ESL + MFB = the best of 2 worlds?

Which means: The combination of an Electro Static Loudspeaker and dynamic loudspeakers-with-Motional-FeedBack Is The Best solution Of Two different approaches to reproduce high quality sound. This statement needs explanation.

'The two worlds'

What do I mean with '2 worlds' or 'two different approaches to reproduce high quality sound'? To be clear: We are talking about loudspeaker systems. In general there are two different systems: 'two different worlds', the world of electro static loudspeakers (ESL's) and electro dynamic speakers. Two worlds indeed: prejudiced folks adore ESL's or are fanatical about electro dynamic systems. However, let us try to be objective. Both systems have their pros and con's.

The ESL

Undoubtedly the sound from well constructed ESL's is superior to that of electro dynamic speakers if you have a large living room and the listener is on the right spot. ESL's placed in the middle of the room, under the right angle produce transparency, brightness, exactness and depth in the sound image which can't hardly be realised with other speaker systems. The only serious shortcomings are the maximum permitted input power and the low sensitivity of wide range ESL's so that the maximum sound pressure level (SPL) leaves a lot to be desired.
Buy yourself a 100 square meter room and two Quad ESL-989's, put them in the correct position in the room, sit down on the right place and you are ready... In a 50 square meter or less room however they will not satisfy. The 989's have the size of a single bed on end. Smaller ESL's will not reproduce frequencies below 60 Hz.

The Electro Dynamic Loudspeaker

During decades, much has been experienced with, and written about, a great variety of speaker systems. Even too much to lift the veiltail. Undoubtedly dynamic speakers could produce a >10 dB higher SPL than ESL's, particularly at lower frequencies and they could be much less critical for the listeners position in the room.
Also with electro dynamic speakers the measurements of the box for the woofer will be huge if frequencies below 50 Hz should be produced at a reasonable level with not too much distortion.

Motional feedback

Already five decades the problem of reproducing low frequencies with speakers in rather small boxes has been investigated. A low-distortion audio power amplifier with a low output resistance will not satisfy. The distortion of the loudspeaker itself around and below the resonance frequency will not be reduced. Correcting the roll off below the resonance frequency in the box (to get a flat frequency response) will make things worse. The only way to tackle this problem is to include the 'movement of the cone' of the woofer into the feedback.
J.A. Klaassen and S.H. de Koning published the article: "Bewegingstegenkoppeling bij luidsprekers". in the "Philips Technisch Tijdschrift, Jaargang 29" in the late sixties. They treat the theoretical background of motional feedback and have built some prototypes.
Highlights in this article are: the difference between transposition-, velocity- and acceleration-feedback, and their mathematical relation. The first two need a (mechanical) stable not moving reference point to fix the detector onto. Such a point is hard to be found on loudspeakers. Acceleration feedback does need no reference point. The choice for this type of feedback is obvious, the more because *the resonance frequency of the system will be lowered!*
Doing so, the Q of the system however will be enlarged, degrading the transience response. The maths proof that the Q is reduced with *velocity feedback*. This means that the resonance frequency and the Q of the system could be modified independently! A weighed combination of the two will be the solution.
By the way: velocity feedback is obtained by integrating the acceleration feedback signal. This could be obtained electronically.

NB.: Motional feedback will only be stable with frequencies below about 600 Hz, depending on the size of the woofer in question.

Panel resonances

Enclosing a speaker in a box, introduces undesired panel resonances which degrade the quality of the reproduction of low frequencies. The sound becomes woolly. The amount of sound from resonating panels may be just a few dB less than the wanted sound from the cone of the speaker at specific frequencies.
Martin van der Hoff (http://hsi-luidsprekers.nl/Kastmaterialenonderzoek.htm) investigated a great num-

ber of materials on this subject. With Martin's rather large panels, the most misery is produced at frequencies over 300 Hz. A 17 litre-box built of 22 mm MDF will be soundproof up till 40 dB at frequencies below 300 Hz, so a motional feedback speaker in such a box, only used below 300 Hz, is the nearly ideal woofer system!

