



(51) International Patent Classification:

G01V 1/00 (2006.01) G01V 1/38 (2006.01)
G01V 1/20 (2006.01)

(21) International Application Number:

PCT/NO2019/050038

(22) International Filing Date:

15 February 2019 (15.02.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1802978.5 23 February 2018 (23.02.2018) GB

(71) Applicant: **EQUINOR ENERGY AS** [NO/NO]; Forus-
been 50, 4035 Stavanger (NO).

(72) Inventor: **RAMIREZ-PEREZ, Adriana Citlali**; Olav
Kyrres gt. 8 H0304, 0273 Oslo (NO).

(74) Agent: **WHITE, Duncan**; Marks & Clerk, Fletcher House
(2nd Floor), Heatley Road, The Oxford Science Park, Ox-
ford Oxfordshire OX4 4GE (GB).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: IMPROVED SEISMIC SOURCE FIRING SEQUENCE AND RECEIVER ARRANGEMENT

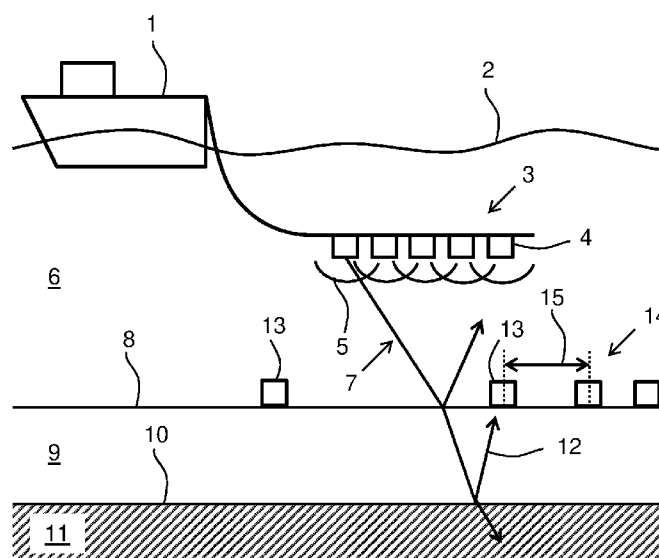


Figure 1

(57) Abstract: A method of determining a firing sequence of a plurality of seismic sources for use in a seismic survey. The method comprises receiving a first low discrepancy sequence and a second low discrepancy sequence, and determining from said first and second low discrepancy sequences the firing sequence by alternately selecting consecutive numbers from said first and second low discrepancy sequences, wherein said plurality of seismic sources are fired according to said firing sequence in said seismic survey.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Improved Seismic Source Firing Sequence and Receiver Arrangement

Technical field

The invention relates to the general field of seismic surveying of a subsurface of the Earth. Specifically, the invention relates to the firing sequence of seismic sources and the layout of receivers.

Background

Seismic surveying is used to map geological features of the subsurface of the Earth. In particular, seismic surveys may be used to identify and locate hydrocarbon rich reservoirs in the subsurface. One or more seismic sources are fired to create seismic waves which are transmitted into the subsurface and reflected back from geological features. For example, the sources may be air guns trailed behind a vessel during a marine seismic survey. The sources are fired to generate acoustic waves which travel down through the sea, and through the sea floor and into the underlying formation. The waves are reflected from interfaces between layers of formation with different acoustic impedances and detected by receivers on or above the sea floor. By analysing the time of flight (also known as the two-way traveltime) of the reflected waves, a map of the subsurface and the geological features within can be generated.

A single reflection from a point is generally insufficient to adequately map that point. Hence, signals generated from multiple sources and multiple "shots" and reflected from the same geological feature may be combined. For example, the sources may be fired at a set repetition rate to produce multiple traces. If the repetition rate is low (comparable to the two-way traveltime) the signals from subsequent shots will not interfere significantly and can easily be separated and analysed. However, a low repetition rate produces less data (i.e. fewer signals for a given amount of time).

There exists technology for generating a shooting pattern in which different sources are shot at a greater rate, so that their generated records overlap with each other (so called blended signals). The pre-defined shot-point interval is generally significantly shorter than the two-way traveltime, signals from individual sources. The individual signal traces at a receiver is a superposition of interfering waves from multiple sources. Such "blended" signals may be complex and cannot be interpreted directly without further

signal processing to “deblend” the signals. A common technique is to specify a constant shot point interval between subsequent firing of sources and add random “dithers” or time delays to each shot point. Alternatively, a firing sequence can be specified in terms of sample spacing (so called pre-plot shooting) instead of shot point interval. That is, the firing sequence specifies the locations of firing instead of the times. As the surveying vessel travels on the sea surface the sources can be fired as the vessel reaches a particular location. A space “dither” can be added to a given firing location similar to the way in which a time “dither” can be added to a firing time.

