4.5 Frequency response

The frequency response of the Trillium 240 can be measured using the calibration coil. The measured response is the product of the calibration system's (first-order low pass) response and the sensor's own response. The nominal Trillium 240 response is obtained by dividing the nominal sensor calibration result by the calibration system's transfer function; the three frequency response functions are shown in Figure 4-2. The calibration system's low-pass response cancels the zero at –161 rad/s in the sensor's transfer function when the sensor frequency response is measured using the calibration coil.

The nominal poles (p_n), zeroes (z_n), normalization factor (k), and normalization frequency of the Trillium 240 are shown in Table 4-2. These parameters define the transfer function according to this equation:

$$F(s) = S_{sensor} \cdot k \cdot \frac{\prod_n (s+z_n)}{\prod_n (s+p_n)} \left[\frac{V \cdot s}{m}\right] \tag{EQ 3}$$

Where the normalization factor is defined as follows:

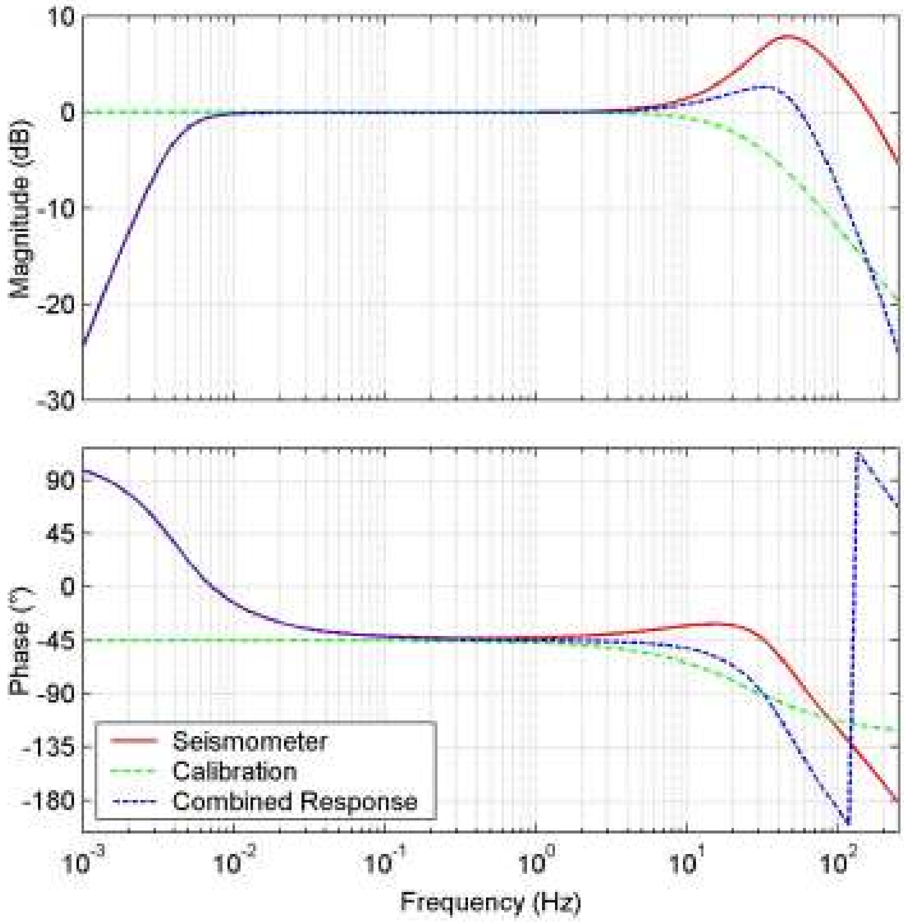
$$k = \frac{1}{\left| \dfrac{\prod_n (i \cdot 2 \cdot \pi \cdot f_0 + z_n)}{\prod_n (i \cdot 2 \cdot \pi \cdot f_0 + p_n)} \right|} \tag{EQ 4}$$

Table 4-2 Poles and zeroes

	Parameter	Nominal values	Units
z_n	Zeroes	0 0 –108 –161	rad/s
p_n	Poles	–0.01815 ±0.01799i –173 –196 ±231i –732 ±1415i	rad/s
k	Normalization factor	2.316×10^9	
S_{sensor}	Passband sensitivity at 1 Hz	1196.5	V·s/m
f_0	Normalization frequency	1	Hz

The transfer function is approximately flat out to 240 s and rolls off at 40 dB/decade below the lower corner frequency, as shown in Figure 4-2.

Figure 4-2 Nominal frequency response



4.6 Self-noise

Typical Trillium 240 self-noise is plotted in Figure 4-3. Three curves are included for reference: Peterson's new low-noise model (NLNM) and new high-noise model (NHNM), and McNamara and Buland's PDF Mode Low Noise Model (MLNM).[1] The noise floor shown is the typical level of instrument self-noise assuming proper installation. To achieve best performance for any sensor, meticulous attention to detail must be paid to choice of site, vault design, and sensor installation. The New Manual of Seismological Observatory Practice (IASPEI 2002) has a good discussion of the relevant

1. See also:

Peterson, J. (1993). *Observations and Modeling of Seismic Background Noise.* Open-file report 93-922, U. S. Geological Survey.

McNamara, D.E., and R. P. Buland (1994). Ambient Noise Levels in the Continental United States. *Bull. Seism. Soc. Am.*, **94**, 1517–1527.

Clinton, J. F., and T. H. Heaton (2002). Potential Advantages of a Strong-motion Velocity Meter over a Strong-motion Accelerometer. *Seism. Res. Lett.*, **73**, 332–342.