The hybrid speaker system

Of course many people already have constructed hybrid systems. This means: a combination of an ESL for the middle- and high frequencies and a dynamic woofer for the low frequencies. Folks say that such a woofer-system also should be a dipole just like the ESL. However, I have never heard a strong bass from such dipole-woofers. Why should it be a dipole? Because of less distortion? Because of panel resonances? Both have been solved with MFB. Because the acoustic wave-form is equal over the whole frequency spectrum?.... Be aware that a frequency of 50 Hz already has a wave length of 7 meter, so that our living room depicts the wave-form! I choose for an MFB-system for frequencies below 300 Hz. With this statement the cross over frequency is fixed.

An ESL for 300 Hz to 20 kHz

With this limited bandwidth the ESL will be much smaller (about 90 cm^2) than a full range ESL (1000 cm^2 or more). Through this the capacitive load on the step up transformer becomes at least ten times less![1] Moreover the number of turns of the primary winding of the step up transformer could be reduced to about 1/4 compared with a full range transformer. For the lowest frequency to transform moves up from 20 Hz to 300 Hz! This means that the step up ratio could be much larger before the capacitive load at the primary winding is too heavy (**<** 4 Ω) at 20 kHz which results in a much larger sensitivity of the ESL and thus a higher SPL.

The diaphragm (http://www2.dupont.com/Kapton/en_US/assets/downloads/pdf/Gen_Specs.pdf)

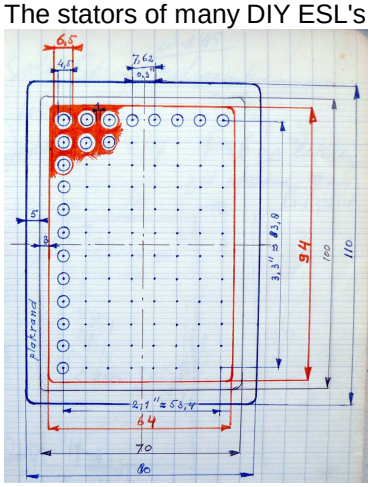
ESL-diaphragms are generally made of boPET foil: Mylar or Melinex[2]. Both cannot withstand high temperatures so that each disruptive discharge ruins the diaphragm. Moreover Mylar gives construction problems because it can't be glued.
The 7 µm thick polyimide film: Kapton 30HN (trade mark of DuPont) is a much better, but expensive, choice. It withstands even corona! Kapton is mechanically much stronger so that it could be heavily stretched over larger surfaces without instability of the diaphragm.

The step up transformer

An excellent electrical balance is preformed with the winding scheme of the rutgerS'Step Up Transformer. It guarantees the lowest distortion and a larger step up ratio with a low capacitive load at 20 kHz. With my set-up, step up ratios of 1 : 180 have been realised for the frequency range of 300 Hz to 20 kHz. Audio 4 (http://www.audio4.nl/trafo.htm) already follows my winding schema.

The stator

The stators of many DIY ESL's have been made of stretched isolated wires or even cords. These



speakers all have a typical sound with which they are to be identified. However, for the best sound, the stators should be rigid. Therefore I have constructed the stators of 10 x 15 cm units of drilled multi-layer epoxy printed circuit boards. It is to say, I used only the inner layer for the conductive stator so that it is completely isolated from its environment end so from the ~~diaphragm~~. This, together with the heavily stretched Kapton, allows high tensions between the diaphragm and the stator enlarging the sensitivity.
The rather small units have been fixed on a 10 mm thick Plexiglas frame.

The radiation pattern

One of the disadvantages of ESL's is their radiation pattern. The dimensions of ESL-units are always larger than the wave length of the highest frequencies so that a strong bundling will take place. Worse is the arising of side lobs: the listener will experience changing sound images moving his head. Unpleasant side lobs will arise if the radiating surface is wider than 7 cm.

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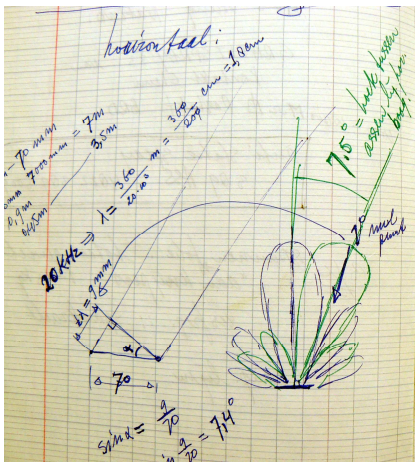
[1] the distance between the two stators will be larger with the full range ESL so that the capacitance of it will be less than the ratio of the two areas presumes.

