ALTERNATIVE SOURCE FOR MARINE GEOPHYSICAL EXPLORATION

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1. INTRODUCTION

High power acoustic sources, such as the air guns used by the marine geophysical industry, are coming under increasing scrutiny by environmentalists for their potentially harmful impact on marine life, and in particular, mammals[1]. As a result, the marine geophysical industry is attempting to develop alternatives to replace traditional air guns and other impulsive broadband sources[2]. This paper discusses the fundamental physics issues associated with low frequency sources, particularly when they are operated near the water surface, and why it is so difficult to achieve even a small fraction of the power that an air gun produces with electro-acoustic or other marine vibroseis technologies. Our investigations show that GeoSpectrum's MPS technology is a strong, environmentally friendly, candidate for geophysical site survey exploration and we discuss what we have learned, as supported by Encana through the Deep Panuke Fund.

2. PHYSICAL CONSTRAINTS

When operating in shallow water, or near the water surface, it is very difficult to produce acoustic energy that is sustained. Near the water surface can be defined as within a fraction of a wave length. As can be seen in Figure 1 below, the power level achieved at 5m depth is about the same as in the free field at 25Hz, but at lower frequency it is attenuated and at higher frequencies it is in fact boosted by the surface reflection. This is because, fundamentally, the air/water boundary cannot sustain pressure so the reflected acoustic wave is 180° out of phase with the incoming acoustic wave[3]. The reflected wave interferes with the incoming wave, which, at shallow depths and low frequencies, results in destructive interference.

With an air gun operating at 5m depth, it would appear to be attenuated by well over 10dB, but this is not the case. The chart reflects steady state signaling. An air gun is impulsive and the detrimental reflection does not occur immediately. The 5m depth gives a reflected path of 10m, or 6.7ms. With a primary pulse width of 20ms, only 2/3 of the pulse is attenuated. For a coherent source, the time domain advantages are largely lost due to the greater pulse length required.

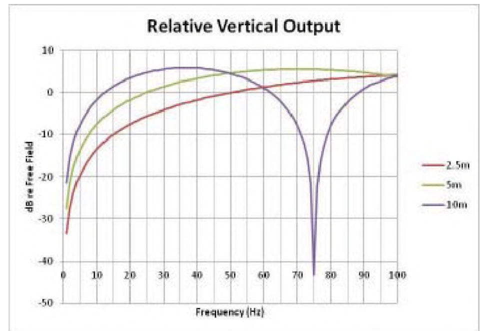

Figure 1 Surface Reflection Attenuation

A further constraint is the size and weight consideration for power at low frequency. The power generated by an acoustic source is proportional to the square of the volume velocity it achieves[4].

To put this in perspective, a piston displacement that generates 1 W at 1 kHz would produce only 10^{-4} W at 10 Hz. Thus, low frequency projectors just either produce large displacements or have large radiating areas, or both. No matter how you look at it, a powerful low frequency projector is large.

3. MPS

The MPS[5] takes advantage of the interactions of closely spaced transducers to increase the radiation impedance and thus increase the relative power transmission at low frequencies. The MPS uses a very large active surface area to spread the energy and stresses seen by the source and also minimize the magnitude of motion required to achieve the desired sound pressure level. This results in a relatively robust system, compared to devices with moving parts that require seals and other regular service parts.

Figure 2 MPS

As can be seen in Figure 2 above, the MPS is built like a set of baffles, and so for a cylindrical form, the radiating area is in fact the area of the end of the cylinder times double the number of elements in the array. For a 5” diameter cylinder with 20 elements spaced at 1” we have 785 in^2 of active area. If this were a moving coil with a 5” face, the active area would be less than 20 in^2 and if this were a radiating cylinder, the active area would be in the order of 345 in^2.

The operating frequency of a transducer greatly affects the transducer size and effectiveness. We have already noted that as we go down in frequency we have to go up in displacement to maintain the same volume velocity of water. To reduce the operating frequency, we need to make the transducer less stiff as well. With air backed transducers, such as flex-tensionals, we can make the operating frequency lower by reducing the mechanical stiffness of the flexing member. This will impact the robustness of the transducer relative to static pressure, and if we go low enough in frequency, we will need to add internal pressure (pressure compensation) to avoid damaging the transducer. As noted in Section 2, the depth of operation will impact performance, with the general note that the lower frequency you wish to operate, the deeper you need to operate. This is in conflict with the fact that the lower frequency transducers will are less able to withstand static pressure. As we head toward 10Hz, the need for pressure compensation becomes unavoidable. To achieve air gun equivalent power cannot be achieved (with existing technology) without an unmanageably large source.

An MPS, using flex-tensional benders, will be more compact and more robust than a transducer producing the same power, using ring shells, hydraulic transducers, moving coils, etc. The MPS provides a very large operating area in a relatively small space and does not require moving seals. The simplicity of the bender element makes it a relatively low cost solution with minimal parts to go wrong. Because the MPS is made up of a large number of identical elements, there is also a clear means of graceful degradation, as no one part will lead to catastrophic system failure.

4. COHERENT ADVANTAGES

When operating with a coherent source, you know the frequency, amplitude and phase content of your source signal and therefore can correlate the receive signals to the source signals in more than one dimension as it were. The received data can also be processed in the time domain, as it can be continuous or longer in duration than an impulsive source. Source signal control allows the operator to avoid destructive or interfering frequencies and also generate sequenced or coded signals for even greater ability to increase S/N ratios and thus reduce the needed power levels. It is also possible to avoid frequencies that pose environmental concerns or even to tailor the operational frequency content to each specific area.

For oil and gas exploration, no operational alternative to air guns exist, and the goal is clearly a lofty one. However, for other purposes, where higher frequencies of operation are possible, because depth of penetration requirements is less, the MPS provides an existing, viable, environmentally friendly solution. This could be for shallow hazard surveys, well monitoring, etc. The operation can be higher in frequency than marine seismic, but still below or above the frequencies of concern for marine mammals or those marine mammals of concern in the area of operation.

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