Seattle Q1 Infrasound Microphone

- Inexpensive
- Simple construction
- 12 Volt low power operation
- 0.24 Hz low freq cutoff
- Usable to 0.05 Hz
- 4 Volt P-P single end high impedance output
- 100 Hz extended response
- Built-in summing manifold

One of the goals of SMU's Seattle infrasound microphone project is to develop a simple inexpensive infrasound microphone.

A prior project datasheet described the Seattle P microphone, a microphone based on a Panasonic microphone cartridge and a simple inverse electronic filter. The Seattle P was designed to give a pressure response that was flat to frequency and to have a balanced output suitable for driving long cables.

The Seattle Q model is a simplified design intended for short cables or an external amplifier and intended as a quick 'disposable' microphone for pilot experiments. It is simple enough to construct in a few hours at a materials cost of about $100.

A total of 6 Seattle Q models have been constructed at SMU. Several similar models have been constructed at other universities. This project datasheet describes the evaluation of four of the models planned for field evaluation in late summer of 2002 at KIGAM.

Circuit Details

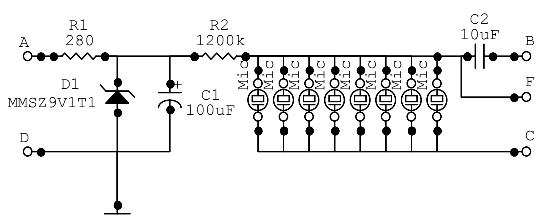

Figure 1. Schematic of Seattle Q. Pin designations are for PT02 connector.

The internal circuit is hand wired on a small perf board. In operation, 12 Volt power is applied to pins A and D, pins C and D are jumpered together, and output is taken off of pin B. During test, or operation with a microphone preamp, the microphone elements may be sampled directly from ping F and C. This allows the microphone to be used with low impedance high dynamic range recorders. To be useful, the recorder must be able to handle 0-8 volt input signals (unipolar signals).

Resistor R1, diode D1, and capacitor C1 form a simple shunt regulated power supply to derive 9.1 volts from the 12 volt input power supply. Noise on the power supply may appear on the output. It may be necessary to shunt an additional small capacitor across pins A and D for noisy environments.

Resistor R2 supplies the bias current for the 8 microphone elements connected in parallel. Capicator C2, a 10 uf metal film capicator is used as a DC blocking output. Output is taken from pin B. The recorder input impedance in series with capicator C2 will form a low cut RC filter and therefore the response of the system will depend on the input impedance of the recorder. The current field installation uses a preamp with a 20 meg ohm input impedance.

Construction Details

The microphone is built from standard rigid PVC plumbing parts. Based on constructing 5 models in a machine shop, the estimated time to drill, tape, and shape all parts averages about 2 hours per microphone. This time is based on hand placement without jigs. Assembly and circuit assembly also takes an average of 2 hours per unit excluding drying time. Final test and calibration takes about an hour excluding the 24 hour unattended acquisition time.

Figure 2. Inside of the Seattle Q microphone.

The microphone includes a built-in 8-port manifold with capillary filters on each port. These capillaries equalize the responses on each of the hoses and help control hose resonance when solid hoses are used next to the microphone. The 8 microphone elements are placed in a common backing volume made from a 2” plastic pipe cap. A 0.003” orifice is used as the backing volume leak capillary. This orifice will produce a low cut 0corner of about ¼ second.

The Seattle Q uses 8 microphone elements in parallel to reduce the microphone self noise floor by about 10 dB. The use of a common backing volume, avoids the problems with differing element response characteristics reported by some previous users of common electret microphone elements. Element electrical connections are still made separately outside the backing volume to allow individual element diagnostics.

