[GC]3-D Design Philosophy – Part 4: The Even-Integer Rule*

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Even-Integer Rule

This article is the fourth of a four-article series. The final guideline that should be used when designing a 3-D survey is the use of the even-integer rule for specifying the exact dimensions of a recording swath. This design principle can be stated as:

*A recording swath should span an even number of receiver lines and an even number of source-line spacings (*Figure 1*).*

This rule defines how wide a 3-D recording swath should be in the inline and cross-line directions so stacking fold is a constant, non-oscillating value across 3-D image space. This even-integer rule does not replace the previously described concept of using the depth of the primary imaging target to define the size of the recording swath; the rule merely adjusts swath dimensions by small amounts to ensure a uniform stacking fold is achieved. For example: If the depth and size of the primary imaging target cause a designer to define the in-line dimension of the recording swath to be 14,000 feet and the receiver station spacing to be 110 feet, the even-integer rule might make a designer adjust the inline dimension to 13,200 feet (120 receiver stations) or to 14,080 feet (128 receiver stations), depending on how many receiver stations occur between adjacent source lines. When applied in the cross-line direction, the even-integer rule says the recording swath should span an even number of receiver lines. For example, a recording swath consisting of eight, 10 or 12 receiver lines is better than one consisting of nine, 11, or 13 lines. Note that the wording of the rule uses the phrase, "should span," not the more restrictive condition, "must span."

Reason for Even-Integer Rule

The reason for this even-integer guideline can be seen by referring to the equation for cross-line stacking fold FXL described in Part 3 of this article series, which is:

FXL = (1/2) (Number of receiver lines in recording swath).

If the number of receiver lines used in that stacking-fold calculation is an even integer – say eight – then the cross-line fold FXL is a whole number: four. In contrast, if the number of receiver lines in the recording swath is an odd number – say nine – then the cross-line stacking fold FXL is a fractional number: 9/2. Data processors can sum four seismic traces to create four-fold data or five traces to make five-fold data, but they cannot include one-half of a trace in the summation process to create 4.5-fold data. Instead, stacking fold in adjacent bins in the cross-line direction oscillates between four and five so that, in an average sense, the cross-line stacking fold is 4.5.

An oscillating stacking fold is not fundamentally wrong; it simply introduces data-processing challenges that if not properly addressed cause a 3-D image to contain geometry-induced amplitude variations that have nothing to do with geology. When the even-integer rule is applied in the in-line direction, it requires the receiver lines to span an even number of source-line spacings, which means an odd number of source lines should be included in the swath.

For example: A recording swath should span six, eight or 10 source-line spacings (which would involve seven, nine or 11 source lines, respectively) rather than span five, seven or nine source-line spacings (which would require six, eight or 10 source lines, respectively).

If for any reason – such as permitting constraints or lack of local surface access – a recording swath cannot span an even number of source-line spacings, the even-integer rule can be amended so the design requirement is:

Receiver lines in the recording swath should start and stop exactly on source lines.

The rationale for this rule is that to avoid oscillations in stacking fold in the in-line direction, the stacking fold value FIL must be a whole number, not a fractional number. The only way to ensure FIL will be a whole number is to force the numerator in the FIL equation stated in last month's article to be an even multiple of the denominator. Consequently, the dimension of a recording swath in the in-line direction should be an even multiple of the source-line spacing.

Example

An example of the even-integer rule in 3-D design is illustrated as Figure 2 and Figure 3. The key geometrical parameters are:

- Source-line spacing = 1,320 feet.
- Receiver-line spacing = 880 feet.
- Source-station spacing = 220 feet.
- Receiver-station spacing = 110 feet.

Consequently, there are 12 receiver stations between adjacent source lines and four source stations between adjacent receiver lines. Two recording swaths, A and B, are shown overlaying the 3-D grid on Figure 2. Swath A honors the even-integer rule; swath B does not. In the cross-line direction, swath A spans 10 receiver lines, which obeys the even-integer requirement. Swath B violates the even-integer rule in the cross-line direction because it spans 11 receiver lines. In the in-line direction, swath A spans 96 receiver stations, but swath B spans 84 receiver stations. For source stations *a* at the center of swath A, there are 48 receiver stations (that is, four source-line spacings) north and south of the source position, causing swath A to span an even number (eight) of source-line spacings.

For source stations *b* at the center of swath B, there are 42 receiver stations. Swath B thus spans an odd number (seven) of source-line spacings and violates the even-integer rule in the inline direction. Swath B is further undesirable because it does not start and stop on receiver lines. Because of these geometrical constraints, swath A creates whole number values of four and five for stacking fold parameters FIL and FXL, respectively, and a uniform stacking fold of 20 across the 3-D grid. In contrast, swath B creates fractional (non-integer) values for in-line, cross-line and 3-D stacking folds. Specifically for swath B:

- FIL = 3.5.
- FXL = 5.5.
- F = 19.25.