- 10 In the case of source dithers: The shooting times of a first source (e.g. a flip source) may be conventional (i.e. at a constant time interval or regular pre-plot spacing). The shooting schedule for a second source (e.g. a flop source) can then be based on a constant time delay relative to the firing times of the first source, plus small, relatively random time dithers within a time window (e.g. ± 100 ms up to ± 500 ms). The same
- 15 applies to any subsequent sources (e.g. using 3 to 6 sources or any other number). The processing, or deblending, strategy may rely on de-noising and/or local continuity and/or iterative and/or inversion algorithms aimed at preserving the coherency of events/signals. The algorithms can be used on data sorted in different ways (such as shot gathers, channel gathers, common midpoint (cmp) gathers, offset gathers, etc).
- 20 Often the input data domain is selected such that the signals from one set of sources (e.g. all the flip sources) are aligned to their zero-firing time and signals from the overlapping sources have a random or noise-like appearance. This characteristic allows deblending based on, e.g., assumptions about local continuity and/or coherency.
- 25 For coherency based processing, in order for the deblending to be successful, coherency of the aligned sources (e.g. the flip sources) and incoherency of the overlapping sources is necessary. However, using a random sequence or pseudo-random sequence to determine the firing sequence does not always provide enough incoherency, as random sequences can have patterns and sequential (or near-by)
- 30 repetitions. When patterns or near-by repetition of the dither times appear, the processing or deblending of the data can be negatively affected.

A Gaussian type random number generator may be used to generate the random sequence, which then has a Gaussian or normal distribution. Some constraints may be imposed to avoid patterns in the sequence. However, these constraints would normally

only avoid repetition of the exact same number sequentially, so that any adjacent dither imposed on a given source (e.g. to flop sources) is never a repetition. This may help to some extent, but does not take into account the possibility of numbers that are different but too close to each other, or numbers that are very similar and close but not next to each other in the sequence. The latter can have a residual, e.g. on the low temporal frequencies and even affect the amplitude of the deblended data, giving false amplitudes, and even false amplitude vs offset (AVO) signals (see e.g. US 9,081,107). US 9,081,107 suggests solving this problem by closely examining several collections of sets or sequences of random numbers and picking the best sequence, and then using such a sequence repeatedly throughout a given acquisition. This might still have some undesired regularities for 3D datasets which have to be addressed.

Another problem may arise if a sub-optimal random number generator is used. This can cause the derived dither times to be more heavily concentrated at the centre of a bell or Gaussian curve. This concentration can have detrimental effects on the deblending (especially at the low temporal frequencies as explained above), as it often means that there is not enough incoherency to enable an effective deblending, making the deblending process more costly or less effective. The problem may not be apparent until after all the data has already been collected and processed. Furthermore, it has been observed that another measure of how optimal a sequence of numbers is, is the distribution of the sequential difference. In other words, one can also evaluate the sequential difference of adjacent dithers, and examine their distribution. Often the distribution of the sequential difference is even more heavily concentrated at the centre of a Gaussian curve. This sequential difference gives an indication of how different or similar nearby numbers are, rather than adjacent numbers.

Another technique uses a sequence that is periodic or semi-periodic as in seismic apparition ideas as described in WO2017179988. Alternatively, the shot point interval can be defined to follow a specific pattern such as a saw-tooth pattern.

In addition to controlling the firing time (or location) of subsequent sources, the pattern in which individual guns are fired may also be controlled. US2015/260867 describes a technique (often referred to as popcorn shooting) where individual guns are shot in a random pattern within a given time interval.

In the case of two or more vessels used in a survey operation, it is also common to rely solely on natural variations (i.e. random variations without human intervention due to e.g. wave movement, vessel speed changes, etc.) between the different vessels. This is usually referred to as Independent Source Shooting.

5

Also the positioning and arrangement of seismic receivers may have an important effect on the results of a seismic survey. In general, to map a 2D slice of the Earth's subsurface a line of receivers may be used, whereas to map a 3D volume of the Earth's subsurface a 2D grid of receivers would generally be used. Random sampling (i.e. a random receiver layout) may in some cases be used to recover a greater bandwidth for a given number of samples compared to regular sampling. However, such random receiver arrangements may suffer similar problems to those of random firing sequences, wherein receivers become too clustered in some areas.

10

15

US 9,632,193 attempts to solve this problem using a new algorithm referred to as Non-Uniform Optimal Sampling (NUOS). An optimisation loop combined with a cost function is used to determine the locations of sources and receivers. The cost function can take many forms, ranging from a conventional array response to more sophisticated matrix analysis techniques.

20

Summary

According to a first aspect of the present invention there is provided a method of determining a firing sequence of a plurality of seismic sources for use in a seismic survey. The method comprises receiving a first low discrepancy sequence and a second low discrepancy sequence; determining from said first and second low discrepancy sequences the firing sequence by alternately selecting consecutive numbers from said first and second low discrepancy sequences, wherein said plurality of seismic sources are fired according to said firing sequence in said seismic survey.

25

30

According to a second aspect of the present invention there is provided a method of operating a plurality of seismic sources during a seismic survey. The method comprises receiving a firing sequence determined according to the method of the first aspect, and firing the sources at respective firing times or firing positions given by the firing sequence.

35

According to a third aspect of the present invention there is provided an apparatus configured to perform the method of the first and/or second aspect.