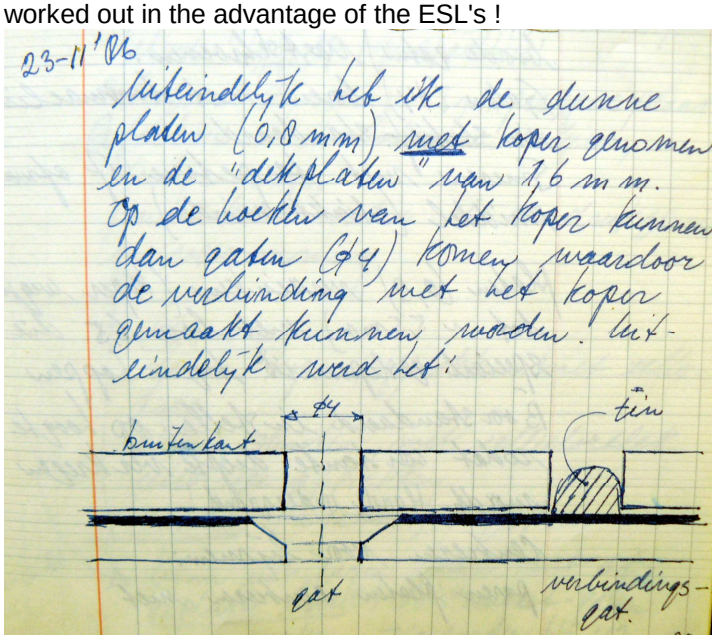
[2] depending on its trade mark. Both are 'boPET foils'. See http://en.wikipedia.org/wiki/PET_film_%28biaxially_oriented%29



The ideal radiation surface is a sphere or the saddle. Both are very difficult to realise. Quad imitated a sphere for the first time in their ESL-63 by dividing the stators in rings which are fed via a large number of coils. Others divided the stators only vertically, feeding the strokes via resistors, so that only the ~~vertical~~ listener's position stays critical.
In the 50's Bowers & Wilkins have sold a hybrid speaker system with an array of 10 x 15 cm ESL-units placed on a horizontal arch. In the 70's SoloSound copied the units and put them on a vertical arch in their Solo Static. Both solutions produced an acceptable radiation pattern, at least for one listener.

The prototype

During the last three decades I have built me a number of dynamic speaker systems with good results, but the Solo Statics of SoloSound sounded better *as long as they would function!* The reason I banished them from the living room was their unreliability.
The comparison of my dynamic systems with the ESL-63's of my good friend Henk ten Pierick always worked out in the advantage of the ESL's !



