

A := READPRN("jbl2241h.prn" )      The READPRN statement reads in the data file.

	0	1	2
0	14.8	7.688	35.37
1	18.5	8.988	40.68
2	22.19	10.7	44.63
3	25.89	13.36	46.89
4	29.59	17.69	46.15
5	33.29	24.4	38.3
6	36.99	32.57	20.27
7	40.69	35.54	-6.951
8	44.39	29.55	-30.39
9	51.79	17.2	-47.21
10	55.49	14.1	-47.34
11	62.88	10.69	-44.15
12	70.28	8.97	-38.8
13	81.38	7.366	-30.98
14	88.78	7.057	-26.35

$A_{n,0}$  is the frequency.  $A_{n,1}$  is the magnitude of the series impedance.  $A_{n,2}$  is the phase in degrees of the series impedance.

Note: Type 1j for the square root of -1.

These are the calculated values:

$$R_E := 5.1 \quad f_S := 39.5 \quad R_{ES} := 26.94 \quad Q_{MS} := 3.16$$

These are the "tweaked" values.

$$R_E := 5.1 \quad f_S := 40 \quad R_{ES} := 30 \quad Q_{MS} := 3.16$$

n := 0.. 61      There are 62 data points in the array. Note that the first one is numbered 0.

Resolve the impedance into real and imaginary parts.

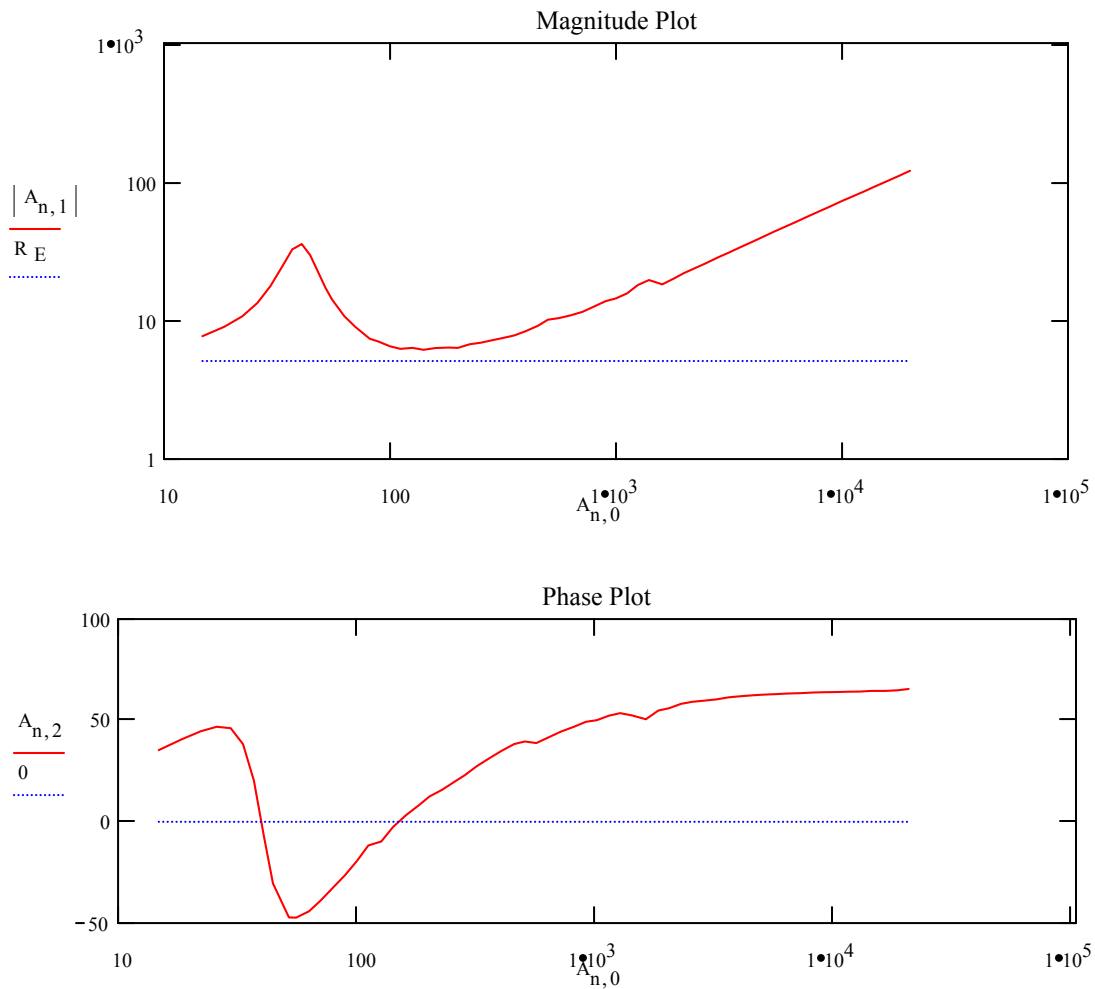
$$B_{n,1} := A_{n,1} \cdot \cos\left(\frac{\pi}{180} \cdot A_{n,2}\right) \quad \text{Real part.}$$

