Testing the Ed Frias EFE Loudspeaker Kit

By Joe D'Appolito

I ran a series of impedance, frequency response, polar response, and distortion tests on the Ed Frias EFE loudspeaker kit supplied by Speaker City and built by the MacArthurs (March '06 *aX*, p. 27).

IMPEDANCE

It is my habit in testing these kits to arbitrarily pick one unit of a pair for all tests and then check the second unit simply to see how it matches against the first. **Figure 1** is a plot of system impedance magnitude (A) and phase (B). At low frequencies the plot displays the double peaked curve typical of vented systems. The impedance minimum between the peaks at 50Hz indicates the vented-box tuning frequency (F_b).

The impedance at this point is 8.4Ω. There is an absolute impedance minimum of 7.4Ω at 200Hz. A maximum phase angle of −40° occurs at 108Hz. The impedance magnitude at this frequency is 14.5Ω. I would rate this an 8Ω speaker.

The impedance minimum 8.4Ω at F_b is rather high compared to the driver voice-coil resistance of 6.1Ω. This is characteristic of a low box Q and an overdamped vented box response. I'll say more on this later.

FREQUENCY RESPONSE

Figure 2 shows the full-range frequency response of one of the pair of speakers.

FIGURE 1: EFE kit impedance magnitude (A) and phase (B).

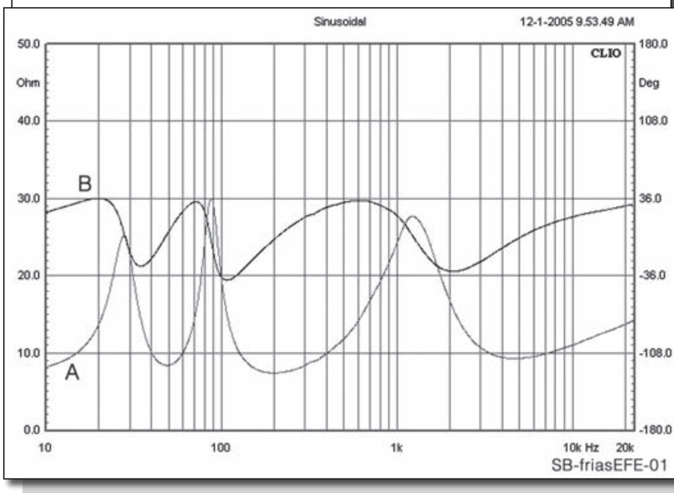


FIGURE 3: EFE kit step response.

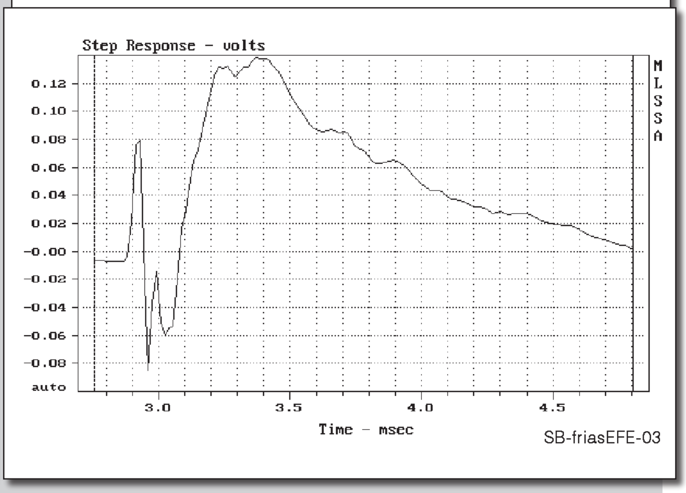


FIGURE 2: EFE kit full-range response.

