Efficiency comparison between moving-coil and piezo film speakers

R H Brown 13 Oct 2000

Summary

Although the voltage sensitivity of a piezo film speaker is generally much lower than a moving-coil speaker, the high impedance of the piezo, especially at low frequencies, means that the efficiency (sound pressure output for given electrical power input) is high. In this experiment, the efficiency of a piezo film element was found to exceed that of a conventional moving-coil device for frequencies below 1 kHz, and also for the total "speech" band of 300 to 3,000 Hz.

Devices tested

A pair of conventional headphones of average quality and price (Philips, type SBC3375) was used as the "reference". A single channel was driven by a random noise source, and the sound pressure level was measured at a few millimeters distance from the mesh cover over the coil driver. The spectrum of the applied noise source voltage was also recorded, and the spectrum of the SPL was divided by drive signal to give a "sensitivity" plot (SPL in dB, for an applied voltage of 0 dB or 1 V rms). Coil resistance was measured to be 38 ohms at 1 kHz, and it was assumed that the speaker presented a purely resistive electrical load.

Two different piezo speaker elements were tested - first a bimorph, comprising two layers of 28 µm PVDF bonded together using 75 µm thickness double-coated adhesive tape, and connected electrically in anti-parallel. The prepared film element was approximately 45 mm wide and around 60 mm long, having a diagonal top edge and a rounded bottom edge. This element comprised one half of a novel stereo speaker system, assembled onto the legs of a pair of sunglasses. Capacitance of the bimorph element was 21 nF at 1 kHz.

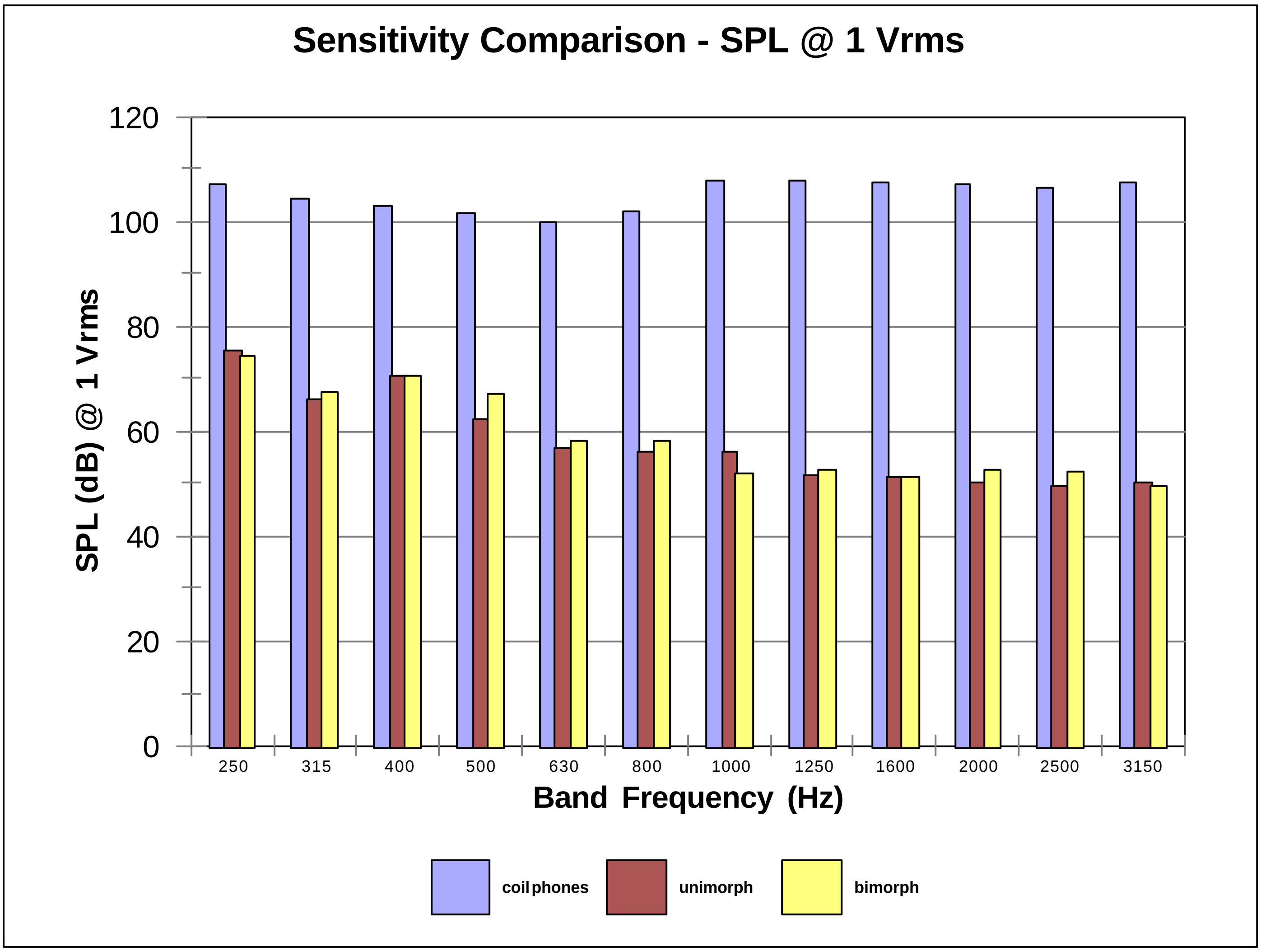
The second piezo speaker element was similar in size and shape to the first, but comprised only a single layer of 28 µm PVDF, bonded to a strip of "0.005" pressure-sensitive adhesive polyester tape. Capacitance of this "unimorph" was 10.5 nF at 1 kHz (exactly half of the bimorph element).