$$B_{n,2} := A_{n,1} \cdot \sin\left(\frac{\pi}{180} \cdot A_{n,2}\right) \quad \text{Imaginary part.}$$

$$Z_{exc}(f) := R_E + R_{ES} \cdot \frac{\frac{1}{Q_{MS}} \cdot \left(\frac{j \cdot f}{f_S}\right)}{\left(\frac{j \cdot f}{f_S}\right)^2 + \frac{1}{Q_{MS}} \cdot \left(\frac{j \cdot f}{f_S}\right) + 1}$$

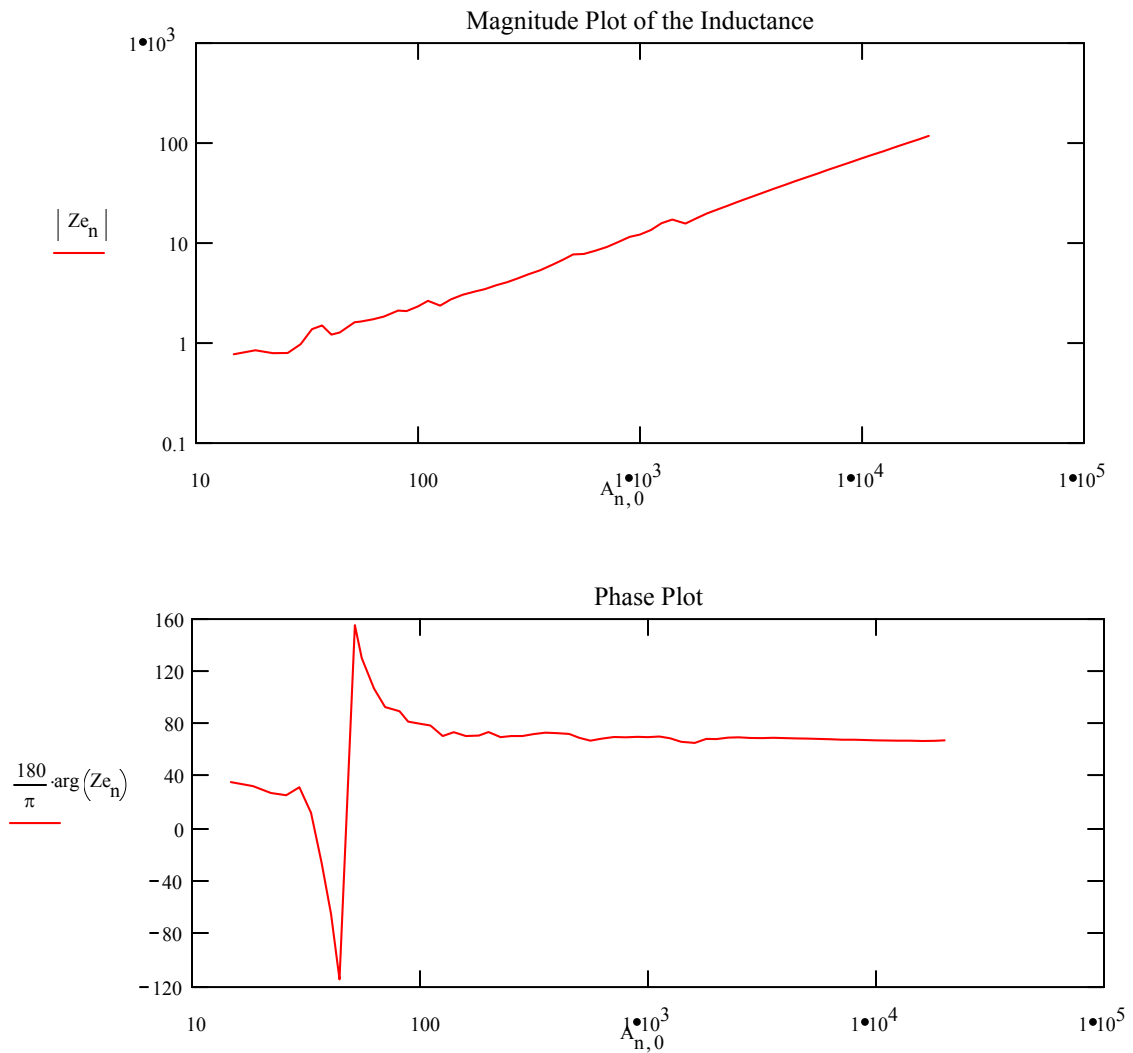
This is the excess impedance to be subtracted out so that we are left only with the impedance of the lossy voice-coil inductance.

