change, the exact area of the network affected by this bad data area can vary.

- As the vessel maneuvers, “ripples” are transmitted along the cable, with a wavelength of the same order of magnitude as the vessel motion – typically 500 – 2,000m.
- Kalman (or other) filtering techniques force some temporal consistency in the errors. If a receiver position is calculated 5m to the north of its true location at one shotpoint, it will still be approximately 5m to the north of its true location at the next shotpoint.
- Network adjustment algorithms will tend to distribute errors across regions of a network, creating transient, but systematic spatial distortions. If a receiver position is calculated 5m to the north of it’s true location, the adjacent receivers (both in-line and crossline) will probably be approximately 5m to the north of their true location as well.

Given these circumstances, it is more reasonable to think of positioning errors as "clusters" of errors that drift around a zero mean, but are not necessarily zero mean at any shot, receiver or CMP location. In the presence of geological dip, the result of these errors is not simply a high cut filter, but also a subtle spatially variant time shift. (Archer *et al*[2])

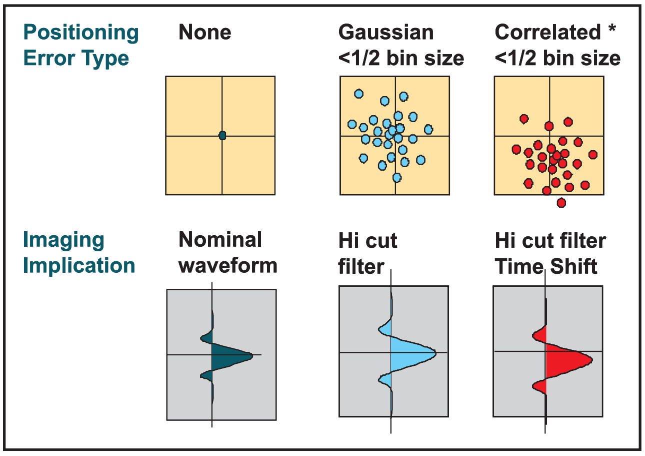

Fig-4. Illustration of impact of positioning errors on seismic wavelet.

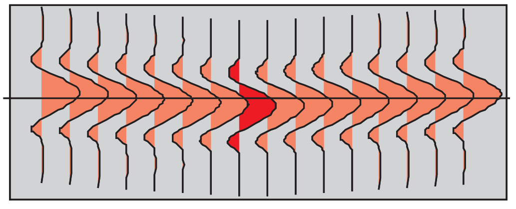

Fig-5(a). Effect of spatially correlated positioning errors on 3D seismic image

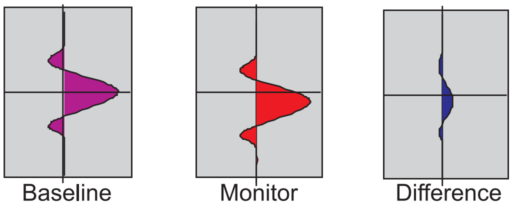

Fig-5(b). Impact on 4D difference signal caused by changes in positioning correlation between baseline and monitor.

Provided that the survey is properly designed, the errors should be less than a single sample period, and within normal tolerances for a traditional 3D structural survey.

Whilst these correlated errors may be acceptable for most 3D applications, they can become a limiting factor for 3D surveys seeking enhanced resolution, and for many 4D applications.

For 4D surveys, there is another factor that can create correlated errors between surveys. Traditional navigation processing techniques require a skilled operator, making many subjective decisions about what data to include or exclude, or what filtering algorithms to apply. If different operators work on the baseline and monitor surveys, further systematic biases could be introduced.

Cost effective strategies to achieve adequate 4D positioning

The primary strategy to improve streamer positioning accuracy is the implementation of full acoustic cross bracing. The concept is simple. The acoustic networks traditionally deployed at the front, mid and tail of the cable are extended along the full length of the streamer network. This can result in improvements in accuracy of 60% or more.

With traditional technologies, the cost of adding all the extra acoustic devices would be prohibitively expensive. Input/Output's solution is to upgrade 50% of the compass birds deployed on the cable, and replace them with DigiRANGE II acoustic birds. This means that for every heading sensor observation removed from the network , 6-8 direct range observations are added.

Benefits of this approach include : -

- 60% improvement in positioning accuracy.
- No additional external devices mounted on the streamer. (No increase in noise, no increase in retrieval and deployment time.)
- The additional redundancy and continuity in the acoustic network allows estimation of spatial and temporal variations in propagation velocity.
- If the streamers are to be deployed with lateral steering devices such as DigiFIN of I/O systems, the streamer shape may have cusps (kinks) at the locations of the lateral steering devices. In this case, heading sensors cannot be used as the primary method of streamer shape estimation. Full acoustic cross bracing is a necessary pre-requisite to applying lateral streamer steering technology as shown, for example in Figure 7 for DigiRANGE II of I/O systems.

Many oil company specifications currently require a "magnetic heading sensor to be placed every 300 meters along the streamer". It should be noted that the upgrade