An RMS average of the microphone signal over the active area of each style of speaker was recorded. This was important with the piezo devices in particular, as the frequency characteristics of different areas of the film were found to vary (due to mechanical resonances).

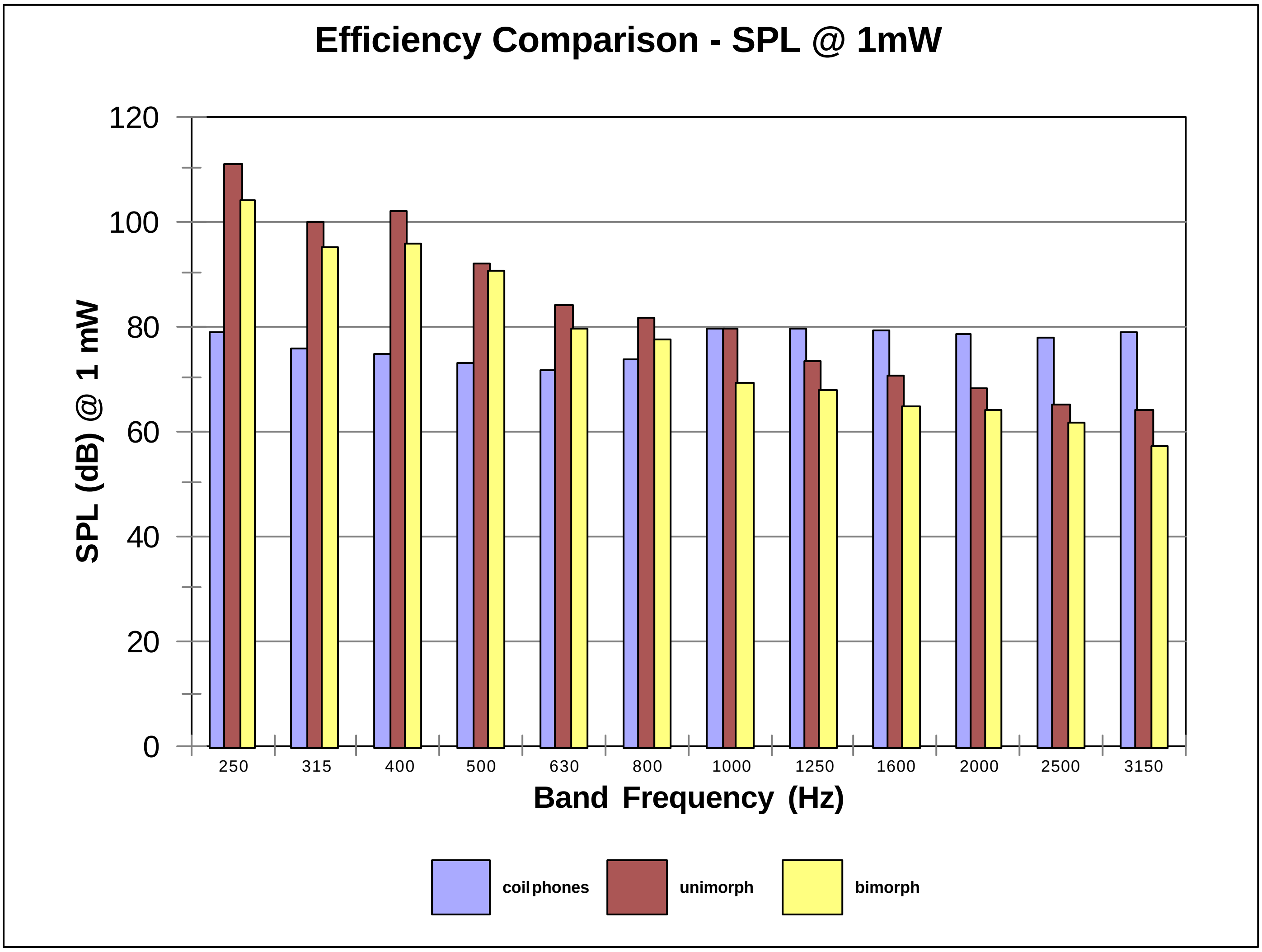
Experimental Results

Although numerous narrow-band results were recorded over different ranges of frequency, perhaps the best indicator of overall results may be seen in the attached third-octave band plots. The two pages each