Initial Evaluation and Tests

Four Seattle Q microphones were compared with a Chaparral Model 2 using ambient noise in a basement laboratory. The Seattle microphones were connected to a Geotech short period seismic amplifier with an input impedance of 20 meg ohms and 30 dB gain. Outputs of the preamps and the Chaparral were digitized on a RefTek 24 bit digitizer at 10 SPS and at 200 SPS.

All microphones were left with open ports and clustered (huddle test) within a 1-foot radius circle around the Chaparral. Results of the high frequency 200 SPS measurements are problematic, probably due to phase differences in the ambient noise. At high frequencies, we have had better results using a B&K microphone rather than the Chaparral.

Figure 3 shows the uncorrected ambient noise drive. The observed noise spectra has not been corrected for instrument response, only for instrument sensitivity. The Chaparral M2 is assumed to have a flat pressure response down to 0.02 Hz. The Seattle Q response is calculated from the cross spectra. Figure 4 shows the amplitude response of each of the Seattle Q with the calculated sensitivity. Error! Not a valid link.

Figure 3. Uncorrected ambient background noise.

When the signals are coherent between the Chaparral and Seattle Q, this transfer function method works well. A plot of 1-coherence square (Figure 5) between the Seattle Q and Chaparral indicates that the two devices are high coherent in the 0.1 to 4 Hz band and that therefore a suitable instrument response function can be derived in this band. The Seattle Q instrument response can be fit with a simple two pole, two zero model (Figure 6). The legend on Figure 6 gives the locations of the poles and zeros for each instrument. The phase response (Figure 7) is determined in a similar fashion

The inverse instrument response for each of the Seattle Q’s may be applied to the time series data. The resultant time series (Figure 8) are almost identical. Small differences do appear in the very low frequencies. This may be due to misfits in the instrument response function (Figures 6 and 7) or may be a result of different local noise (either electronic or thermal at each instrument.

This particular test in a high signal environment with loosely coupled sensors is not well suited to estimate instrument self noise. In this case a measure of the instrument self noise will be pessimistic (Figure 8). The top black curve indicates the input signal or driving noise. The blue line is the estimated instrument noise assuming that the Chaparral has no measurable self-noise and therefore all the noise is due to the Seattle Q. The green line is the estimated instrument noise using two Seattle Q’s. The best estimate for the Seattle Q is probably the green line. The separation between the two lines above 1 Hz indicates that either the Chaparral has a high self noise in this region or that the instrument response between the two kinds of instruments is not coherent enough to allow a good noise estimate. Also plotted on the graph are the measured self-noise of the Seattle Q (in dotted turquoise) and the measured self-noise of the Seattle P (in dotted magenta). The microphone self-noise of the Seattle Q was measured by removing the low cut bleed resistor. This is a pessimistic measure since it does not completely isolate the diaphragm from atmospheric disturbances. It is more likely to be correct at high frequencies. The magenta dotted line is the self-noise of the Seattle P measured with a dummy microphone element. The dummy element is a microphone element completely enclosed in an epoxy block. Theoretically, the 8-element Seattle Q microphone should have a 10 dB self noise improvement over the Seattle, about the separation between the magenta and green line at 4 Hz.

Although the Seattle Q is not intended as a direct replacement for the more expensive IMS infrasound microphones, it is useful to compare it to the IMS specifications (shown as dotted lines on Figure 9). Most of the IMS specifications are defined only a 1 Hz. The bottommost dotted line is the instrument self noise specification. From coherence noise estimates the Seattle Q is about 3 dB above this line. The estimate using a high pass acoustic filter (removing the backing volume capillary bleed), a more likely estimate, is about 5 dB below the requirement. RMS dynamic range, a ratio of the clip level to the instrument noise is only 60 dB for the Seattle Q. This could easily be increased to 70 dB by reducing the preamp gain from 30 to 10 dB. If the band is restricted to 0.1 to 4 Hz (rather than 0.02 Hz) the RMS dynamic range with the reduced preamp gain is over 80 dB. If the estimates of instrument self noise are high in the 0.02 to 0.1 Hz band, as is suggested by the magenta and turquoise lines, then the RMS dynamic range over the 0.02 to 4 Hz band may be close to 80 dB.

