Recent Advances in Point Receiver Technology – Are Field Arrays a Requirement Any Longer?

D. J. Tessman, M. Bahorich, D. Monk, Apache Corporation

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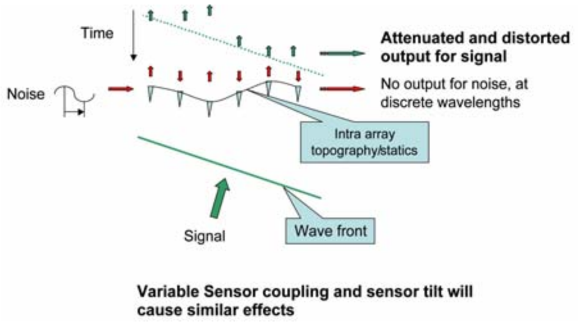
Summary:

The recent introduction of full wavefield (i.e. multicomponent) point receiver technology has re-kindled an ongoing debate amongst geophysicists as to the suitability of point receivers for use in the acquisition of standard compressional (P-wave) seismic data. Conventional wisdom tells most geophysicists that for a variety of reasons, P-wave data should be acquired using arrays of receivers (and sources). While the spatial dimensions and number of elements deployed varies greatly throughout the world, it is nonetheless common practice to employ some form of array.

This paper presents a solution based on recording the entire wavefield with single point receivers. Based on the inherently high vector fidelity of a new generation of sensors, this method can be shown to deliver data free of aliased energy without the use of field arrays. Given the problems associated with field arrays, point receiver data can at times be demonstrably superior to conventional data. Elimination of field arrays may in many cases also lead to dramatic improvements in field efficiency (less equipment to be transported and maintained). Ultimately these improvements are manifest as both turnaround improvement and lower overall project costs. These efficiency improvements are scalable and are seen across projects of all sizes.

Field Arrays:

Since the early days of reflection seismology geophones have been deployed so as to form spatial arrays. The initial requirement for these arrays was to act as K filters (wave number filters) to attenuate high amplitude source related energy (usually Rayleigh waves) in order to preserve the available dynamic range within the recording system for the far weaker reflection data. Field data were analyzed closely and the offending wavelengths identified. Array dimensions were calculated so as to generate rejection notches at the appropriate wavelengths. The geophones composing the group were often deployed as a linear 2D array. As a side effect additional rejection notches were also present (number dependant on the array design). In many cases these and other effects were judged to be a necessary trade off to preserve the dynamic range of the recording system (see Figure 1). A summary of some of the problems associated with the use of field arrays can be found in Table 1.



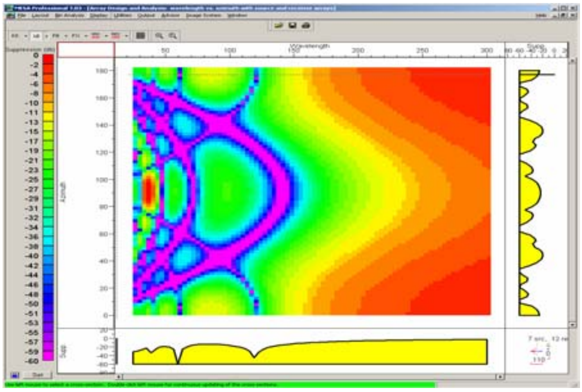


Figure 1 (left): Various phenomena that combine to distort the seismic signal when recorded by an array. Note that while the noise is effectively cancelled in Figure 1, inter array statics caused by elevation changes and lateral inhomogeniety cause misalignment in the output of the individual array elements thereby degrading the output of the array. As a result, the array behaves as a low pass filter. Figure 2 (right): Azimuthal response (left axis 0 - 180 degrees) of a linear geophone array response (right axis) convolved with a linear source array (bottom axis). Note that the net effect is a unique response at every azimuth.

As system design progressed, the industry achieved architectures which supported very high instantaneous dynamic range, usually in the order of 120dB. At this point the requirement for long linear arrays to function directly as K filters was greatly reduced. Instead they became more useful to fulfill sampling requirements and avoid spatial aliasing problems. Coincident with the arrival of modern ΔΣ systems architecture was the commercialization of Land 3D acquisition techniques. Despite the wide variety of azimuths acquired by most 3D designs, geophones are still deployed predominately as linear 1D arrays (often due to limitations in placing receivers "off line"). The result is a unique array response for each source-receiver azimuth (see Figure 2).