First we plot the measured magnitude and phase.



Now we subtract out the excess impedance so that we can look at only the impedance of the lossy voice-coil inductance.

$$Z_{e_n} := B_{n,1} + j \cdot B_{n,2} - Z_{exc}(A_{n,0})$$



The "tweaked" parameters at the top of the page gave the straightest lines at high frequencies for the above 2 plots.

Notice the glitches due to resonances in the diaphragm. There are no glitches above 1.8 kHz. This corresponds to the range for  $n$  from  $n = 40$  to  $n = 61$ .

Curve fit to the points from 40 to 61. There are 22 points.

$$m := 0 .. 21 \quad m_1 := 40$$

$$f_m := A_{m+m_1,0}$$

Mathcad doesn't seem to want to give the right answers unless you start the range variable at zero. Thus we have to add 40 to  $m$  so that the actual range is from 40 to 61.

$$\omega_m := 2 \cdot \pi \cdot f_m \quad N := 22$$

The following formulas come from the voice-coil inductance paper posted on the class web page.

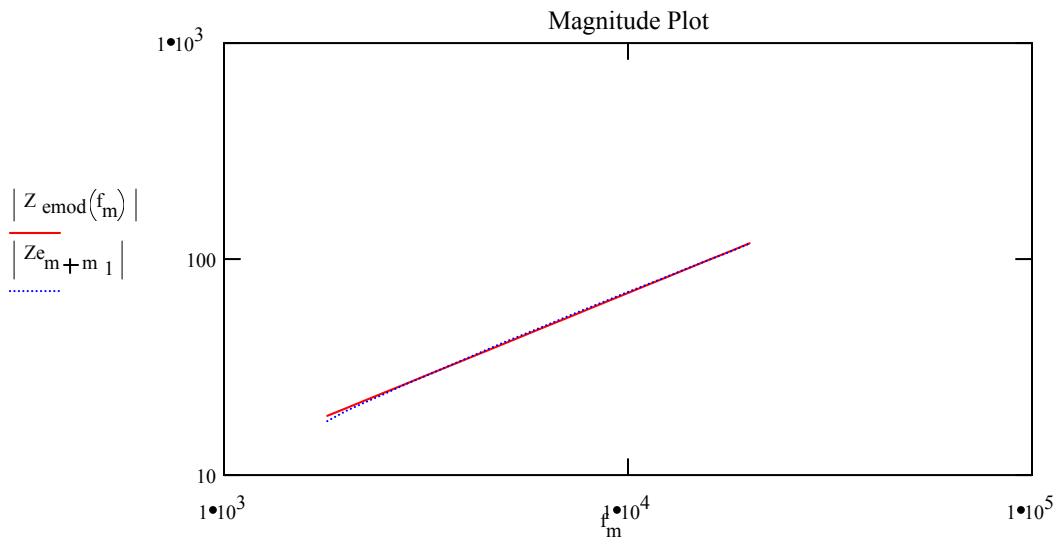
$$n_e := \frac{\sum_m \ln(|Z_{e_{m+m_1}}|) \cdot \ln(\omega_m) - \frac{1}{N} \cdot \sum_m \ln(|Z_{e_{m+m_1}}|) \cdot \sum_m \ln(\omega_m) + \frac{\pi}{2} \cdot \sum_m \arg(Z_{e_{m+m_1}})}{\sum_m (\ln(\omega_m))^2 - \frac{1}{N} \cdot \left(\sum_m \ln(\omega_m)\right)^2 + N \cdot \left(\frac{\pi}{2}\right)^2}$$

