

Albedo: philosophy of design

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1 Introduction

As we present here the original motivation, the development and the actual realization of a loudspeaker system, we also take the occasion to reflect on many aspects of the recent history of design and listening enjoyment of High Fidelity sound.

Albedo's project philosophy has its roots in a thorough analysis of the two basic problems in the area of sound reproduction: on one side the technological development, and in this specific case, the state-of-the-art required for the design of a loudspeaker system, while on the other side there are the actual user requirements, as high quality sound performance, reliability and practicality of use. The ongoing debate on these two subjects is the main motivation for technical advances in our world, and we hope therefore that this article may be of interest both for the audio amateur as well as for the professional.

From the point of view of the audio amateur, the market offers an extremely wide range of fine products, in particular in the area of loudspeaker systems; however, if his aim is to get a speaker that is, at the same time, tonally well balanced, with a good soundstage and not too expensive, the most common choice is still for a bookshelf or, in any case, a small/medium-size system. Several loudspeaker manufacturers offer full-range systems which have all the sonic qualities of small ones but without their limitations in dynamics and response, but they are often very expensive and dimensionally cumbersome. The motivations that led to the creation of the Albedo loudspeakers, through a long work of research and development, originate from an intuition which was, at the start, barely more than a dream: could we make a system with the sound of a reference small bookshelf, with the size of such a mini speaker on its stand but with a good low frequencies response and that would not cost a fortune?

It is clear that a final answer to this question is elusive, since every project, even the ones with unlimited budget and therefore free of any cost limitations, is anyway still the result of a

compromise dictated by other technical or cultural restrictions. However, we were (and still are) certain that these challenges make sense since they focus on a well defined problem and, as it is well known to anybody who may work in research, the most important thing in all fields of research is to ask the right questions.

2 Technical issues

There are three main aspects of the Albedo project:

- 1) Linear phase system.
- 2) Acoustically equalized transmission line woofer loading.
- 3) Ultra stiff mechanical coupling.

From the very beginning these elements have been considered fundamental to achieve the design specifications. The linear phase response is an absolute requirement for the accurate reproduction of the transients and, as a consequence, for a correct perspective reproduction of the sound sources and the focusing of their physical positioning. To achieve these objectives, the geometrical position of the transducers must be combined with the topology of the crossover network (an “acoustic” first order) with the objective to exactly compensate for the intrinsic phase shifts of the ways. It is to be noted that, at the light of recently discovered psycho-acoustic mechanisms at the base of our perception system, which just now are beginning to be properly understood, the coherence of reproduction in the time domain also plays a major role for tonal balance, role that is at least as important as the linearity in the frequency response.

Our choice, of loading the woofer through the transmission line, is driven by our firm belief that this guarantees the best quantitative increment in the bass response without compromising quality in tonal balance and response to transients. On the other hand, in order to reach this desired performance we developed a very innovative system which represents a major step forward in the technology of transmission lines. To achieve a sensitivity aligned with the rest of the bandwidth, we chose an “empty” line only stuffed on its walls, in which the control of resonances is performed by a properly tuned resonator. At the same time, the decreasing conic section allows to tune the system to a frequency that is lower than it would be possible with a constant section line of the same length, allowing therefore an extension of low frequencies which is frankly unimaginable for a speaker of such small dimensions.

As far as the purely mechanical aspect, the speakers in a system must work in such a way to convert all electrical energy provided by the amplifier into sound energy. This objective can be achieved through an ideal speaker-cabinet coupling and of the overall system of cabinet-support-listening environment, and through the elimination of the spurious effects due to the resonance modes of the overall mechanical system.

In addition to these criterions, which we could call design philosophy, we adopted components that would best benefit from these solutions: the Accuton transducers are built with ceramic, ultra stiff, low mass, diaphragms which provide excellent transient response and very low distortion. They are made available in matched pairs to guarantee the lowest deviation from the specifications, therefore contributing to a firm, reliable soundstage. The woofer shows a very good linearity and extension in the mid/high band, allowing us to choose a crossover frequency high enough so that it does not disturb the frequency range of the maximum psycho-acoustic relevance. In the crossover network we used only air core coils and poly capacitors, mounted on a double layer high thickness copper board.