- 5 According to a fourth aspect of the present invention there is provided a computer readable storage medium for storing computer executable instructions, which cause the computer to perform the method of the first and/or second aspect when executed.

- 10 According to a fifth aspect of the present invention there is provided a method of determining an arrangement of a plurality of receivers for conducting a seismic survey. The method comprises receiving a first low discrepancy sequence, determining for each receiver, from the first low discrepancy sequence, a position in which the receiver is to be placed for the survey.

- 15 According to a sixth aspect of the present invention there is provided a receiver arrangement which comprises a plurality of receivers in an arrangement as determined according to the fifth aspect.

- 20 According to a seventh aspect of the present invention there is provided receiver arrangement for use in a seismic survey, the receiver arrangement comprises a plurality of receivers at respective positions, wherein said positions are determined from a low discrepancy sequence.

- 25 According to an eighth aspect of the present invention there is provided a method of determining an output signal of a continuous seismic source. The method comprises determining a frequency range within which said source is configured to generate output signals, selecting a subset of frequencies corresponding to a low discrepancy sequence from said frequency range, and then determining an output signal having a frequency content comprising substantially only the frequencies from said subset of
30 frequencies.

Each and any of the above aspects may include further features, as set out in the claims appended hereto or in the present description.

Brief Description of Drawings

- Figure 1 is a schematic diagram of a marine seismic survey;
- Figure 2a is a graph of amplitude plotted against time for a long shot-point interval;
- Figure 2b is a graph of amplitude plotted against time for a short shot-point interval;
- 5 Figure 2c is a graph of amplitude plotted against time showing a blended signal;
- Figure 3a is a graph of amplitude plotted against time for a long shot-point interval;
- Figure 3b is a graph of amplitude plotted against time for a medium shot-point interval;
- Figure 3c is a graph of amplitude plotted against time showing a blended signal;
- Figure 4a is a schematic time vs offset graph;
- 10 Figure 4b is another schematic time vs offset graph;
- Figure 5 is a schematic diagram of a firing sequence for two sources according to an embodiment;
- Figure 6a is a graph of amplitude plotted against time for a continuous source output signal;
- 15 Figure 6b is another graph of amplitude plotted against time for a continuous source output signal;
- Figure 6c is a graph of amplitude plotted against time for a continuous source output signal according to an embodiment;
- Figure 7a is a frequency spectrum;
- 20 Figure 7b is another frequency spectrum;
- Figure 7c is a further frequency spectrum;
- Figure 8 is a graph showing points in a Hammersley sequence;
- Figure 9 is a graph showing the difference between consecutive points in a Hammersley sequence;
- 25 Figure 10 is a graph showing points from two dimensions of a Hammersley sequence;
- Figure 11 is a graph showing the difference between consecutive points from two different dimensions of a Hammersley sequence;
- Figure 12 is a schematic diagram of a regular receiver arrangement;

Figure 13 is a schematic diagram of a regular and sparse receiver arrangement;

Figure 14 is a schematic diagram of a random and sparse receiver arrangement;

Figure 15 is a schematic diagram of an irregular receiver arrangement according to an embodiment;

5 Figure 16 is another schematic diagram of the irregular receiver arrangement according to an embodiment;

Figure 17 is a schematic diagram of another irregular receiver arrangement according to an embodiment;

10 Figure 18 is a schematic diagram of a regular receiver arrangement deployed on a cable or rope;

Figure 19 is a schematic diagram of a regular and sparse receiver arrangement deployed on a cable or rope; and

Figure 20 is a schematic diagram of an irregular receiver arrangement deployed on a cable or rope according to an embodiment.

15

Detailed Description

To overcome the above outlined problems with using a sequence of random numbers, embodiments described herein use a Quasi-Monte Carlo sampling method, also known as a quasi-random, low discrepancy or sub-random sampling method. In the normal
20 Monte Carlo method, random numbers are used as inputs to solve an integral or other function. In the Quasi-Monte Carlo method, the random numbers are replaced by a low discrepancy sequence. In this specification, "Quasi-Monte Carlo sequence" is used interchangeably with "low discrepancy sequence".

25 A low discrepancy sequence is a deterministic sequence of N points (i.e. of numbers, values, etc.) that fills a given space more uniformly than uncorrelated random points. Low-discrepancy sequences sample such a space more evenly than random sequences, by reducing gaps and clustering. A low discrepancy sequence is a set of s -dimensional points, filling the sample area in an efficient manner, where such a set has
30 a lower discrepancy than a random number set but not as low as an equidistributed (i.e. regular) sequence. Discrepancy is a measure of deviation from uniformity. A discrepancy that tends to zero as N tends to infinity is a property of an equidistributed

sequence. Examples of low discrepancy sequences include: Halton, Faure, and Hammersley sequences.