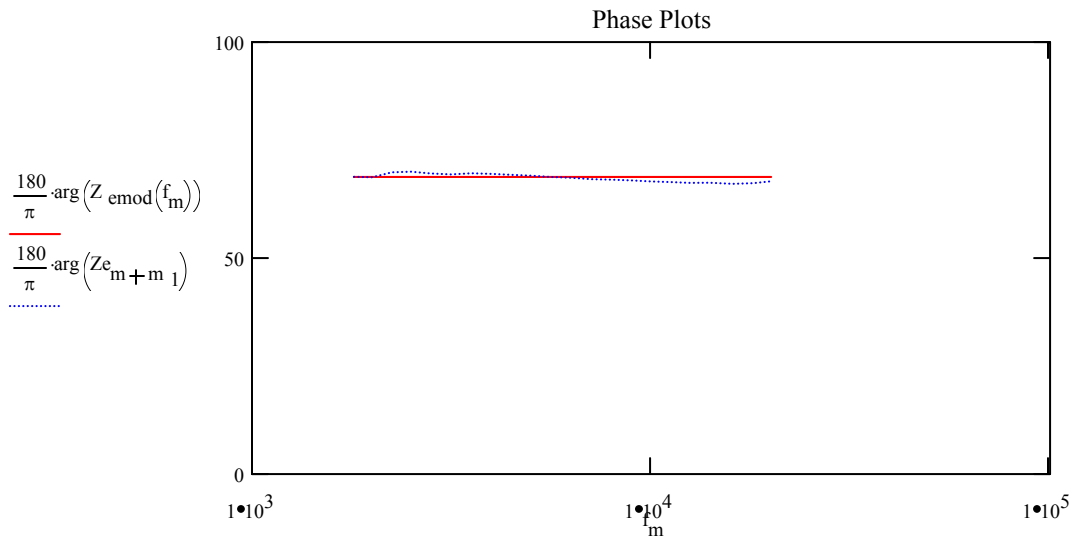
$$n_e = 0.76432$$

$$\ln L_e := \frac{1}{N} \cdot \left( \sum_m \ln(|Z_{e_{m+m_1}}|) - n_e \cdot \sum_m \ln(\omega_m) \right) \quad L_e := \exp(\ln L_e) \quad L_e = 0.01498$$

$$Z_{\text{emod}}(f) := L_e \cdot (j \cdot 2 \cdot \pi \cdot f)^{n_e} \quad \text{This is the model impedance of the lossy voice-coil inductance.}$$

Now to compare the model data to the measured data over the range from 1.8 kHz to 20 kHz.