The 3-D stacking fold patterns produced by swaths A and B are compared on Figure 3. Swath A, which honors the even-integer design rule, creates a uniform stacking fold of 20 across the full-fold central portion of the 3-D grid. Swath B, which violates the even-integer rule, produces an oscillating stacking fold in both the in-line and cross-line directions, which results in a less-desirable checkerboard pattern of variable fold across the grid. Because the 3-D stacking fold is 19.25, the checkerboard pattern consists of abutted areas having stacking folds of 14, 18 and 22 that when averaged together give an average stacking fold of 19.25 over the full-fold portion of the image space. Although seismic data processors can usually adjust reflection amplitudes resulting from this type of irregular stacking fold so that the amplitudes are correctly balanced across the image space, it is prudent to use an acquisition geometry that does not create such data-processing problems.

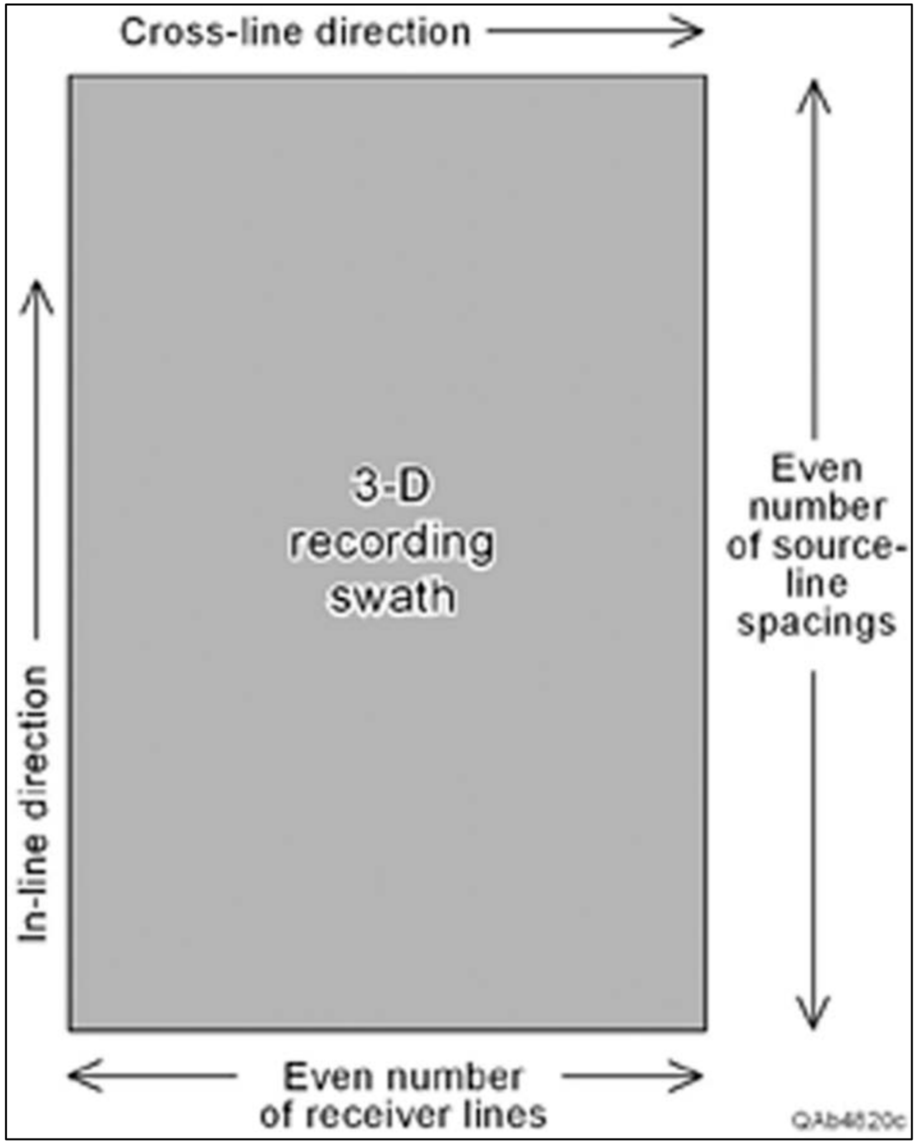

Figure 1. The even-integer rule for onshore 3-D seismic design. This rule defines what the in-line and cross-line dimensions of a 3-D recording swath should be, so that 3-D stacking fold has a constant integer value across most of a 3-D acquisition grid. The rule specifies that the in-line dimension of a recording swath should span an even number of source-line spacings. This geometrical constraint causes the in-line stacking fold FIL to be a whole number, not a fractional number. A fractional value for FIL causes stacking fold oscillations in the inline direction; a whole number value creates a constant in-line stacking fold. The even-integer rule further specifies that the cross-line dimension of the recording swath should span an even number of receiver lines. This constraint causes the cross-line stacking fold to be a whole number, not a fractional number, and results in a constant, non-oscillating integer-value stacking fold in the cross-line direction.