A low discrepancy sequence can be generated from random numbers by imposing a negative correlation on those random numbers. For example, starting with a set of random numbers r_i on $[0, 0.5)$, subrandom numbers s_i which are uniform on $[0, 1)$ can be generated by

$$\begin{aligned} s_i &= r_i, \text{ for } i = \text{odd} \\ s_i &= 0.5 + r_i, \text{ for } i = \text{even.} \end{aligned}$$

In a preferred embodiment, a double Quasi-Monte Carlo sequence, with predefined constraints is used to draw numbers and generate the dithers for each source. The predefined constraints are related to practical aspects, such as the minimum interval that can be used in the gun controller, the minimum time required to recharge a given gun or gun cluster, and whether or not the dither can be zero, etc. The idea can be used to design any experiment/survey where a certain degree of incoherency in a given domain is desired.

Figure 1 is a schematic diagram of a marine seismic survey. A vessel 1 at the sea surface 2 trails a seismic source 3 which is an array of five guns 4. The guns 4 may be air-guns 4 that rapidly release compressed air into the water to generate an acoustic wave. Each gun 4 is fired to create acoustic waves 5 travelling down through the sea water 6. The path of a single ray 7 of an acoustic wave 5 from one of the air guns is shown. Some of the energy of the wave is reflected from the sea floor 8. Another portion of the wave penetrates the sea floor 8 into the underlying formation 9. The wave travels through the formation 9 and is reflected from an interface 10 between the formation 9 and a layer 11 having a different acoustic impedance. The reflected wave 12 is detected by a receiver 13 in an arrangement of receivers 14 on the sea floor 8. The distance 15 between adjacent receivers is different, and may be determined according to an embodiment. A part of the wave is transmitted through the interface between the upper layer 9 and the lower layer 11, and may subsequently be reflected from deeper layers (not shown).

Although Figure 1 only shows one source 3 comprising one string 3, generally a single vessel will trail multiple (e.g. 3 to 6) arrays in parallel and a source may comprise multiple (e.g. 3) sub-arrays/strings. For example, in triple source mode, each source

(flip, flop, flap) comprises two sub-arrays. Different combinations of two sub-arrays can be used in a penta-source (equipped with six strings in total). A single line 14 of receivers 13 is shown, which may be used to generate a 2D map (slice) of the subsurface. However, to generate a 3D (volumetric) map of the subsurface a 2D arrangement of receivers 13 may be used. In Figure 1, the guns 4 are fired simultaneously, creating a single wave front as the superposition of individual waves 5. However, in some embodiments the individual guns 4 may be fired at different times. By firing the guns 4 over an extended period of time, instead of simultaneously, lower acoustic amplitudes may be achieved for a given amount of energy.

Figure 2a is a graph 20 of amplitude plotted against time. A first signal (associated with a first wave) 21 from a first source arrives before a second signal 22 (associated with a second wave) from a second source. The firing times of the two sources are sufficiently spaced so that the reflected waves 21 and 22 do not interfere. That is, the first signal 21 can easily be separated from the second signal 22. In Figure 2b the second source was fired shortly after the first source (near simultaneous source shooting), and there is significant overlap of the reflected signals 21 and 22. In practice, these signals 21 and 22 are superposed and the receiver “sees” a single trace 23 as depicted in Figure 2c. The blended signal 23 may be the superposition of signals 21 and 22 in Figure 2b. The received signal 23 then has to be processed to resolve the two separate signals 21 and 22.

Figures 3a is a graph 30 similar to Figure 2a, in which the amplitude of two waves/signals 31 and 32 from different shots is recorded. The interval (which could be either a shot point interval or a pre-plot spacing) between the shots is sufficient that the signals 31 and 32 do not interfere. In Figure 3b, the shot interval has been chosen so that signal from the second shot 32 appears in a relatively quiet period of the first signal 31 (medium shot-point interval or pre-plot spacing). Figure 3c shows the superposed signal 33 (i.e. the actual received signal) due to the waves of both shots interfering. The overlap is less than that of the signal 23 in Figure 2c. This may allow the signal 33 to be deblended more easily. Alternatively, this setting (i.e. medium shot-point or pre-plot interval) may be preferred due to sampling requirements, or because there is less risk to deblend the signal of interest (e.g. if the initial pulse 31 before the overlapping time is more important), or because the deblending algorithm works better.

Figures 4a and 4b are schematic time vs offset graphs. The offset represents the distance between the source and the receiver in a measurement. In marine surveys, the offset changes as the vessel trailing the seismic sources moves on the sea surface. Figure 4a illustrates a scenario in which two sources are fired with a long shot-point interval (greater than the two-way traveltime). The straight lines represent the direct waves which travel from the source to the receiver without being reflected from a subsurface. The slightly curved lines 41 and 42 represent waves reflected from some geological feature in the subsurface. The graph may be constructed from multiple signal traces as depicted in Figure 2a or Figure 3a and recorded for different offsets. Figure 4b shows a similar time vs offset graph but for a shorter shot-point interval. Reflected waves 41 and 42 arrive much closer in time. The graph may be constructed from multiple signal traces as depicted in Figure 2b and recorded for different offsets.