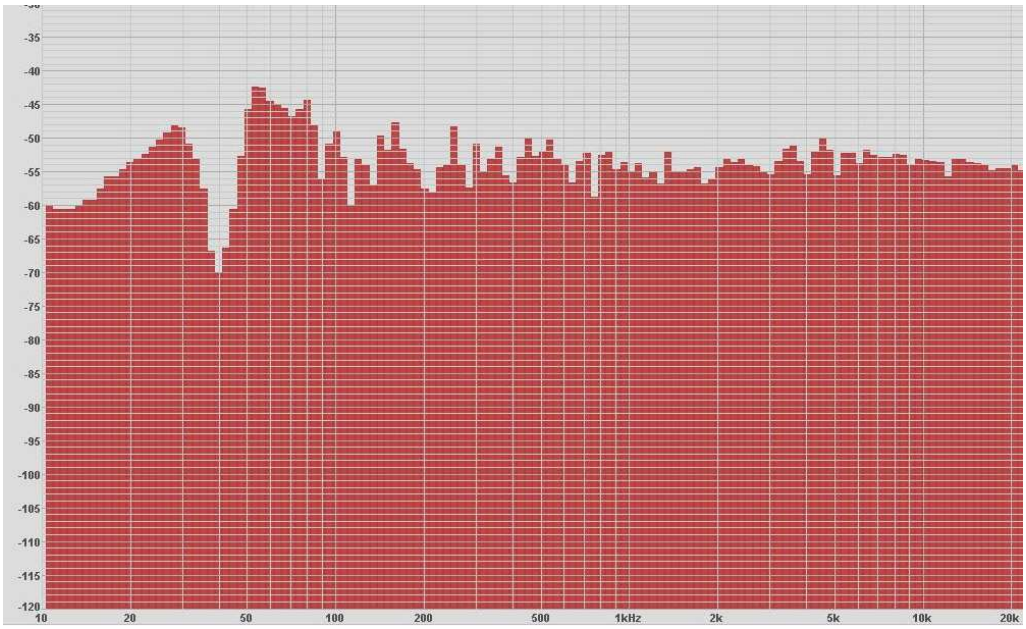
Already in the late 80's I prepared the ESL-units as I have described roughly above. In fact I copied the measurements of the Solo Static units but much better engineered and with Kapton 30HN diaphragms. About fifteen years later (when I retired from work) I took them from the shelf to build my present hybrid system. It touched me to find the units after so many years in the same condition and specifications as I left them! The units seemed to be very stable and have still the same specs after four years application.
I developed the rutgerS'Step Up Transformer, bought me two Philips motional feedback boxes: 22RH544 (see www.mfbfreaks.nl) and went to work.
The 8" MFB-speaker has been mounted in a two compartment 35 litre box, together with a same type of 8" Philips woofer **without** the MFB-pick-up element; the amplifier and power supply have been matched to engage the two 4 Ω speakers in parallel and to lower the cross over frequency to 300 Hz.
Six 10 x 15 cm ESL-units have been assembled to a Plexiglas frame in a 2 x 3-configuration: three over each other, two beside each other in a 176° angle.
Of course the system never could have been built without the computer-based audio measuring system: CLIO from Audiomatica.....

The results

I demonstrated my system during development to a number of HiFi-friends as Guido Tent and Henk ten Pierick. Henk advised me through all the time. I'm very grateful to him!
I demonstrated the system two times for the Dutch ESL-club (http://esl.hifi.nl). Both times folks were touched by the quality and the sound level. Do not forget that the demonstration rooms were about ten times my living room!
Sure, the quality is greatly influenced by the TentLabs modifications in my CD-player (Philips CD624), the DAC (a TentLabs pre-product) and the home brew amplifier which never could have its perfect behaviour without Douglas Self's publications.
I'm satisfied, the more there the size of each speaker is limited to a width of 27,5 cm, a depth of 35 cm at the foot and a height of 128 cm. Such boxes always can be placed in an optimal listening position in a not so large room.

Measurements

With MCE2000 electret microphones I made some measurements in my living room:



Of course room-resonances pop up below 100 Hz and a roll of 2 dB at 20 kHz because of the I/V-converter in my CD-player. But I'm satisfied….

To conclude

No any speaker system will perform depth in the sound image when it is placed close to the wall behind it. The best listening-position is: the listener and the two speakers form an isosceles triangle with legs of, say, 1,5 to 2 meter (depending on the size of the room) [Onno Scholte]. The distance of the speakers to the wall behind them should also be at least 2 meter.
During the last two years, we (Henk, Guido, Pieter Meijer and I) examined the influence of jitter in the digital parts of the CD-player. Manufacturers of even very expensive CD-players (and other digital equipment) do not know the significance of jitter on the system clock, especially in DAC's and ADC's. Whatever player you will have, first order for a TentLabs XO! There are more critical points in the system, but this is the most important one.
Elsewhere on this site you will find some photo's of the hybrid speaker system.

Eindhoven, januari 6, 2008
Herbert Rutgers.

Postface

What is the secret behind ESL's? Is it the lack of 'time smear' which for instance originates from cross over filters? (Hans van Maanen). It could be because I got the same experience with an array of small full range dynamic loudspeakers (VISATON FR 58) many years later (2015). The next item on this website treats this approach (in dutch).
Whatever the reason is, speakers that reproduce sound within the frequency range 300 Hz to 20 kHz at one time is to be preferred.