2 extreme cases, it is important to note than even smaller echoes are still echoes, and that their perturbation nature will undoubtedly affect the signal.

5.3.3 Total mismatch

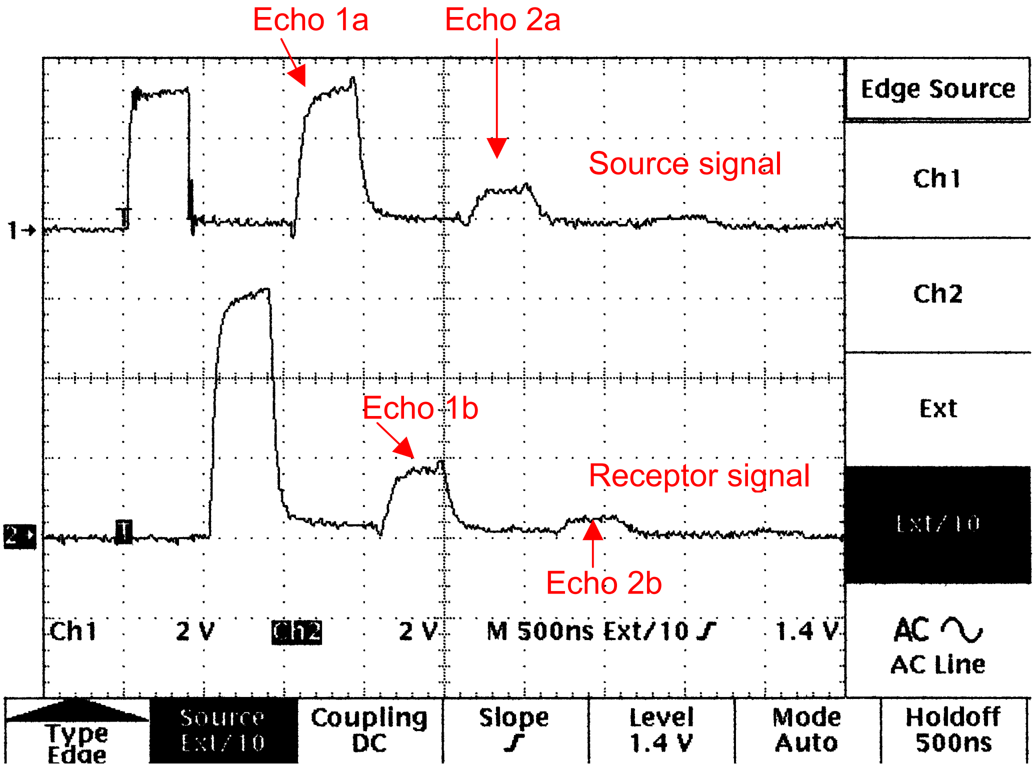


Fig. 7

Out = 150 Ω, In = 10 kΩ

Same sourced signal, same 75 ohms cable, but both source and receptor with unmatched impedance. This is in fact **always the case with audio gear**. The chosen impedance values are similar to those found in today's audio gear, with a 150 ohms source feeding a 10 kohms receptor.

Now, a lot of echoes become visible. Echo 1a is due to the 10 kΩ receptor impedance, which induces itself the echo 1b on the 150 Ω source impedance, which generates the echo 2a, and so on.

These echoes are clearly visible here, since the sourced signal is of very high frequency and small pulse width.

As we will see, these multiple echoes will also affect the signal at much lower frequencies, even if the result will be too often misinterpreted.