Figure 5 shows a short firing sequence 50 of two sources according to an embodiment. Source 1 is fired at a first time t_1 and at a second time t_3 with a fixed time interval 41 in between. Source 2 is fired at times t_2 and t_4 . The time t_2 of the first shot 52 of the second source is given by the time of the first shot 53 of the first source plus a time delay (dither) 54. The time delay 54 is determined from a Quasi-Monte Carlo sequence. Alternatively, the time delay 54 may comprise a fixed time constant plus a small time dither, wherein the time dither is determined from a Quasi-Monte Carlo sequence. The time t_4 of the second shot 55 of the second source is similarly given by the time of the second shot 56 of the first source plus a second time delay (dither) 57. The second time delay 57 is determined from a second (different) Quasi-Monte Carlo sequence. Alternatively, the time delay 57 may comprise a fixed time constant plus a small time dither, wherein the time dither is determined from the second Quasi-Monte Carlo sequence. The skilled person would readily appreciate how the method could be extended to longer firing sequences containing any number of shots, as well as to any number of sources. In one embodiment, points from a first sequence of positive numbers are used to generate positive dithers, and points from a second sequence of negative numbers are used to generate negative dithers. That is, one Quasi-Monte Carlo sequence may be used to generate positive dithers while a second Quasi-Monte Carlo sequence is used to generate negative dithers. For example, a Quasi-Monte Carlo sequence may be multiplied by -1 in order to generate a sequence of negative numbers to generate negative dithers.

Although the embodiment described above with reference to Figure 5 specifies a method of determining a firing sequence in terms of the firing times (i.e. shot point interval), a similar method may be applied to determine a firing sequence in terms of pre-plot shooting. In such an embodiment, the times t1 and t3 of firing the first source are replaced by locations l1 and l3 with a fixed spacing in between where the first source is fired. The firing times of the second source t2 and t4 are replaced by firing locations l2 and l4 which are determined from l1 and l3 and two Quasi-Monte Carlo sequences. Traditional seismic acquisition experiments have favoured regularity, which often translates into a frequency or wavenumber band constraint by aliasing limits which are defined by the sampling interval in a given dimension or set of dimensions. Irregular sampling does not encounter the same aliasing challenges or limits related to regular sampling. The frequency or wavenumber content of an irregularly sampled signal is mostly challenged by noise instead of aliasing. Noise is often easier to deal with than aliasing

In one embodiment, Quasi-Monte Carlo sampling is used to determine a seismic source firing sequence by generating a sequence of time delays (dithers) and/or the absolute shooting times. In another embodiment, Quasi-Monte Carlo sampling is used to determine a source order (i.e. the order in which the sources are fired). In this way more advanced shooting patterns may be generated. In a further embodiment, a combination of Quasi-Monte Carlo source order with Quasi-Monte Carlo shooting times (either absolute or dithered times) can be generated to design a more advance pattern similar to, for example, triple-, penta-, hexa-source type of experiments. This embodiment may be referred to as "Double Quasi-Monte Carlo shooting", and would provide a degree of randomization in two dimensions. That is, randomization in source shooting times vs. one of:

1. individual guns;
2. gun's within a string or set of strings acting as a combined source;
3. any other combination or grouping of gun.

Note that the above described embodiments can be used in experiments with other types of sources and/or more than one vessel, and/or in on-shore experiments. Currently the number of sources are limited by operational constraints (e.g. the number of guns, gun strings, plus compressor capacity, desired minimum output volume, etc.)

In other embodiments, instead of using air-guns or other impulsive sources, continuous (non-impulsive) sources (e.g. marine vibrators or EM sources) may be used. Marine vibrators emit continuous waves by mechanically vibrating in the water at a given frequency (narrowband). However, sampling a single frequency (i.e. a narrow frequency range) generally provides insufficient information about the subsurface. Therefore, a marine vibrator may be chirped in order to sweep through a range of frequencies. The received signal may then be processed to reconstruct the response from an impulsive (broadband) source. A chirped signal may take up a large time slot in order to sample a sufficiently large frequency range. This may limit the fold (i.e. the number of recorded signals relating to a particular feature in the subsurface). In order to reduce the signal length, the frequencies may be irregularly sampled. Specifically, a Quasi-Monte Carlo (low discrepancy) sequence may be used to pick the sampling frequencies.

Figure 6a is a graph showing the output amplitude of a continuous source (e.g. a marine vibrator) operating at a given (fixed) frequency. The signal 60 may have a slow rise time compared to an impulsive source.

Figure 6b is a graph showing the output amplitude of a continuous source emitting a (linear) chirp signal 61. The signal 61 starts at a high frequency which is gradually lowered. Alternatively, the chirp 61 may start at a low frequency which is gradually increased.

Figure 6c is a graph showing the output amplitude of a continuous source emitting a chirp signal 62 with irregularly sampled frequencies. The sampling frequencies used in the source output are chosen from a Quasi-Monte Carlo sequence. The method allows a large frequency range to be sampled with a relatively short output signal, as compared to a normal frequency sweep signal.

The frequency content of a narrowband signal, such as the signal 60 in Figure 6a, is illustrated in Figure 7a. The frequency spectrum has a peak 63 centred on the operating frequency of the source and a narrow bandwidth.