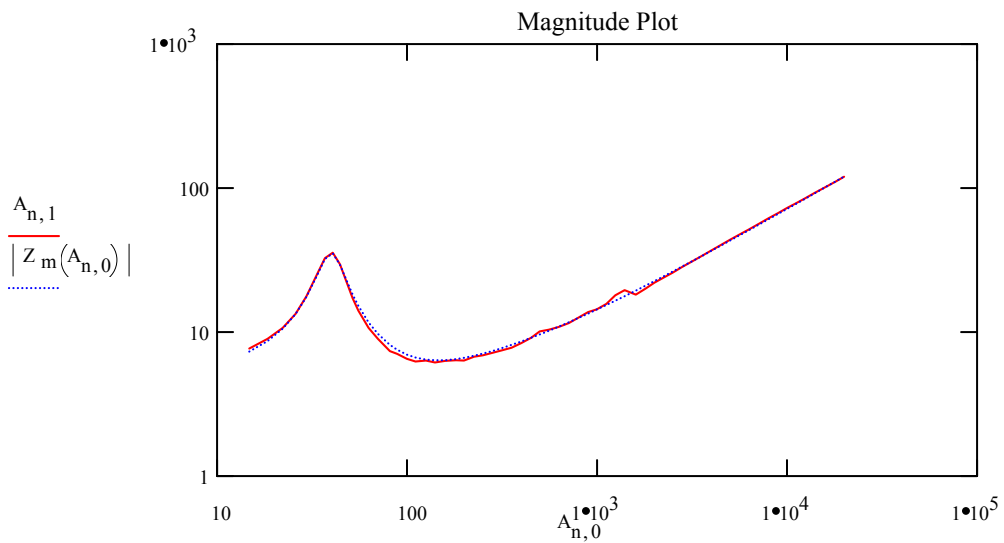


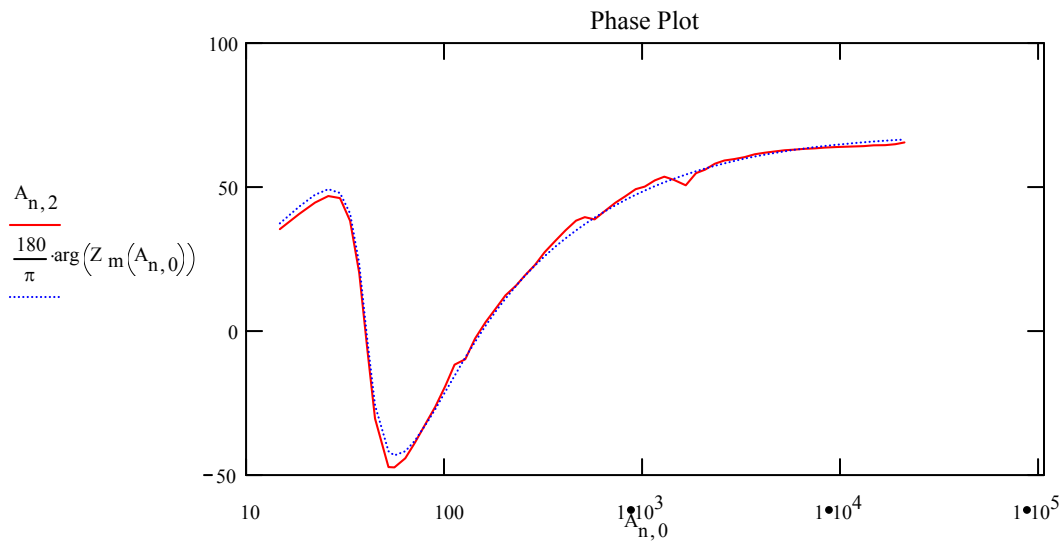


Almost perfect fits for both the magnitude and the phase. Notice that the phase ripples slightly about a constant value of about 69 degrees.

Now to compare the model impedance to the measured impedance over the range from 20 Hz to 20 kHz.

$Z_m(f) := L_e \cdot (j \cdot 2 \cdot \pi \cdot f)^{n_e} + Z_{\text{exc}}(f)$  This is the calculated model impedance.





Notice the almost perfect agreement between the calculated model impedance (red line) and the measured values (blue circles).