5.3.4 Perfectly matched audio signal

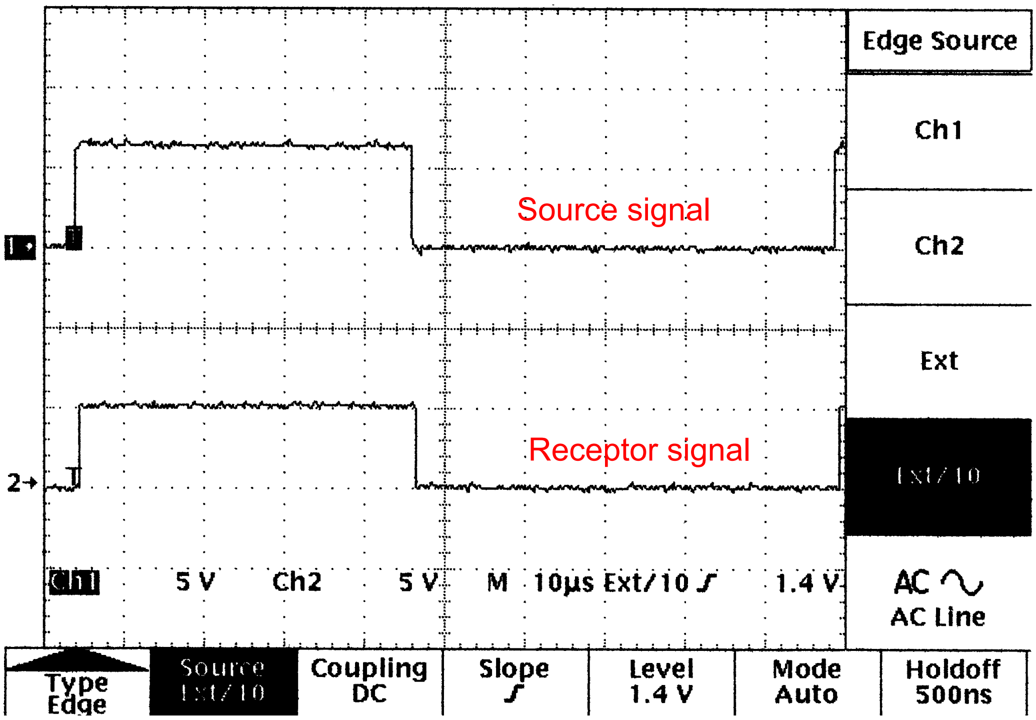


Fig. 8

10 kHz fully matched signal

Now, we are sending an **audio band** signal through the cable. The rectangular shape is surely not very musical, but the 10 kHz frequency is well in the audio range, and even aged people can hear it. All the chain is matched, say that the source, cable and receptor have the same impedance of 75 ohms.

The pulse width is much higher here, the signal period being 100 µs, say 20 times higher then the signal traveling time through the 100 meters cable.

Nothing wrong with fig. 8, the signal at the receptor is perfectly mirroring the source one.