The frequency content of a chirp signal, such as the signal 61 in Figure 6b, is illustrated in Figure 7b. As can be seen from Figure 7b, a wide range 64 of frequencies is

sampled more or less evenly across the range 64. As the spectrum contains many frequencies the associate signal can be used to reconstruct the response from a broadband (impulse) source.

- 5 The frequency content of an irregularly sampled signal, such as the signal 62 in Figure 6c, is illustrated in Figure 7c. As can be seen from Figure 7c, a wide range of frequencies is sampled unevenly across the frequency range.

10 There are different known Quasi-Monte Carlo sequences that can be used. Taking the difference between consecutive numbers in a Quasi-Monte Carlo sequence, gives a difference sequence that is very regular. This is not desirable for seismic source firing sequences. However, this problem may be solved by combining numbers drawn from two different Quasi-Monte Carlo sequences (such as Halton, Hammersley, Sobol, etc., and avoiding repeated numbers). In addition, the numbers can also be combined with
15 constraints to avoid selecting the same number consecutively when drawing from more than one sequence. Using higher dimensional generators for e.g. the Hammersley sequence, can also provide the extra degree of variation that is desired. That is, the numbers may be drawn from alternating dimensions in a two dimensional sequence.

20 Figure 8 shows the points from a one dimensional Hammersley sequence. The sequence comprises 100 (one hundred) points between 0 and 350. The point values could represent time dithers in units of milliseconds (ms). Figure 9 shows the difference between consecutive Hammersley points. The consecutive difference plot is ordered and not ideal for deblending when incoherency is used as a measure.

25 Figure 10 shows points from two dimensions of a Hammersley sequence. Empty circles represent one dimension and circles with crosses a second dimension. In one embodiment, the Hammersley points of one dimension may be multiplied by -1 (negative one) to generate a low discrepancy sequence of negative numbers. The
30 negative sequence can then be used to generate negative dithers.

Figure 11 shows the difference between consecutive Hammersley points drawn from two dimensions. This consecutive difference of a combined sequence has improved qualities for deblending when incoherency is used as a measure. Using one sequence
35 (i.e. one dimension) for positive and one sequence for consecutive negative dither

values, and combining them sequentially, may give an even larger spread in the difference between consecutive points.

5 After determining the firing sequence, the sequence may be stored in a computer readable storage medium (e.g. a computer memory). The sequence may be loaded onto a computer connected to the source controller. The source controller may be an array controller with parallel output ports, one for each source, or for each sub-array, or gun or arbitrarily defined group of guns. Alternatively or in addition, the array controller may comprise a multiplexer for controlling individual sources. The firing sequence is
10 translated into firing commands that are sent to the source controller. The source controller sends signals through specific ports at specific times as specified by the firing commands.

15 According to an embodiment there is provided a method of conducting a seismic survey using a plurality of seismic sources. The method comprises firing a first source of said plurality of sources at a first firing time and firing a second source of said plurality of sources at a second firing time. The second firing time is a constant time interval after the first firing time plus a time dither equal to a first number in a first low discrepancy sequence. The method then comprises firing the first source at a third
20 firing time at a constant shot point interval after the first firing time, wherein the third firing time is after the second firing time, and firing the second source at a fourth firing time, wherein the fourth firing time is the constant time interval after the third firing time plus a time dither equal to a first number in a second low discrepancy sequence.

25 The method may then comprise firing the first source at a fifth firing time at the constant shot point interval after the third firing time, wherein the fifth firing time is after the fourth firing time, and then firing the second source at a sixth firing time, wherein the sixth firing time is the constant time interval after the fifth firing time plus a time dither equal to a second number in the first low discrepancy sequence. The first and second
30 numbers in the first low discrepancy sequence are consecutive numbers in said sequence.

The method may naturally be extended to any number of source firings by drawing further numbers from alternating first and second low discrepancy sequences to
35 determine the firing times of the overlapping (i.e. the second) source. The method may

also be extended to any number of sources, for example, a third source can be fired after the second source and before the first source is fired again in the firing sequence. The firing times of such a third source would also comprise dithers similar to the firing times of the second source.

5

In another embodiment, the method described immediately above is adapted to pre-plot shooting by specifying the firing sequence in terms of firing locations instead of firing times.

10 The above described embodiments may provide an alternative to existing technology for determining and executing the firing sequence of two or more seismic sources. The embodiments provide a recipe to generate dither or shooting patterns.

15 The above described embodiments relate to the source firing sequence. Here follows a description of embodiments of the receiver layout or arrangement.

Apart from the source firing, the positioning and arrangement of receivers may have an important effect on the results of a seismic survey. In general, to map a 2D slice of the Earth's subsurface a line of receivers may be used, whereas to map a 3D volume of the Earth's subsurface a 2D grid of receivers would generally be used.

20 Figure 12 shows a receiver arrangement 100 on a square grid 101 with $N = 45$ receivers 102. To achieve a high resolution, i.e. in order to resolve small features in the subsurface, a high density of receivers 102 may be used. When the amount of sample points (i.e. receivers 102) is not a constraint, the optimal sampling is regular. This is especially true when the signal that is being sampled has a Fourier transform that is bandlimited, as the distance between sequential sample points can be defined by Shannon's sampling theorem. This means that a set of N regular samples, $x(n)$, with a sample rate T , allows a signal of a maximum (Nyquist frequency) of $\frac{1}{2} T$ to be recovered. Signals above that frequency will be aliased.