This is not to say that the Seattle Q could meet IMS specifications. A key specification is that the sensor have a flat to pressure response in the 0.02 to 4 Hz band. The Seattle Q does not attempt to meet this specification, instead applying an instrument correction after data acquisition. Although this post acquisition correction is a possible source of error (depending on the instrument stability) it does give a signal more useful for small aperture arrays, field analysis, and lower resolution digitizers.

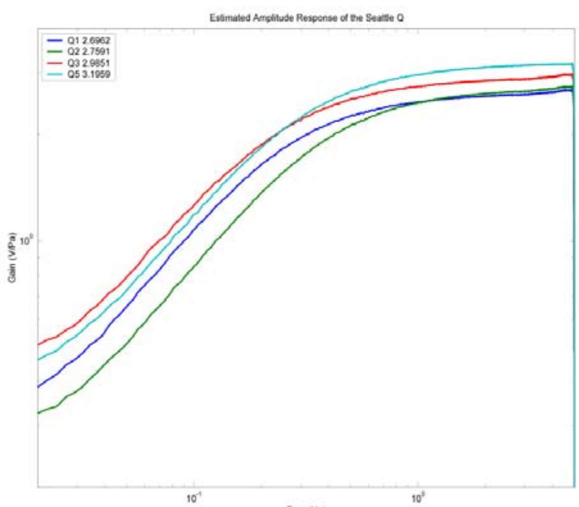

Figure 4. Calculated transfer function of the Seattle Q. Legend shows sensitivity in volts/Pa.

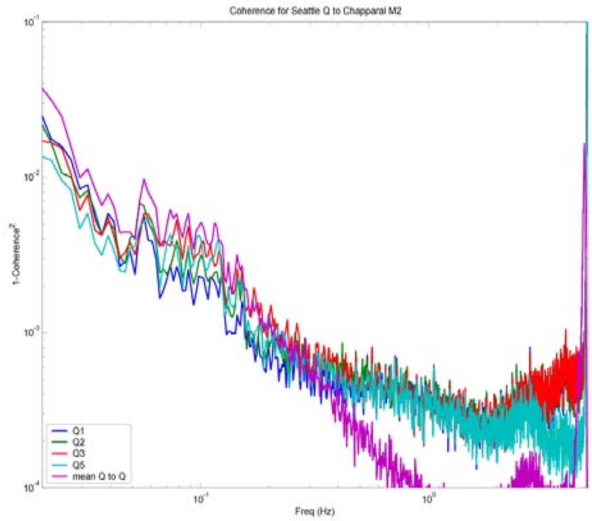

Figure 5. 1-Coherence squared between Seattle Q and Chaparral.

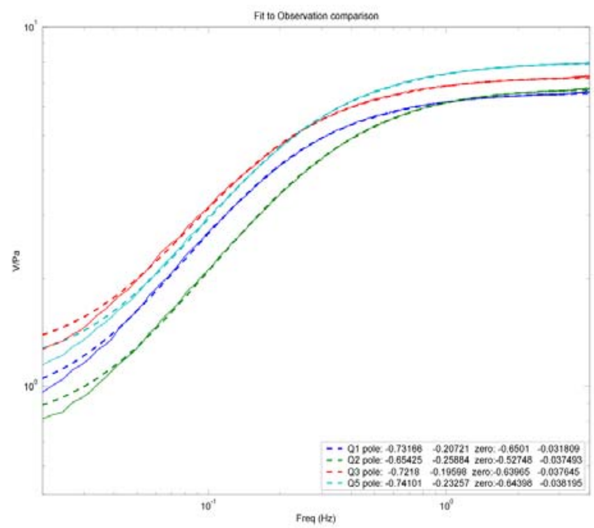

Figure 6. Measured and fitted amplitude response.

