Broadband active seismology: the challenge of sourcing and receiving low frequency signal

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Two important features of the new generation of seismic equipment and methods are (1) lower environmental impact, and (2) broadband signal above ambient and instrument noise. The subject of this paper is sourcing and receiving low frequency signal. The high frequency limit comes from attenuation and scattering of high frequency waves. The low frequency limit is coming from the limitation of the sources and the receivers.

On the source side, generating low frequency waves requires sources that are different from conventional Airguns. The new generation sources must have a lower environmental impact, which they do, but the subject of this paper is the emission of more low frequency signal. The Tuned Pulse Source is shown in Figure 1 (a) to (c) in comparison to Airguns.

On the receiver side, recording low frequency signal is also a challenge. In addition to Hydrophones, we need data from sensors that record vector motion. Geophones have served the industry well, but their low frequency response is limited by the transfer function of their induction coils-and-magnets. New generation equipment is based on Micro-Electro Mechanical Systems (MEMS) accelerometer. These are based on capacitors instead of induction coils. MEMS have a number of advantages compared to Geophones. They do not have high frequency spurious noise. They use the earth's gravity to record their orientation. Their advantage in low frequency data quality is because they do not require instrument designature in data processing. Geophones require such designature which depends on their resonance frequency and damping resistor which changes from geophone to geophone and with age, leading to node to node amplitude and phase data jitter. Importantly, geophone designature involves boosting instrument noise at low frequency. This can be overcome by pre-amplification gain, but this leads to full-scale saturation also known as overdrive of shots at near offsets. Such overdrive may happen even in deep water. Figure 1 (d) to (g) shows a comparison between Geophones and MEMS.

In summary, broadband seismic methods depend on generating low frequency waves by the source, recording them by receivers, long offset and wide azimuth geometry, retaining the low frequency signal in processing, and using it in inversion of broadband reflectivity data to blocky impedance and velocity earth models.

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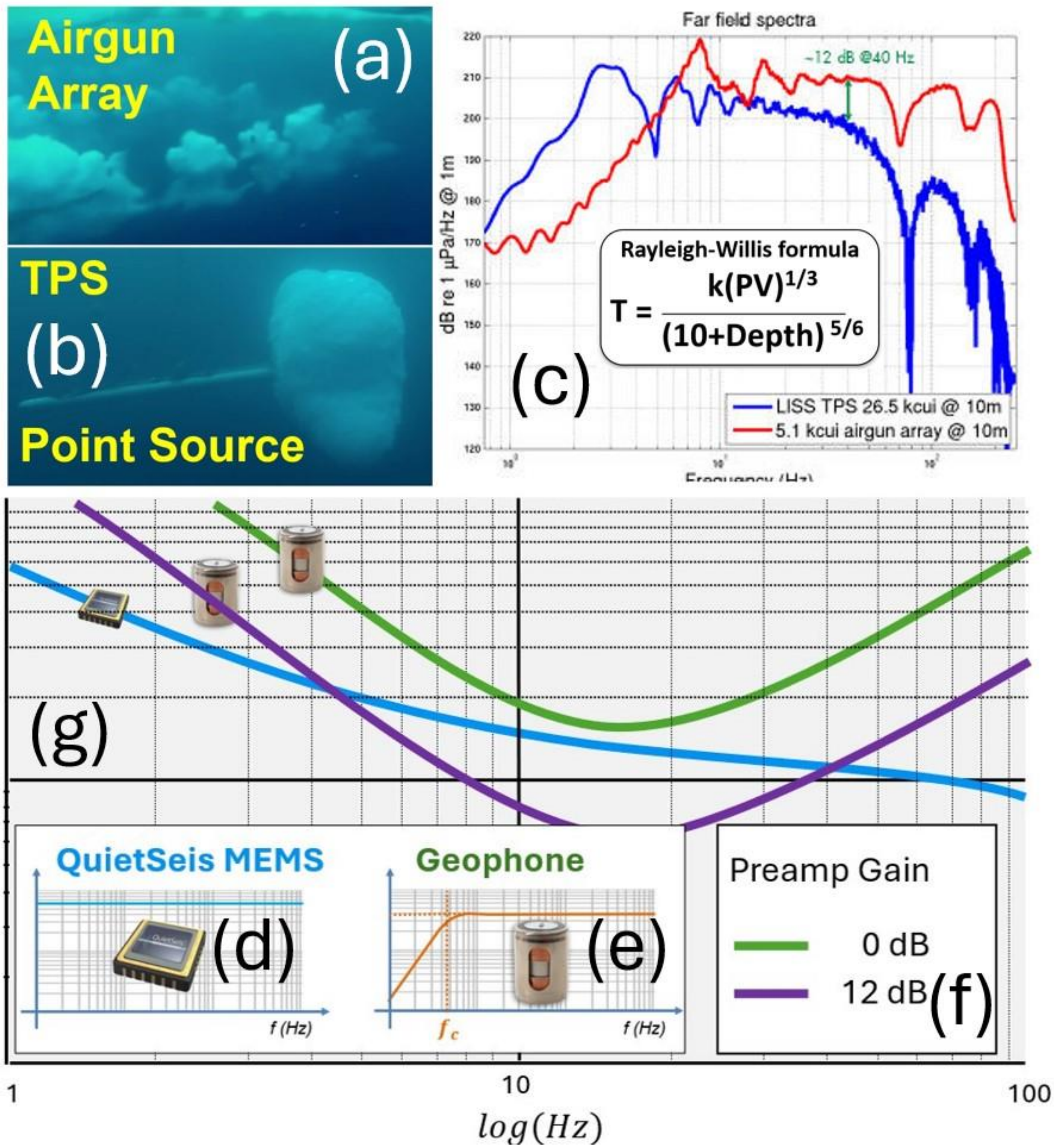

Figure 1. (a) The radius of the largest bubble of a typical Airgun array is 60 cm. (b) The radius of the bubble from a TPS is 2 meters. (c) The resonance frequency is proportional to the bubble radius. (d) the transfer function of a MEMS accelerometer is flat all the way down to zero frequency. (e) the transfer function of a Geophone has a 12 dB per octave analog low cut. (f) Pre-amp gain can be used to allow geophones to record low frequency signal. (g) Designature boosts instrument noise. This can be mitigated by high gain. However, at a risk of over-drive saturation of near offset shots.

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