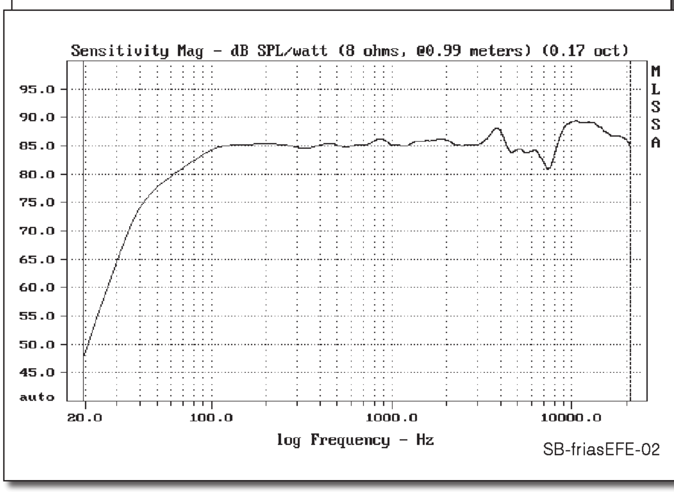
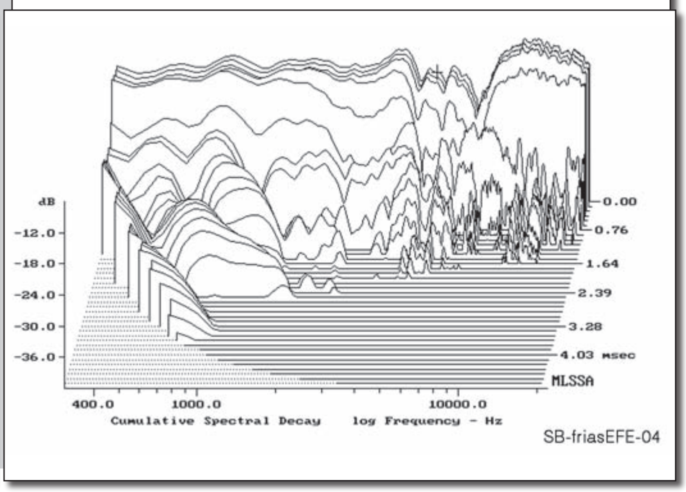


FIGURE 4: EFE kit cumulative spectral decay.



This response is obtained as a combination of the far-field quasi-anechoic response in the freestanding position and a set of appropriately combined near-field woofer and port measurements[1]. I placed the microphone along the tweeter axis at a distance of 0.99m to produce the far-field freestanding response, and spliced near-field and far-field responses together at 200Hz to produce the full-range response[1]. The response data is ⅙ octave smoothed. Sensitivity averages 86dB SPL/2.83V/1m in the two octaves between 500Hz and 2kHz.

Relative to this level, response is down 3dB at 80Hz. This is a rather high F3 point for this driver in a vented box. I'll comment on this in more detail at the end of my report.

Between 120Hz and 3kHz response is extremely flat, varying by only ±0.8dB. This is the active frequency range of the woofer. From 3kHz to 20kHz, however, tweeter response shows a peak-to-peak variation of 8.4dB! This is surprisingly poor. The Frias EFE is not configured for bi-wiring, so I could not determine responses for the individual drivers, but it is clear that the tweeter is operating above 3kHz.

WOOFER/TWEETER TIMING

The step response is plotted in **Fig. 3**, which shows two separate arrivals of acoustic energy. The initial sharper positive spike is the tweeter arrival, followed by the woofer arrival, also positive. The woofer peak is delayed relative to the tweeter peak by approximately 300μs. This is a rough estimate of the tweeter/woofer delay.

Although both drivers are connected with positive polarity, the system is not time-coherent. The double negative peaks approximately 60μs apart are characteristic of a reflection in the tweeter back volume, which may explain the poor tweeter response.

CUMULATIVE SPECTRAL DECAY

The cumulative spectral decay (CSD) response is presented in **Fig. 4**, a waterfall plot that shows the frequency content of the system response following a sharp impulsive input at time zero. On the CSD plot, frequency increases from left to right and time moves forward from the rear. Each slice represents a 0.12ms increment of time. The total vertical scale covers a 30dB dynamic range.

Ideally, the response should decay to zero instantaneously. Real speakers, however, involve inertia and stored energy that take a finite amount of time to die away. A prominent ridge parallel to the time axis indicates the presence of a strong system resonance.

The first time slice in **Fig. 4** (0.00ms) represents the system frequency response. There are no distinct ridges in the CSD over its valid time interval, although there is a lot of "hash" in the tweeter's decay response.