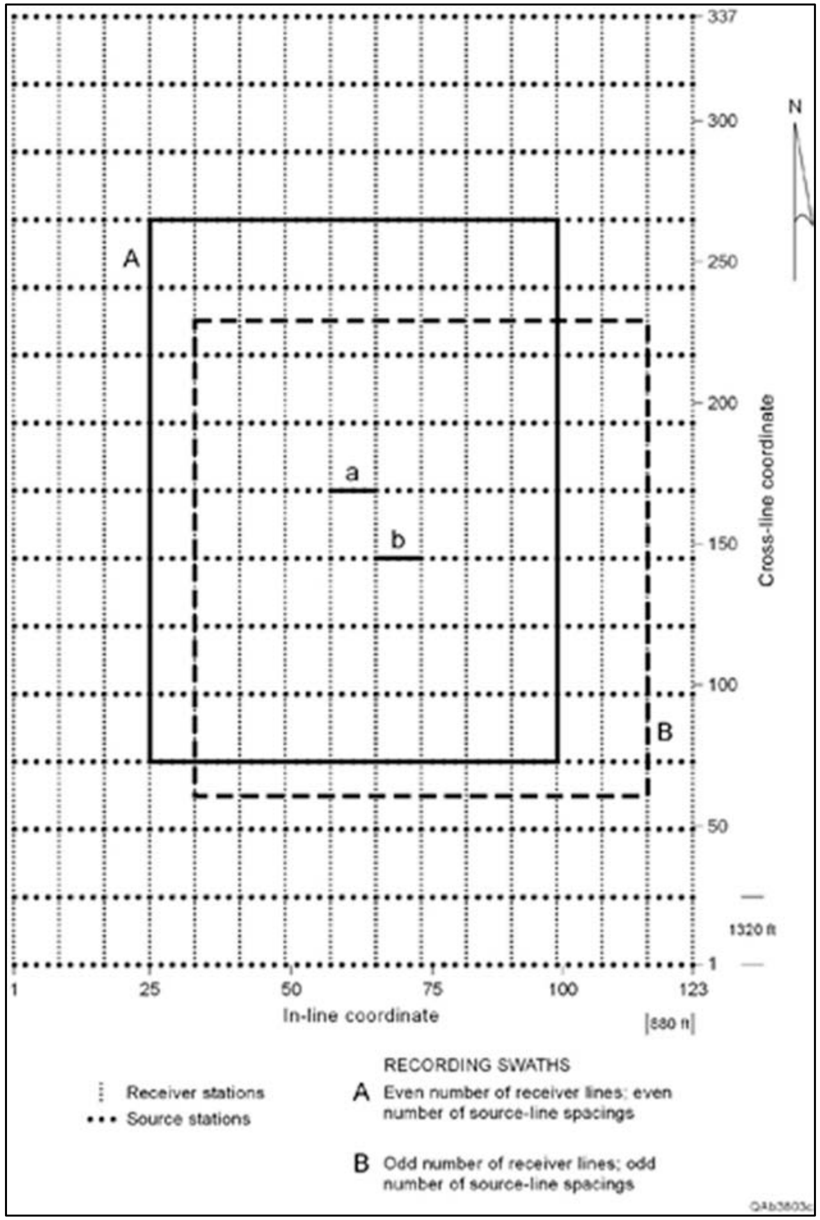

Figure 2. Comparison of two 3-D recording swaths, A and B. Swath A honors the even-integer rule because it spans 10 receiver lines in the cross-line direction (east-west) and eight source-line spacings in the in-line direction (north-south). Swath B violates the even-integer rule twice because it spans 11 receiver lines in the cross-line direction (violation one) and seven source-line spacings in the in-line direction (violation two). The source-line and receiver-line spacings and the source-station and receiver-station intervals used in this 3-D design are 1,320 feet, 880 feet, 220 feet, and 110 feet, respectively.