present plots over 250 to 20,000 Hz, and reduced spans showing only the "speech" band used in most telephony of 300 to 3,000 Hz (actually 250 to 3150 Hz is presented). The two ranges are selected from the same full data sets.

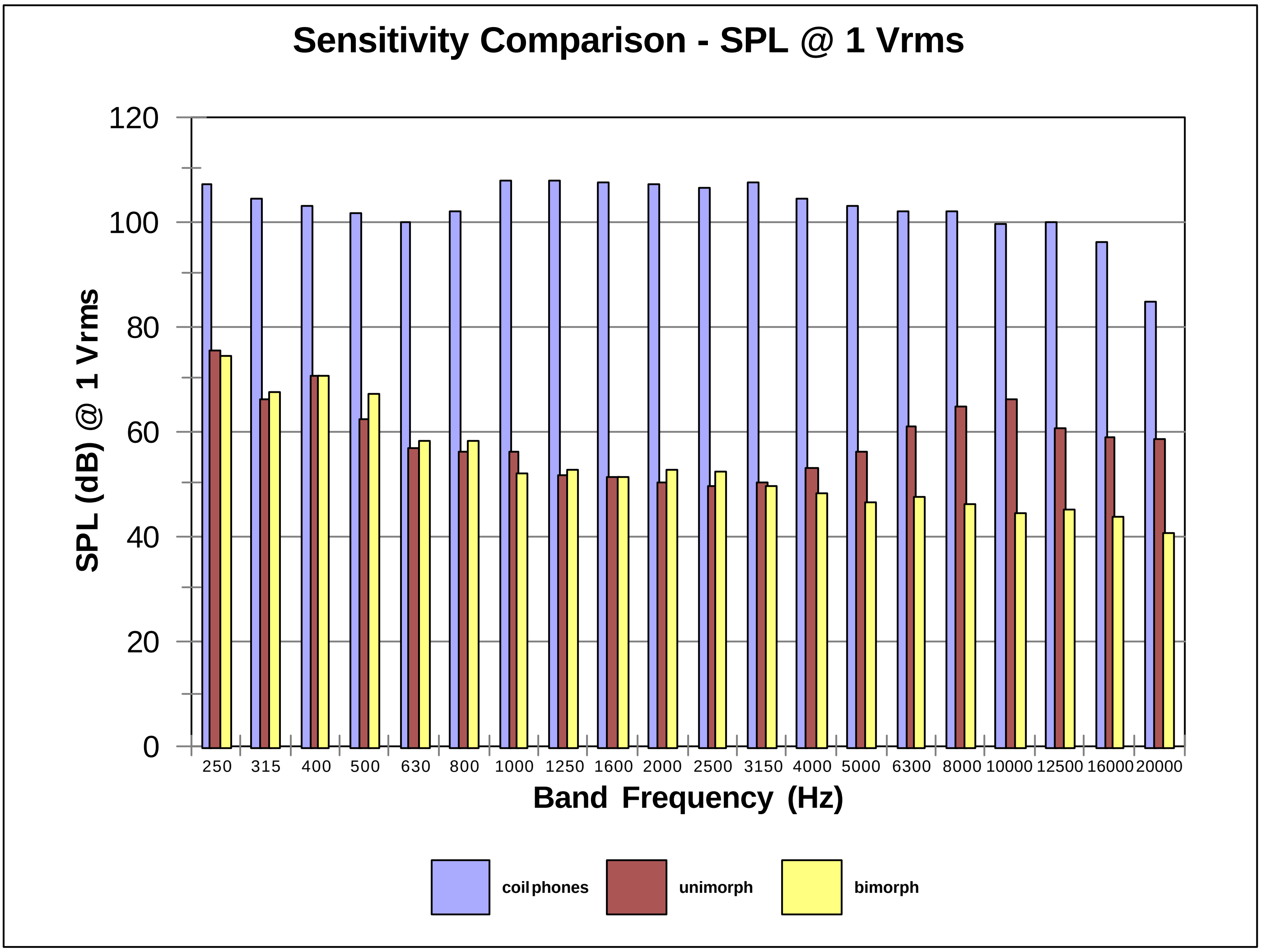
The first page shows a comparison of sensitivity (SPL achieved for a drive voltage of 1 V rms). As expected, the piezo film elements produce much lower sound pressure levels for the given applied voltage, compared with the moving-coil speaker. The unimorph shows a boost