HORIZONTAL POLAR RESPONSE

Horizontal polar response is examined in **Figs. 5**, **6**, and **7**. **Figure 5** is a waterfall plot of horizontal polar response in 10° increments from 60° right (+60°) to 60° left (–60°) when facing the speaker. All off-axis plots are referenced to the on-axis response, which appears as a straight line at 0.00°. For this reason, the plotted curves show the *change* in response as you move off-axis. For good stereo imaging the off-axis curves should be smooth, evenly spaced replicas of the on-axis response with the possible exception of some tweeter roll-off at higher frequencies and larger off-axis angles.

Below 3kHz and within ±30° off-axis, the curves are indeed fairly smooth replicas of the on-axis response. Above 3kHz, however, there appears to be substantial off-axis flare in the tweeter response. This

FIGURE 5: EFE kit horizontal polar response.

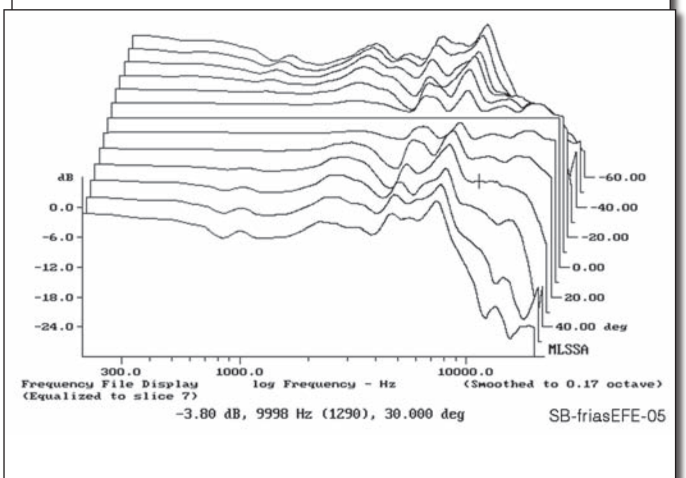


FIGURE 6: Comparing on-axis (A) and 30° off-axis (B) responses.

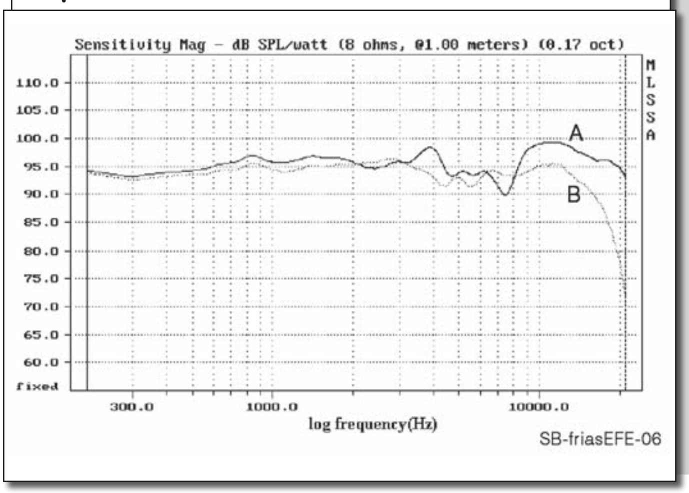
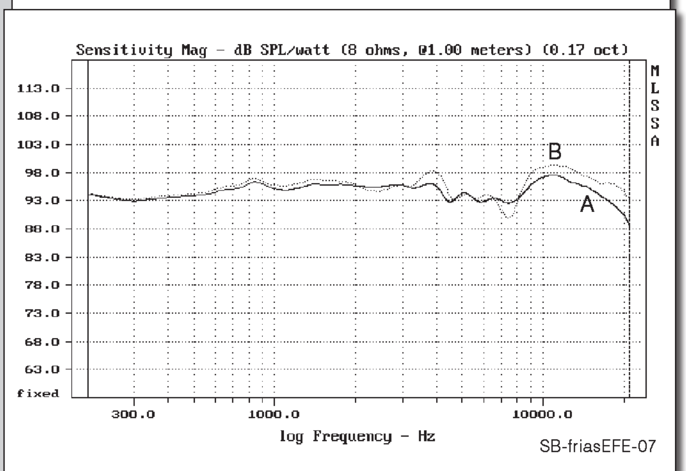


FIGURE 7: Average horizontal response (A), on-axis (B).



is an artifact of the waterfall plot. When subtracted from the on-axis response, the flaring tweeter response appears.