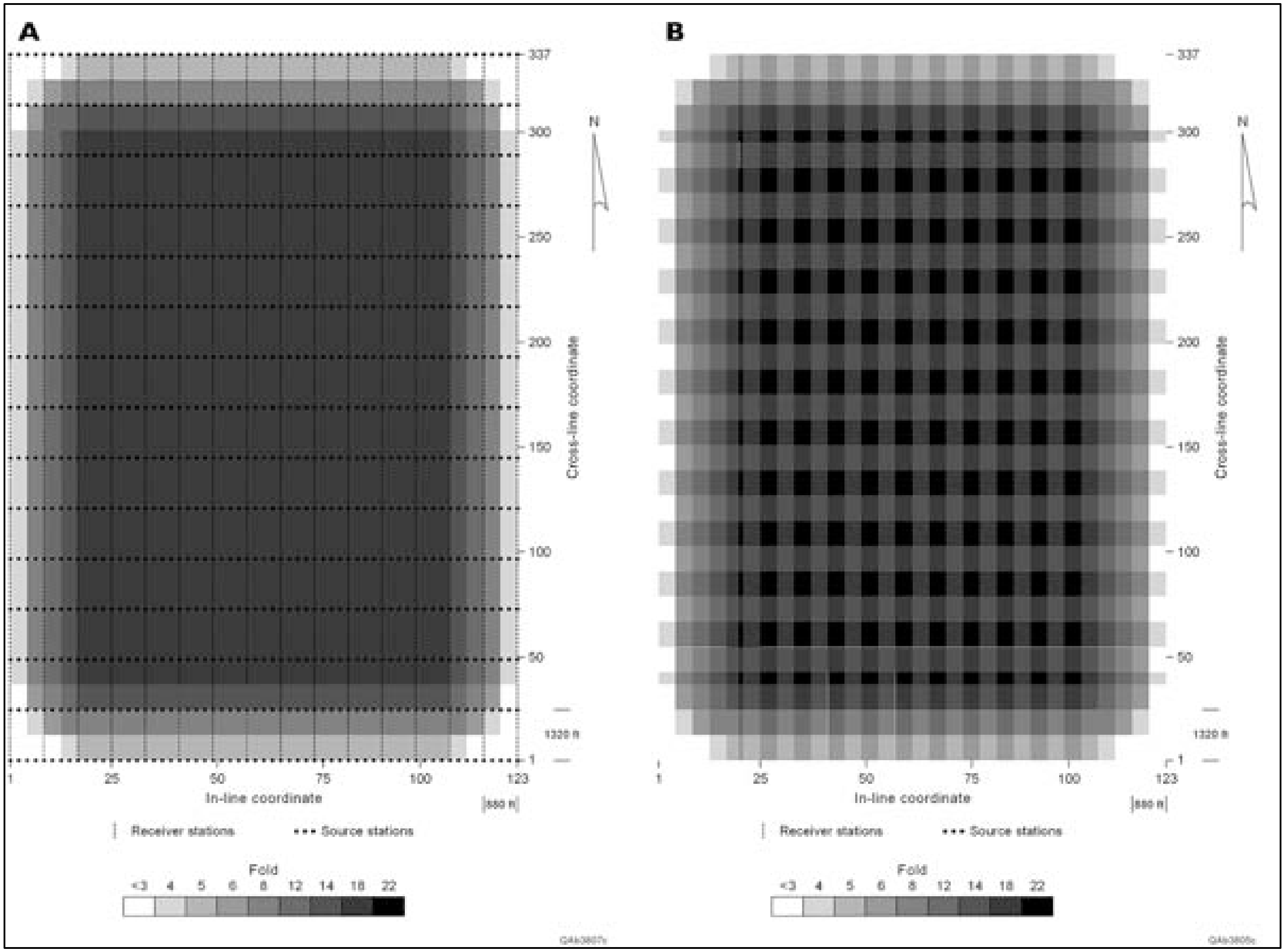

Figure 3. Comparison of software-generated stacking folds created by swaths A and B. The geometrical parameters for swath A result in a 3-D stacking fold having a value of 20. The 3-D design software achieves that same answer (a). Because swath A honors the even-integer rule, the stacking fold has a constant, non-oscillating behavior over the entire full-fold coverage area (a). The geometrical parameters for swath B cause stacking fold to be a fractional number, 19.25, because swath B violates the even-integer rule. The stacking fold produced by a commercial software design for swath B has a checkerboard pattern consisting of small, abutted areas that have stacking folds ranging from 14 to 22 (b). The spatial distribution and size of each of these distinct stacking-fold areas are such that the average stacking fold over the total full-fold portion of the grid is 19.25. The laterally varying stacking fold produced by swath B makes it difficult to do some data-processing steps (particularly amplitude balancing). The uniform stacking fold created by swath A simplifies data processing and creates confidence in any interpretational process that analyzes variations in reflection amplitudes.