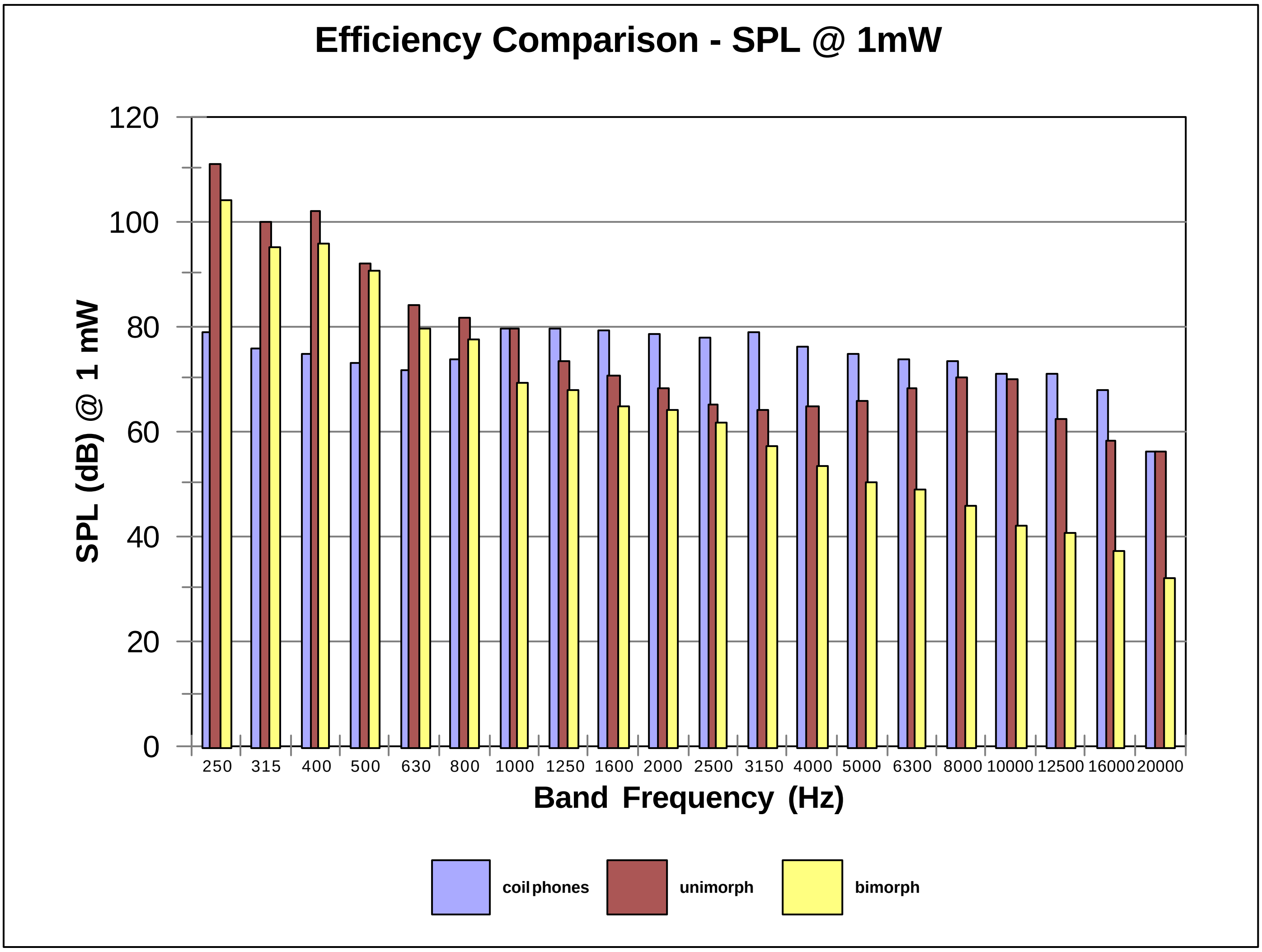
Sensitivity Comparison - SPL @ 1 Vrms
SPL (dB) @ 1 Vrms
120
100
80
60
40
20
0
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
Band Frequency (Hz)
coil phones
unimorph
bimorph