35 Figure 13 shows a receiver arrangement 100 on a square grid 101 with a reduced number, $N = 25$, of receivers 102. When mapping a large area of the Earth's subsurface, a high receiver density can become very costly, or may be prevented by physical constraints. Hence, the spacing between receivers 102 may be increased (i.e.

the sampling rate T is reduced). This may be referred to as sparse sampling, or a sparse arrangement, or a sparse array. Reducing the amount of samples means that less of the signal can be recovered, as the sample rate T is reduced. That is, sparse sampling causes spatial aliasing. Aliasing occurs when the sampling frequency is less than twice the frequency of the sampled signal. High frequency signals may then appear as lower frequency signals in the recorded data. Traditional seismic acquisition have favoured regularity, which often translates into a frequency band constraint by aliasing limits which are defined by the sampling interval in a given dimension or set of dimensions.

Figure 14 shows a receiver arrangement 100 on a square grid 101 with receivers 102 located/positioned randomly across the surface of the grid 101. The positions of the receivers 102 are not constrained by the grid lines. One solution to the aliasing problem when using a sparse receiver arrangement is to use irregular spacing between receivers (i.e. irregular sampling). Irregular sampling does not encounter the same aliasing challenges or limits that are related to regular sampling. The frequency content of an irregular signal is mostly challenged by noise instead of aliasing. Hence, irregular sampling can be used to reduce the amount of sample points and recover the signal without being limited by aliasing. However, irregular sampling introduces extra noise when the data is transformed into other domains such as the Fourier domain. Techniques like compressed sensing and sparsity constraints imposed on inverse problems can be used to recover the signal that would have been measured with a less-sparse and regularly sampled signal. However, not all random sampling is the same. Pure random sampling is not always optimal as it can introduce holes and clusters of sampling points.

Figure 15 shows a receiver arrangement 100 according to an embodiment. Receivers 102 are irregularly spaced on a grid 101. The positions of the receivers 102 are not constrained by the grid lines. A Quasi-Monte Carlo sequence is used to determine the receiver positions in a sparse arrangement 100. Preferably the positions of adjacent receivers 102 are determined from two different Quasi-Monte Carlo sequences (or from separate dimensions of a two dimensional sequence). It can be seen, by comparison to Figure 14, that the receivers 102 are more evenly distributed across the grid surface compared to a random distribution.

The receiver positions may be generated within a given area without further constraints. This could be implemented for acquisitions using nodes that can be deployed by Remotely Operable Vehicle (ROV) units to any desired location. Alternatively, if a pre-specified grid exists, such as lines in a permanent reservoir monitoring (PRM) acquisition, or a minimum sample interval in a gun controller, the irregular samples can be mapped onto the grid. Figure 16 shows a receiver arrangement 100 with arrows 103 indicating a spatial translation of some of the receivers 102 to the closest node/point on the grid 101. Figure 17 shows the resulting receiver arrangement according to an embodiment. After generating the positions of the receivers 102 using Quasi-Monte Carlo sampling, each position may be updated to equal the coordinates of the closest grid node.

One or both coordinates (x and y) of each receiver within an area (i.e. within the region of interest where the seismic survey is to be carried out) could be drawn directly from a low discrepancy sequence, or from two different sequences. Alternatively, each receiver position may be defined in relation to an adjacent receiver. For example, according to an embodiment, a receiver arrangement may comprise a first receiver placed at a first arbitrary position within the region and a second receiver at a second position, wherein the second position is displaced from the first position by a first distance along a first direction (e.g. x) and by a second distance along a second direction (e.g. y) perpendicular to the first direction. At least the one of the first and second distances is given by low discrepancy sequence. For example, the first distance may be equal to a first number in a first low discrepancy sequence or equal to a constant spacing plus/minus the first number from said sequence. The receiver arrangement also comprises a third receiver at a third position within the region of interest, wherein the third position is displaced from the second position by a third distance along the first direction and a fourth distance along the second direction and at least one of the third and fourth distances is given by a low discrepancy sequence. For example, the third distance may be equal to a second (consecutive) number in the first low discrepancy sequence or equal to a constant spacing plus/minus the second number from said sequence. Alternatively, and preferably, a second low discrepancy sequence is used to determine the third distance in this example.

Figure 18 shows a dense receiver arrangement 100 on a regular grid 101. The receivers 102 are deployed on a cable (or rope) 104 which runs along the grid lines.

Figure 19 shows a sparse receiver arrangement 100 on a regular grid 101. The receivers 102 are deployed on a cable 104 which runs along the grid lines

If cables or ropes are used to position the receivers 102, one direction may be more sparsely sampled than the other (e.g. 25 m inline vs 300 m or 400 m crossline), as seen in Figure 16. Embodiments allow more sparsely sampling the inline direction, while keeping the crossline direction either regular or irregular. This allows less data to be measured while still recovering the frequencies of choice, by using, for example, sparsity promotion or compressed sensing techniques.