5.3.4 Mismatched audio signal

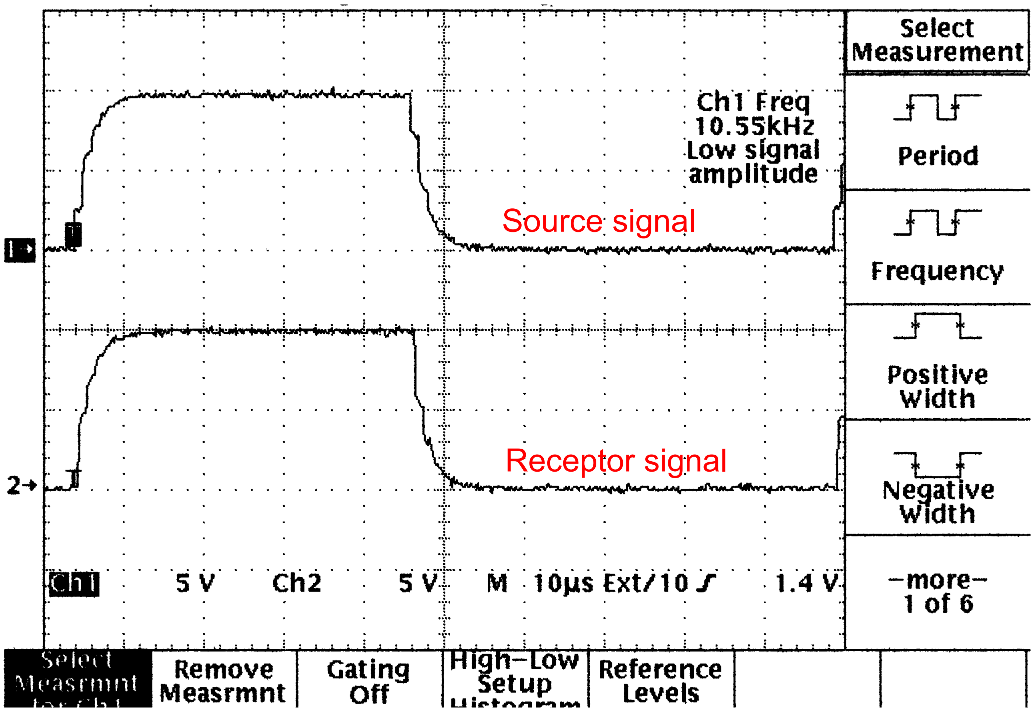


Fig. 9

10 kHz, Z_o = 250 Ω, Z_i = 10 kΩ

In this test, we also chose source and receptor impedances close to real audio gear. Lower source and/or higher receptor impedances would be even worse than the fig. 9 shows.
In the same manner, the choice of the coaxial cable is not important, any other cable used in mismatched condition would have the same behavior.

Surprise, surprise! High frequency attenuation, guys! As all the manufacturers and audiophiles have being saying for decades, it's the parasitic capacitance that acts as a low pass filter, and when using 100 meters of cable, you will be lucky if the result is not worse! So what is the point in writing an article that explains what everybody already knows?

Er, wait, wait, wait, my friends. What if the oscillogram's resolution wasn't high enough? What if the rounded shape of the signal was due to multiple echoes? Hard to believe, but, just have a look at the next and last oscillogram.