As **Fig. 6** shows, the tweeter is actually smoother off-axis. In this plot the on-axis response (A) is compared with the response 30° off-axis (B). Even though response falls rapidly beyond 12kHz, this suggests that you may prefer to listen to this speaker somewhat off-axis. The –3dB coverage at 15kHz is ±20°. At 10kHz the -3dB coverage extends to ±28°. This is somewhat poorer than typical 25mm dome tweeters.

The average response over a 60° horizontal window (±30°) in the forward direction is a good approximation of the way a speaker will sound in a typical listening environment. This response is plotted in **Fig. 7** (A) and compared with the on-axis response (B). Here you see that much of the tweeter response variation has smoothed out. This further suggests that off-axis listening may be preferred.

VERTICAL POLAR RESPONSE

Figure 8 is the waterfall plot of vertical polar response. Responses are shown in 5° increments from 25° below (–25°) the tweeter axis to 25° above it. Moving below the tweeter (negative angles), the response changes little from the on-axis curve out to –15° for frequencies below 3kHz.

As you move above the tweeter, a deep response notch develops rapidly centered on 3kHz. Moving off-axis vertically, you see the same tweeter response flare that you saw on the horizontal waterfall plot. This further suggests that you may prefer to listen to this speaker off-axis and below the tweeter axis.

INTERMODULATION DISTORTION

I believe that intermodulation distortion (IMD) tests are more revealing of loudspeaker performance than harmonic distortion tests. In IMD tests two frequencies are input to the speaker. Intermodulation distortion produces output frequencies that are not harmonically related to the input. These frequencies are much more audible and annoying than harmonic distortion and a better measure of driver nonlinearities.

Let the symbols f_1 and f_2 represent the two frequencies used in the test. Then a 2nd-order nonlinearity will produce intermods at frequencies of $f_1 \pm f_2$. A 3rd-order nonlinearity generates intermods at $2f_1 \pm f_2$ and $f_1 \pm 2f_2$.

First, I examined woofer intermods by inputting 400Hz and 550Hz signals at equal levels. These frequencies should

FIGURE 8: EFE kit vertical polar response.

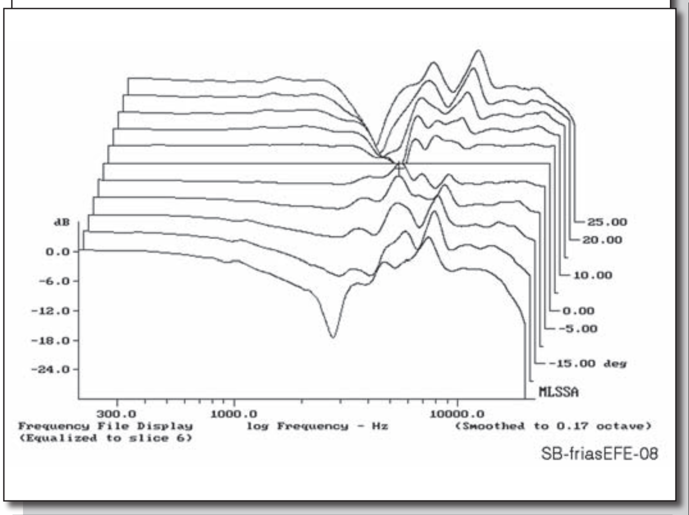


FIGURE 9: EFE woofer IMD.