3 The phase response

There are several articles for an interested reader about the problems related to the measurement and interpretation of phase response. They are also the subject of expressly written notes [1, 2] available on this website. In any case, we can say that an electro-acoustic system with a linear phase response is able to reproduce complex impulse signals without phase distortions [3]. This means that every harmonic components in input appear in the output without any time delay among the components. Now, since the impulse can be seen as the superposition of an infinite number of sinusoidal components (“harmonics”), the correct reproduction of an impulse means that all harmonic components sent to the speaker are reproduced without any time delay introduced among them and in form virtually identical to the original. The very nature of impulse-type musical signal indicates therefore how limiting it can be to only consider the frequency response, and not the phase response, of a loudspeaker system.

In order to achieve this goal of a linear phase response, Albedo worked on two fronts at the same time: first, aligning physically the acoustic centers of the speakers, and second, equipping them with a filtering network to achieve such time coherence. It is now several years that first-order filters are widely used and especially employed in mini-speakers. However, we would like to remark that a first-order electric filter does not provide, by itself, a linear phase response. The first-order crossover between each pair of ways must be acoustic (and not electrical) and is therefore implemented by starting with the physical alignment of acoustic centers.

4 The transmission line

Transmission line loudspeaker systems based on the theory available up to a while ago were quite simple: the low-end driver (either the woofer or the mid-woofer) produces a front emission towards the environment and a rear emission in a duct (a “line”) uniformly stuffed with a fibrous material through which it emits into the environment. This second emission, from the “port” of the duct, gets combined in amplitude and phase with the frontal one, in a way that extends and regularizes the low-frequency range; at the same time the speaker works under the best conditions since the acoustic load presented by the stuffed duct is particularly favorable. The possibility to extend the range further into the bass frequencies is provided by the fact that once the duct is filled with phono-absorbing material it has an effective length which is greater than a line simply filled with air. So, the line resonance frequency becomes low enough to offer a substantial extension of the bass response. Furthermore, above a certain cutoff frequency, the absorbing material behaves as a filter and attenuates the emission of the line in the range in which there is destructive interference with the front emission. The physical motivation for this phenomenon has been described by Bradbury [4]: what should happen is that the fibrous material in the duct, at sufficiently low frequencies, becomes mechanically coupled with the acoustic waves, so that sound propagates in a medium which is thicker and softer than air, so its speed is lowered. Above the cutoff frequency, which depends on the density and composition of the material, the coupling is ineffective and remains only the absorbing effect of the filter (with a slope of 6 dB/oct).

On those premises, we started to make experiments with several materials and ducts of various shapes and dimensions. We also made a simulation program of the system, able to compute the total response, that of the port, the electric impedance, etc. We then started to compare the theoretical predictions with the laboratory measurements made with Clio on the physical system [7, 8]. The result was that between theory and measurements there were substantial differences.

We tried fibrous material of every kind, from natural and artificial wool to several form of cotton, from acrylic fibers to polyurethane; we arrived to test even steel wool. We systematically got experimental results which were falling short of our expectations, both as far as performance at low frequencies and in efficiency. The inescapable conclusion was that the Bradbury model could be wrong or, at best, incomplete. We made a first modification to the theory by taking into consideration the intrinsic elasticity and dissipations in the fibers; the comparison with measurements gave better results but was still not completely satisfactory. A much better match between theory and actual measurements, practically within experimental errors, was obtained when we identified the main problem with Bradburys approach: it is simply too optimistic in considering the air-fibers mechanical coupling. Every fibrous material, due to its intrinsic nature, makes available at full efficiency only a small fraction of its fibers (this is due to factors as orientation and intrinsic structure): by introducing in the model a parameter that takes into account these points and, in particular, by assuming that on average only one third of the fibers take part in the transport of the acoustic wave, theoretical simulations have then an optimum match with actual measurements. From the point of view of the theory we considered ourselves satisfied for having clarified a problem but, for the purpose of designing a high performance transmission line system these shortcomings were decisive. We abandoned therefore the idea of using completely stuffed lines.