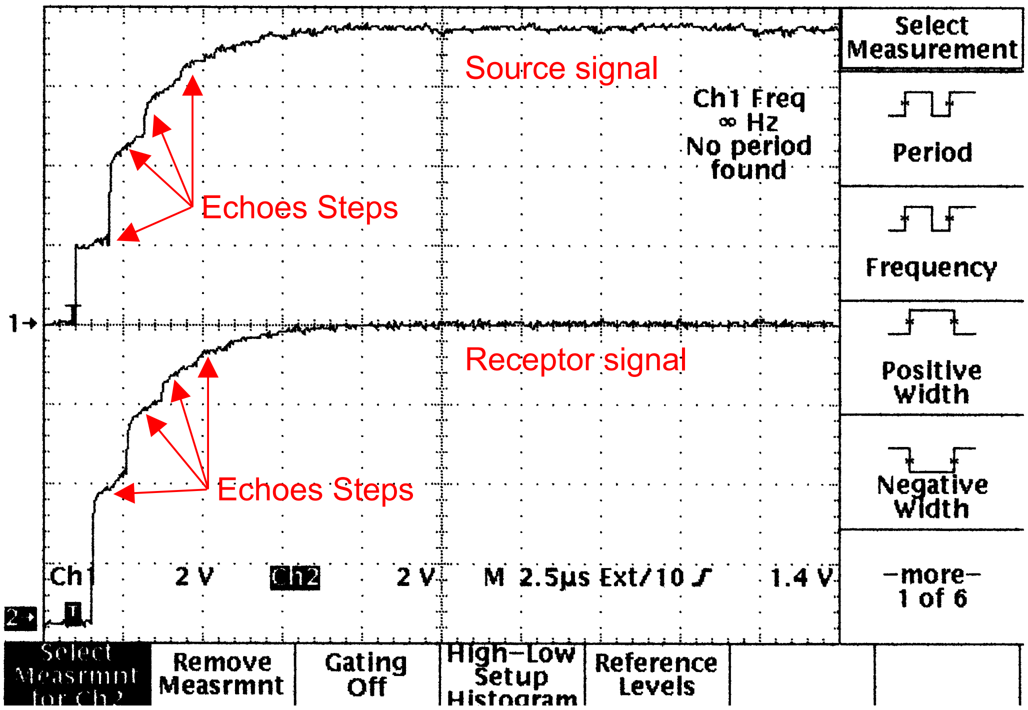


Fig. 10

Zoom of fig. 9

Do you see better now? I was very surprised myself, not being exactly prepared to see what fig. 10 shows. What we take as high frequencies attenuation is in fact "simply" the superimposition of multiple echoes, which are 500 ns wide, corresponding to the propagation time of the cable. The echoes being each time delayed by the propagation time, they add together, forming steps, exactly like the discrete echoes seen in the fig. 7.

This experience clearly shows that the signal will be surely modified when links are not perfectly matched. **This mismatching case represents 99.99 % of the audio gear in the audio world, including high end, thus YOUR system!**

Now, it is true that if the cable is only 1 meter long instead of 100, the problem will be divided by 100. Divided, yes, but eliminated, surely not. Can the ear make the difference between matched and mismatched audio line ?
I would be tempted to answer "surely yes", but I have not conducted serious comparative listening tests yet. This project was conducted only a few months ago (February 2001), and the results were so surprising and interesting that I couldn't resist so far to share them with you.

6. Practical considerations

6.1 Matching lines at home

We just saw that impedance matching *does* improve the measured performances, as it certainly contributes to better clarity in sound. The big question, however, is whether the average audiophile can easily adapt her/his audio system in order to directly benefit from matching impedance.

6.2 Systems' disparity

Given that every manufacturer imposes his own standards, it is not easy to match an existing system to the cables used, without seriously modifying the components, thus losing the warranty rights. Furthermore, most of audiophiles are not familiar with electronic tweaking.

A smart solution consists in adding an active box at the source, and a passive one at the receptor end. The problem is using a transparent enough system that won't deteriorate the sound more than the matching action would improve.

This matching option is different than that offered by some cable manufacturers, who put some black boxes along their flagship cables. These black boxes are all passive, and don't take into account the real impedance of the components, simply because they cannot "know" which components you will link together.

At the other end, few high-end manufacturers offer such matching linking as an alternative option. But it is unfortunately very rare.

6.3 Matching modules

These modules, which are not expensive by high-end standards, will soon be available, ready to work by adjusting the impedance to that of the cable used. Any skilled DIYer will be able to build them. The only critical component is the active module, but now some ICs are of high-end quality.

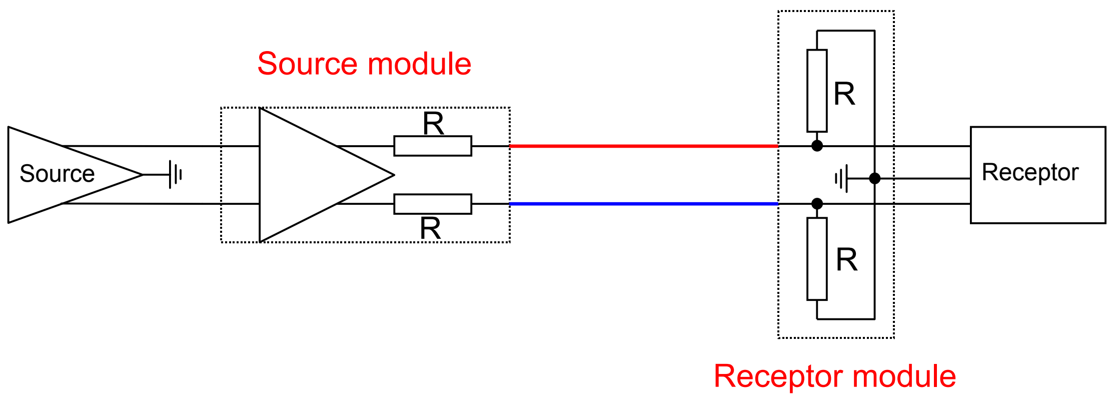


Fig. 12

Matching modules

Fig. 12 shows a symmetrical (balanced) matching module. For single-ended operation, half components will be used, i.e. only one matching resistor R at both ends.