Efficiency Comparison - SPL @ 1mW
SPL (dB) @ 1 mW
120
100
80
60
40
20
0
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
Band Frequency (Hz)
coil phones
unimorph
bimorph



Sensitivity Comparison - SPL @ 1 Vrms
SPL (dB) @ 1 Vrms
120
100
80
60
40
20
0
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
12500
16000
20000
Band Frequency (Hz)
coil phones
unimorph
bimorph



Efficiency Comparison - SPL @ 1mW
SPL (dB) @ 1 mW
120
100
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5000
6300
8000
10000
12500
16000
20000
Band Frequency (Hz)
coil phones
unimorph
bimorph

in level around 10 kHz compared with the bimorph (which subjectively made the unimorph sound louder and "brighter" than the bimorph version).

Then the electrical power level was calculated for each speaker, and the SPL normalised to an applied power of 1 mW. The results are shown on the second page, under the heading "efficiency comparison". Here, both the bimorph and the unimorph exceed the efficiency of the coil speaker, up to a frequency of around 1 kHz. The unimorph approaches the efficiency level of the coil speaker again at around 10 kHz, due to the resonant behaviour described above.

In the reduced bandwidth of 300 to 3,000 Hz, the average efficiency level of the unimorph exceeds that of the coil speaker by a significant margin (+18 dB as a linear average of band levels, +24 dB as RMS average). The bimorph is less efficient than the unimorph, but still higher than the coil speaker (+12 dB lin, +17 dB RMS).

Conclusions

At low frequencies (< 1 kHz), the reactive power required by a piezo film speaker may be signifcantly lower than the equivalent real power consumed by a coil/magnet loudspeaker, for similar radiating surface area.

Remarks:

The high voltage requirement still remains a major obstacle in the deployment of piezo film loudspeakers. Transformer networks may be very efficient means of supplying high voltage at low current from a low voltage source, but audio-bandwidth transformers of suitable inductance values to work well with typical speaker applications are physically large.

The above experiment does not take into account the acoustic behaviour of the cavity which is formed by the padded surround of the Philips headphones, engaging against the outer ear, nor the similar cavity or gap between the flat film elements and the ear.

The piezo film elements, when mounted on the legs of glasses, induce vibration directly into the frame of the glasses and thus also transmit vibration into the skull. The magnitude and significance of this vibration, relative to perceived loudness or sound quality, is not known.

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