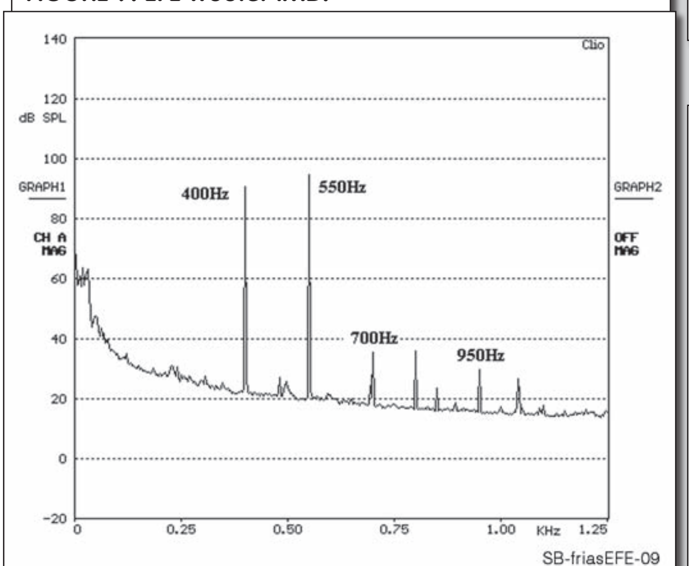


FIGURE 10: EFE tweeter IMD.

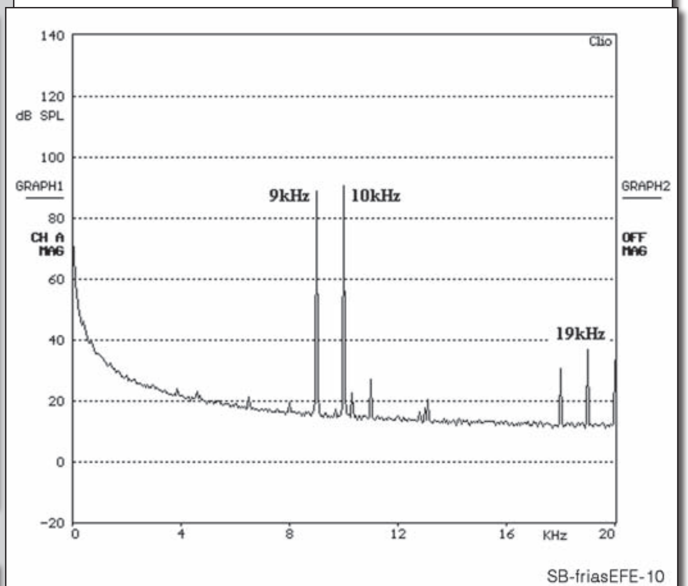
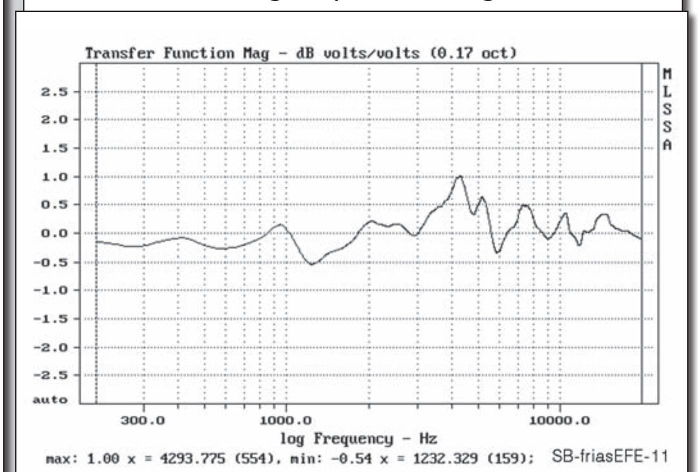


FIGURE 11: Illustrating EFE pair matching.



appear predominantly in the woofer output. Total SPL with the two signals was adjusted to 90dB at 1m. **Figure 9** is a plot of the resulting output spectrum. The principal output frequencies of 400 and 550Hz are highlighted on the graph.

In addition to these frequencies, you will see many other vertical lines representing both IMD products and harmonics of the 400 and 550Hz signals. Counting only the IMD products, there are significant lines at 700 and 950Hz. The overall level of 0.12% is typical of many good 6.5″ woofers.

Next, I measured tweeter intermods with a 9kHz and 10kHz input pair adjusted to produce an 87dB SPL at 1m. Results are plotted in **Fig. 10**. The major IM products occurred at 11 and 19kHz. Total IMD was 0.16%, a result somewhat on the high end of the many tweeters I have tested for *audioXpress*, but still acceptable.