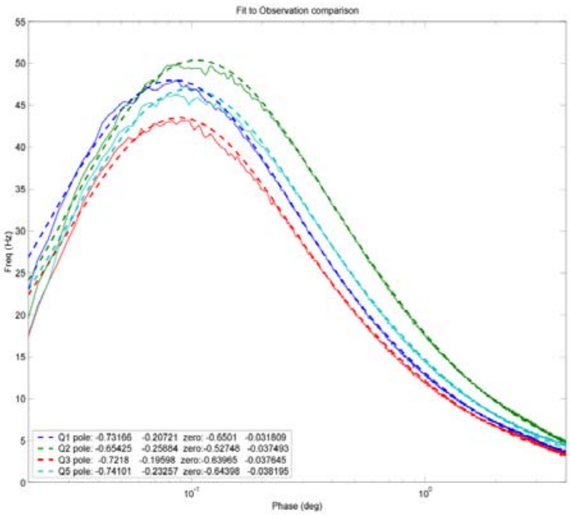

Figure 7. Measured and fitted phase response

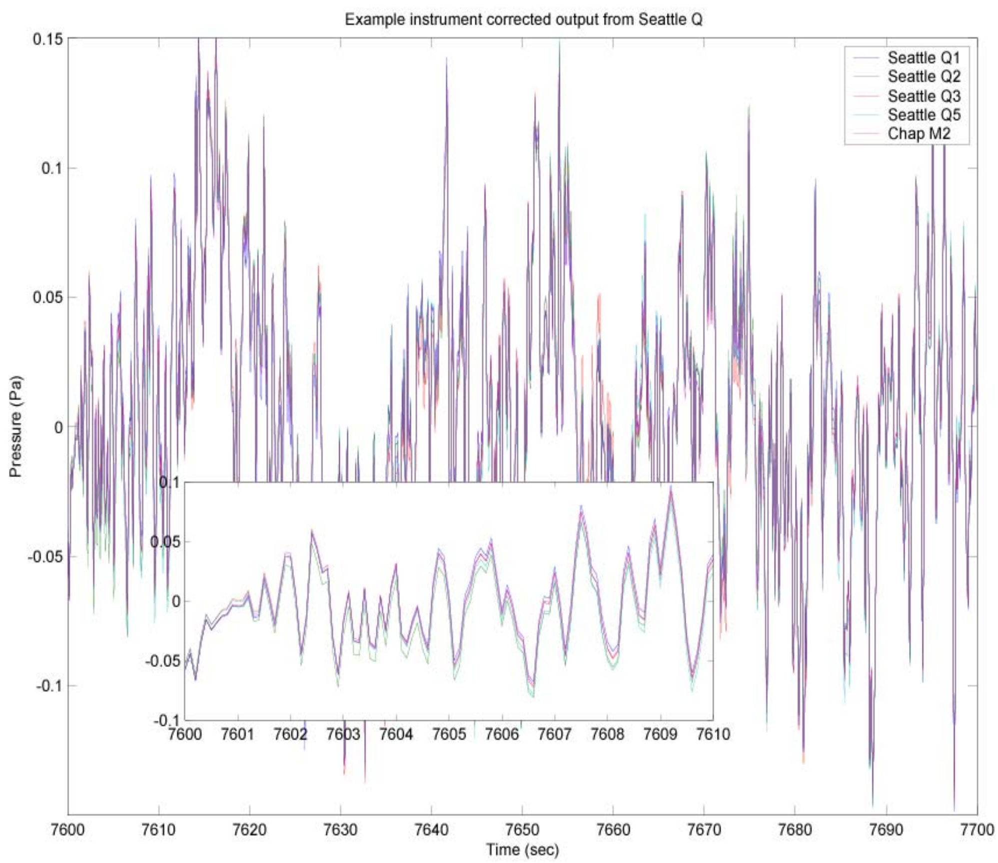

Figure 8. Comparison of Chaparral and inverse filtered Seattle Q.