On the other side, what is the reason that makes it not recommendable to use empty lines? Essentially two practical problems [5, 6]: in order to extend the response to low frequencies the line must be very long; furthermore, secondary emissions from the port determine strong fluctuations in the mid-bass response.

We started looking for possible solutions to these problems. First of all the one related the tuning frequency. In order to solve this problem it is sufficient to consider that the use of a uniform section duct is certainly not mandatory; it has the only advantage to make simple the computation of the relevant frequencies. it only presents the advantage to make all calculations related to the determination of the frequencies involved in the project much simpler. On the other hand, it is possible to correctly describe the propagation of acoustic waves also in other types of ducts: significant examples are the ducts with conic and exponential shape [9]. Considering a duct with decreasing section in one of these shape families, one discovers that, with the same physical length, the resonance frequency is lower with respect to the one in a cylindrical duct. The effective lengthening factor of the line depends on the ratio between input and output sections: therefore, it cannot be increased too much to not penalize the emission of the port. In the case of Albedo loudspeakers, with a ratio of one to three between output and input, the line is effectively 70 % longer: the system can be tuned to 50 hertz and the real length of the line is less than one meter.

Let us consider now the much more complex issue of the non-linearity in the response. First of all, a partial effect of filtering and damping of unwanted resonances can be achieved by covering the walls of the duct. By using a proper porous material it is possible to minimize the loss of system efficiency, or acoustic losses, reducing at the same time the counter-phase interference. We found that a good open-cell medium porosity polyurethane performs very well as a damper, especially if its lay-out is optimized following a suitable filtering model and comparing with laboratory measurements. However this is still not enough, because the troughs in the response curve due to the main counter-phase and its higher-order harmonics, are still unacceptably deep. The solution to this problem is one of the most original peculiarities of the Albedo project. The idea is to remove the unwanted frequency bands from the line response by means of a selective acoustic filtering provided by Helmholtz resonators tuned to the necessary frequencies and quality factor. The most attractive aspect of using series resonators is that, in addition to substantially reducing

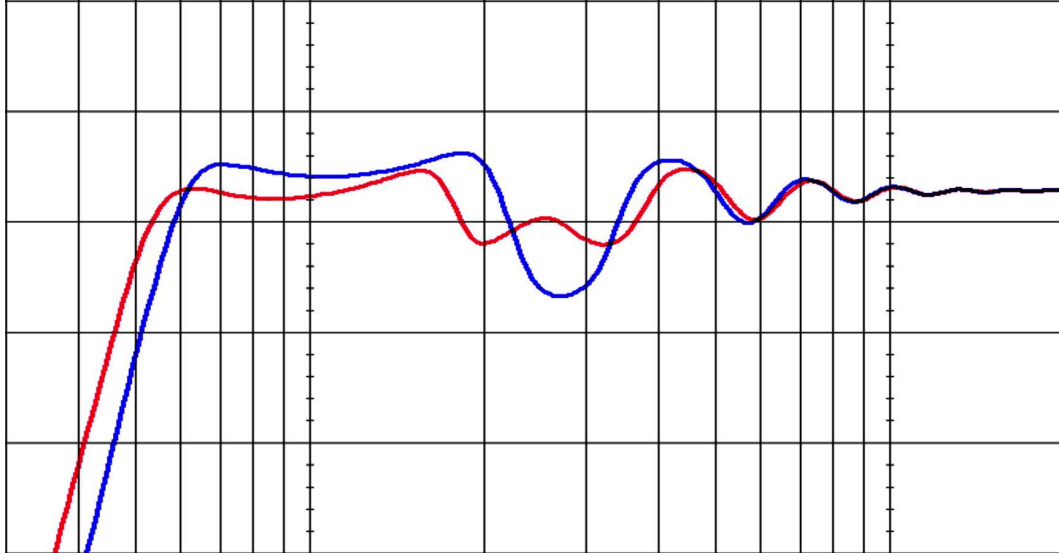


Figure 1: Blue curve: the line response. Red curve: the same line equalized with an Helmholtz resonator.