ARRAY BENEFITS	ARRAY PROBLEMS
• Tunable to reject undesirable wavelengths	• Generally not tuned correctly (if at all)
• Protects against spatial aliasing of short wavelengths	• Other rejection notches present, unique azimuthal response
• Coupling and tilt response averaged over multiple sensors	• Functions as low pass filter
• Attenuation of random noise	• Inter array statics attenuate high frequencies
• √n improvement in signal (if properly coupled with no tilt)	• Slow deployment/retrieval

Table 1: Array Benefits and Problems.

Full Wavefield Point Receivers:

In 2001 Input/Output commercialized their MEMS based VectorSeis® TrueDigital™ sensor system. Besides being the first commercially available digital multicomponent sensors, these sensors have a number of unique properties (Tessman et al, 2002), chief amongst these is their inherently high vector fidelity. As such the sensor system is capable of recording the full wavefield particle motion with only a 1% error (i.e. 40dB of Vector Fidelity). These sensors have a direct digital output and are intended for use as point receivers. While economics dictate that the sensors are deployed as point receivers, nothing other than cost preclude their use in a densely spaced manner which would allow the use of more conventional array forming techniques to achieve the same goals (Ongkiehong et al, 1988)

Because of concerns over spatial aliasing, additional research has been performed on techniques which would allow suppression of these unwanted wavelengths when using point receivers (Crews, G., Kappius, R., 2002). Based on an adaptive vector filtering technique a method has been developed which solves many of the problems associated with the lack of a field array when employing high fidelity full wavefield point receivers. Many unwanted wave phenomena that are difficult to identify and attenuate when recording the P scalar only are much easier to identify and suppress when the full wavefield vector is preserved. Table 2 summarizes the benefits and problems associated with the use of full wavefield (i.e. multicomponent) point receivers when used in conjunction with adaptive vector filtering (Figure 3a, 3b, 4). Table 3 highlights the potential cost savings associated with the use of point receivers. These are actual crew productivity numbers achieved under real field situations.

POINT RECEIVER BENEFITS	POINT RECEIVER PROBLEMS
• Same response at all azimuths	• Requires high Vector Fidelity sensor system
• Technique works for any sample interval, irregular sample intervals	• No redundancy for coupling
• Technique adapts to multiple wavelengths	• No multiplicity for S/N improvement
• Technique does not degrade data	• Industry acceptance
• Rapid deployment/retrieval	

Table 2: Point Receiver Benefits and Problems.

	Project 1	Project 2	Project 3	Total Days
Planned Field Days	75	37	14	126
Actual Field Days	49	26	8	83
Savings	**26**	**11**	**6**	**43**

Table 3: Operational efficiencies achieved for a single client using point receiver deployment. Note that the use of point receivers over conventional arrays resulted in a total savings of 6 weeks in field time and hence overall project costs decreased while data were delivered to interpretation staff sooner.

Data Examples:

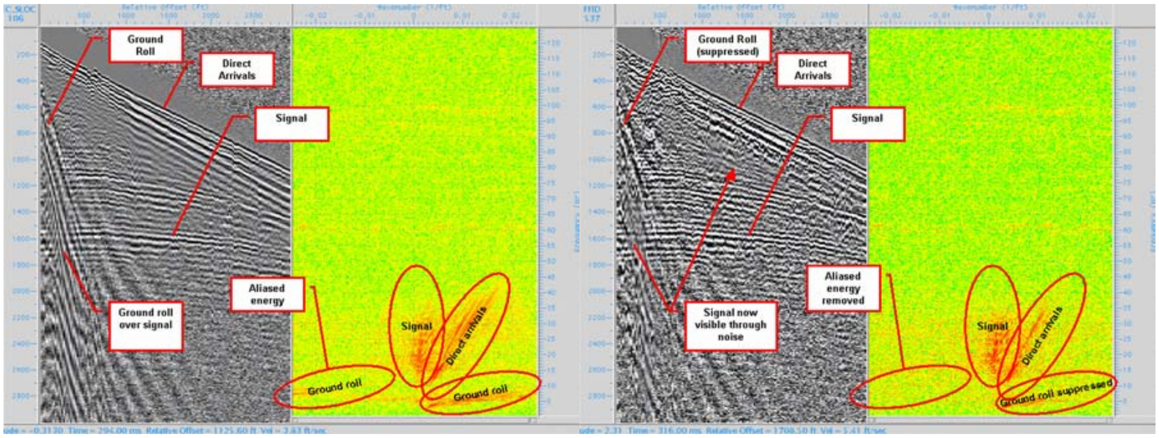
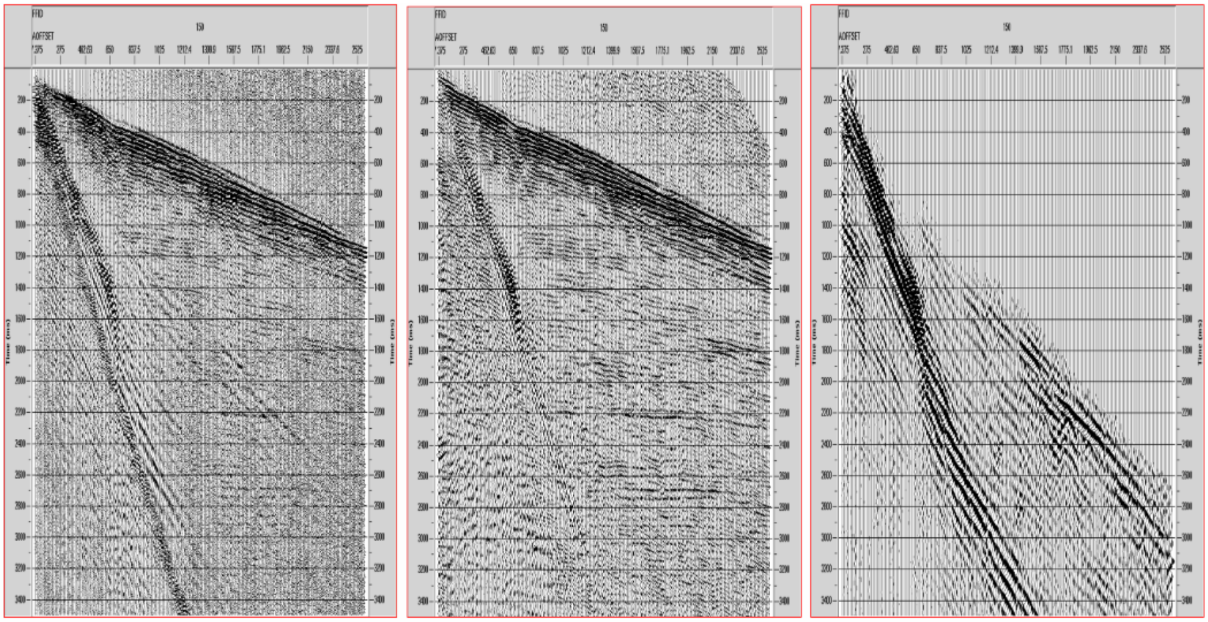


Figure 3a and 3b: early examples of adaptive filtering in time domain and FK domain. Note how the Rayleigh wave is no longer aliased. Significant amount of suppression has been achieved.



Original Shot Record

After Adaptive Vector Filter

Noise removed

Figure 4: Example shot record before and after one application of Adaptive Vector Filtering algorithm. Note how well the Rayleigh wave and the direct shear arrival are suppressed. Deep reflection events are now clearly visible on the single fold shot record.

Conclusions:

The use of full wavefield (i.e. multicomponent) point receivers in conjunction with techniques like adaptive vector filtering can in many cases replace the use of traditional field arrays with little or no danger of contamination of data by aliased energy. In many cases, the point receiver data can yield higher frequency content. This is especially true in 3D geometries where a wide variety of azimuths are present. In addition, the efficiencies generated by using this technology can lead to higher crew productivity and lower overall project costs.

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