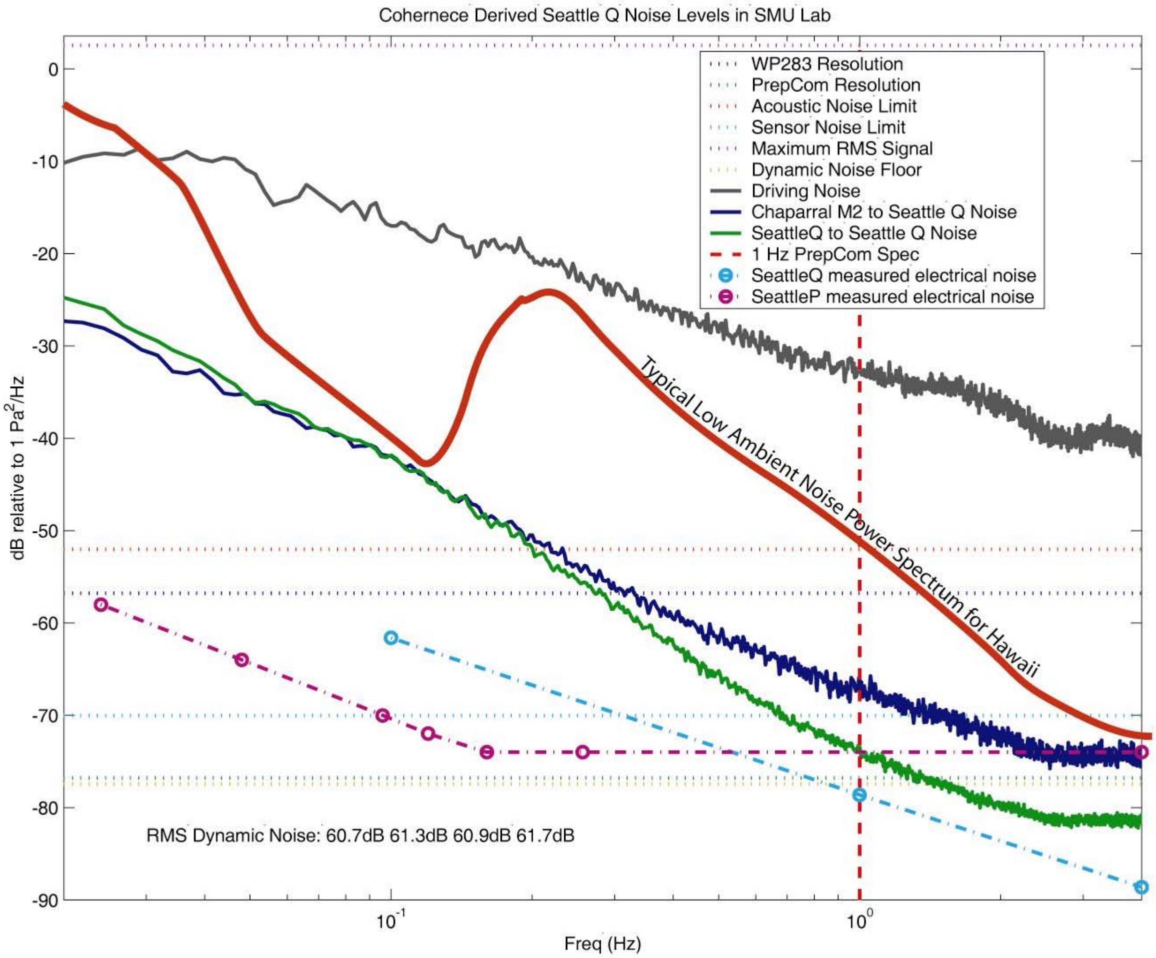

Figure 9. Noise level estimates for Seattle Q.