The source module is basically an op amp, or a very high-speed discrete buffer, with the desired matched serial output impedance.
The receptor module is much simpler, using only 2 resistors – or even one for single-ended operation – of the same value than those used in the source module, connected to the signal ground path.

Both modules will be linked as close as possible to the components (10 centimeters or less). The great thing then is that the line could be as long as needed, without any virtual signal alteration.

The four resistors R (only 2 for single-ended operation) have all the same value as the cable. For example, if we choose to use Klotz microphone cable, which has 150 ohms of intrinsic impedance, all resistors will be also 150 Ω.

If a cable of unknown impedance is used, we will calculate it using the formula (5) or (6), from chapter 4.2.

7. Subjective thoughts

7.1 The sound of cables

It is well known that the audiophile has a different view than the mass consumer, or even than most of pro audio community, regarding the sound of the cables. For the latter, wires are wires and no matter what kind of cable they have to use. For the audiophile, cables are considered as a component per se.

Who is right? Maybe both. I'm not saying that *any* cable can be used for interconnecting hi-fi components. I personally use silver cables in my system, and find that they sound pretty good. However, as for most of the sound planet, my links are not matched. Not yet.

When using mismatched links, it becomes obvious that every cable has its own sound signature. I believe that if perfect matching is performed, the cables tend to be of lesser influence in the sound perception.

I strongly recommend to all curious tweakers to experiment with that. A first step approach can be tried at very low cost (another trick for the J-10 Fine Tunes editorial).

Provided you own a CD or another source with known impedance of around 50 ohms or less, you can try this little experience :

- Calculate your cable impedance with formula (5) or (6).
- Add a complementary serial resistor at the output of your CD.
- Terminate the cable at the preamp by a parallel resistor between the signal wire and ground.
- Listen for differences.

7.2 Practical example

Your CD has 30 ohms of output impedance. After calculation, you found that the intrinsic impedance of your interconnect is 250 ohms.
By inserting a serial 220 ohms resistor directly at the output of the CD, or even better, inside the RCA jack of the cable, you get a source impedance of 250 ohms.
At the other end of the cable, put a resistor of 250 ohms between the signal wire (central pin on a RCA jack) and the ground. You get the receptor impedance of 250 ohms.
Proceed twice for both channels.

This can be done WITHOUT opening your components.

This trick works only if your CD output accepts low load impedance without significant increase of THD. With solid-state output, this trick is non destructive, provided the output impedance of the CD is less than 100 ohms. In practical use, even shorts at CD output will not destroy anything, the output circuits being designed to handle such – bad – treatment. For tube output, just forget it. A matching module will be needed.

It is 100% sure that the sound will dramatically change. Will it change for the best or for the worst? Just try and let me know. If you lose dynamics or bass, it is only because your CD output cannot handle such load. So you'll need a matching module.

For all of you eager to tweak a bit, your questions are welcome if you are not sure about the trick.

8. Conclusion

It is still a bit early to claim that matching links will make 2 cents/meter cables sound as good as 1000$/m ones. But I'm convinced that 1000$/m cables *do* sound better when matched in impedance with the source and the receptor.

As we saw above, a mismatched link leads to smeared signal response. Whatever the amount of the smearing, the signal is distorted.
As you all know, every high-end product tries to offer the best sound possible, by modifying the least possible the audio signal. It is a very difficult task to realize with active components, and some degradation cannot be avoided. In the cable, where the signal is "only" passing through, it would be too bad not to

try to eliminate a known source of signal degradation. Echoes are a physical fact, even if they are very small. Canceling them by matching the transmission line is cheap and easy to do; the result can be both measured and heard. So why wait any longer?

9. Acknowledgements

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Hervé Delétraz