non-linearities, it contribute to regularize the acoustic load as seen by the driver since it has an action of redistribution of energy in the sidebands. In order to further clarify the concept, it may be useful to refer to the electrical equivalent: the resonator plays the same role of compensation of the acoustic impedance as the one made by an RCL circuit to compensate the electrical impedance of a driver connected to a filtering network. This balancing of the load has the main effect of facilitating the working of the woofer; in particular, the diaphragm excursion in the areas of higher solicitations turns out to be quite reduced if compared, for example, with a bass-reflex of analogous characteristics.

From Fig.1, which shows the calculated frequency response, we can appreciate the correction introduced by the Helmholtz resonator. Moreover, we remark that the residual oscillations in proximity of its operating frequency are more fictitious than real, because they are determined by the interactions between the port and the woofer in the near field measurements; in other words, in standard room listening positions, such fluctuations are substantially reduced at the actual physical distances by the far field combination.

5 Ultra-stiff mechanical coupling

The drivers of a loudspeaker systems should work in such a way to convert into sound energy all the electrical energy supplied by the amplifier. In fact, it must be strictly forbidden that other parts of the system catch and store part of this energy, giving up it after a while to the environment or back to the drivers themselves. Both these effects are highly harmful:

1. The energy wasted in vibration of the structure and of the prop/stand and in parasitic sound emission are simply noise added to the unperturbed emission;
2. The incoherent back transfer of energy to the drivers disturbs their correct working, further increasing noise and distortion.

The necessary condition to warrant the absence of those deleterious phenomena is that of

minimizing perturbation effects. This objective is reached through a perfect coupling of the drivers to the cabinet and an ideal matching of the cabinet-support-environment chain, suppressing the effects due to the resonant modes of the mechanical system.

In the new Albedo loudspeakers this is achieved by an ultra-stiff mechanical coupling of the cabinet to the support and then to “Earth” by means of:

- A damped steel binding bar.
- A massive basement with adjustable ultra-rigid spikes.
- A loaded sandwich tapered cabinet.
- Ceramic low-moving-mass drivers with ultra-stiff basket.

6 Room placement

As for the interactions of the speaker with the listening room, we recall the usual criterions, not so constraining, adopted for small/medium-size loudspeakers mounted on their own stands: by placing the units at least one meter from the back and lateral walls it is possible to obtain an ideal soundstage and optimize the total response.

One last remark is on the sensitivity which, once we consider an anechoic signal, is in the range of 86 dB and therefore does not preclude the use, at least in normal home environments, of even low power output tube amplifiers, also considering the favourable impedance load. The overall result is able to offer easiness at home with nice looking and handy practical usage.

7 Conclusions

Under many aspects Albedo is a pretty new speaker concept. In the paragraphs above we have just seen its technical innovative elements, which allowed an optimal answer to the basic requirements of the design philosophy. These elements eventually also lead to the shape and the external look of the speaker. In fact, its unusual appearance does not originate from the need to propose a new shape for its own sake, but rather is strictly related to the design criteria we described above. The conic segment shape for the cabinet, the slanted front panel, the dimensional proportions which result in very contained volumes, all these derive naturally from the initial technical choices made. Similarly, the materials used, as doped sandwich for the folded boards and steel for the base, derive from the need to be able to execute very precise work on odd shaped pieces, in order to ensure a perfect sealing and stiffness. The overall result offers therefore great ease and flexibility for incorporation of the speakers in any environment, both from an aesthetic and practical point of view.

With the new line of Albedo products we feel confident that we are proposing a new instrument for new and very rewarding experiences in sound reproduction

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