The last IMD test examines cross-intermodulation distortion between the woofer and tweeter using frequencies of 550Hz and 10kHz, again at a 90dB level. Ideally, the crossover should prevent high-frequency energy from entering the woofer and low-frequency energy from entering the tweeter. A single tweeter sideband appeared at 9450Hz (not shown) at an overall level of 0.05%. This is a very good result and indicates good inter-driver isolation by the crossover.

SPEAKER MATCHING

All of the tests results reported so far were obtained from a single sample. Now look at how well the two speakers match in frequency response. A frequency response plot of the *difference* between the two samples is shown in **Fig. 11**. The two samples match within +0.1 and −0.5dB below 3kHz. Thus woofer samples match well. The tweeters match less well, but at +1dB and −0.4dB the matching is still quite good. Sonically, the pair will sound little different.

GRILLE EFFECTS

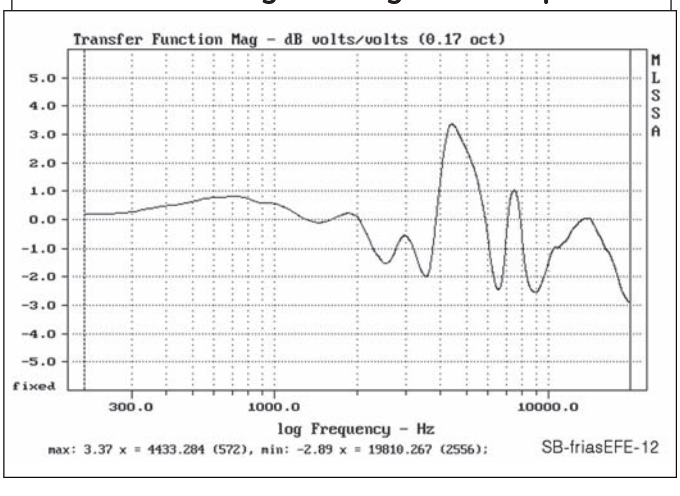
I conducted all of the above tests with the grille off. **Figure 12** shows the EFE Frias response with the grille on, but referenced to the response with the grille off; that is, it plots the *change* in response under the two conditions. The grille has a fairly substantial effect on response at all frequencies above 2kHz. Overall response variations of +3.4dB to −2.9dB are seen. As usual, the grille is there only for cosmetic effect and to protect the drivers from prying fingers.

FINAL COMMENT

The low-frequency −3dB point of 80Hz seemed very high for this Peerless driver. Just to check the near-field approach I used to get the low-frequency response I tested the speaker again in a much larger test facility at Boston Acoustics. Here a full-range response measurement is possible. The result was the same.

Given the rather high Q_{TS} of the Peerless woofer, the SC4/C4 alignment is appropriate and should produce an F3 of 33Hz in a 34 ltr box tuned to 32Hz. The EFE Frias box of about 12 ltr is tuned to 50Hz and lightly filled with dacron polyfil. This produces a very low box Q. As mentioned earlier, the first indication of this was the rather high impedance of 8.4Ω at F_b relative to the voice-coil resistance of 6.1Ω. Typical box vented box Qs are in the range of 7 to 10. Using Eq. 3.30 of reference 1, the calculated box Q is 2.

FIGURE 12: Illustrating effect of grille on EFE speaker.



The net effect of the very low Q, the small box, and the high F_b is to cause the woofer to act as though it were in a closed box. Indeed, in the first octave below F3 the rolloff is just 12dB rather than the 24dB you would expect from a vented enclosure. It would be interesting to know why the designer chose this alignment. aX

REFERENCE

1. J. D'Appolito, *Testing Loudspeakers*, Audio Amateur Inc., Peterborough, NH, 1998.

A note on testing: The EFE Frias speaker was tested in the laboratories of Audio and Acoustics, Ltd. using the MLSSA and CLIO PC-based acoustic data acquisition and analysis systems. Acoustic data were measured with an ACO 7016 ¼" laboratory grade condenser microphone and a custom designed wide-band, low-noise preamp. Polar response tests were performed with a computer controlled OUTLINE turntable on loan from the Old Colony Division of Audio Amateur Inc.