Figure 20 shows an irregular and sparse receiver arrangement 100 according to an embodiment. The receiver positions can be generated from either a single, or from two different, Quasi-Monte Carlo sequences and mapped onto a regular grid 101. The receivers 102 are deployed on a cable 104 which runs along the grid lines. Alternatively, the locations generated by the Quasi-Monte Carlo sequence might only be mapped onto a regular grid in one direction (crossline/vertical in Figure 20), while they are kept irregular in the second direction (inline/horizontal along the cables). The latter is possible with deployment technology like nodes-on-a-rope, where the nodes (receivers) can be attached to a rope at any desired interval from each other. As an extension, the crossline direction, or distance between the horizontal sections of the cables or ropes can be selected to be irregular, by drawing a new set of Quasi Monte Carlo numbers and using it to have irregular crossline distances between the cables. The receiver positions may be translated into a distance along the rope/cable where the receiver needs to be installed in order to reach the specified position after being deployed. Alternatively, the distance between two adjacent receivers 102 along the cable 104 may be determined by a fixed constant plus a dither determined from a Quasi-Monte Carlo sequence. Similarly, the (crossline) distance between parallel cables 104 may be determined by a fixed constant plus a dither determined from a Quasi-Monte Carlo sequence.

The receivers may be placed on land, or on the sea floor, or be suspended in the sea some distance above the sea floor depending on the survey. The method may preferably be used to arrange a large number of receivers. For example, the method may be used to determine an arrangement of more than 1000 receivers. However, the

method is not limited to large arrangements and may generally be used to determine the positions of as few as three receivers.

CLAIMS:

1. A method of determining a firing sequence of a plurality of seismic sources for use in a seismic survey, the method comprising:
 - 5 receiving a first low discrepancy sequence and a second low discrepancy sequence; and
 - determining from said first and second low discrepancy sequences the firing sequence by alternately selecting consecutive numbers from said first and second low discrepancy sequences, wherein said plurality of seismic sources are fired according to
 - 10 said firing sequence in said seismic survey.
2. A method according to claim 1 and comprising generating the first and second low discrepancy sequences.
- 15 3. A method according to claim 1 or 2, wherein at least one of the first and second low discrepancy sequences is a Hammersley sequence, a Halton sequence, a Faure sequence or a Sobol sequence.
4. A method according to any one of the preceding claims, wherein the first and
- 20 second low discrepancy sequences are different types of low discrepancy sequences.
5. A method according to claim 1, 2 or 3, wherein the first and second low discrepancy sequences are different dimensions of the same low discrepancy sequence.
- 25 6. A method according to any one of claims 1 to 5, wherein the firing sequence comprises at least one firing time for each source.
7. A method according to claim 6, wherein consecutive firing times of one or more
- 30 sources in the sequence of firing times are determined from alternating between first and second low discrepancy sequences.

8. A method according to claim 6 or 7, wherein said step of determining comprises setting the firing times of at least one source of said plurality of sources to equal numbers of the low discrepancy sequences.
- 5 9. A method according to claim 6 or 7, wherein said step of determining comprises determining time dithers from numbers in the low discrepancy sequences, and using the time dithers to determine the firing times of at least one source of said plurality of sources.
- 10 10. A method according to claim 9, wherein each firing time of said at least one source is determined by adding one of said determined time dithers to a constant shot point interval.
- 15 11. A method according to claim 9, wherein each firing time of said at least one source is determined by adding said time dither to a preceding firing time of another source.
- 20 12. A method according to any one of claims 6 to 11, wherein the low discrepancy sequences are constrained such that each firing time falls within a pre-set time window.
13. A method according to any one of the preceding claims, wherein the firing sequence comprises at least one firing position for each source.
- 25 14. A method according to claim 13, wherein consecutive firing positions of one or more sources in the sequence of firing positions are determined from alternating first and second low discrepancy sequences.
- 30 15. A method according to claim 13 or 14, wherein said step of determining comprises setting the firing positions of at least one source of said plurality of sources to equal numbers of the low discrepancy sequences.
- 35 16. A method according to claim 13 or 14, wherein said step of determining comprises determining space dithers from numbers in the low discrepancy sequences, and using the space dithers to determine the firing positions of at least one source of said plurality of sources.

17. A method according to claim 16, wherein each firing position of said at least one source is determined by adding one of said determined space dithers to a constant space interval.
- 5
18. A method according to claim 16, wherein each firing position of said at least one source is determined by adding said space dither to a firing position of another source.
19. A method according to any one of claims 13 to 18, wherein the low discrepancy sequences are constrained such that each firing position falls within a pre-set distance.
- 10
20. A method according to any one of the preceding claims and comprising obtaining a third low discrepancy sequence, and determining from said third low discrepancy sequence an order of firing the sources of the plurality of sources.
- 15
21. A method according to any one of the preceding claims, wherein each source comprises an array of guns, and comprising:
- obtaining a further low discrepancy sequence; and
- for each of the one or more sources, determining from said further low discrepancy sequence a sequence of firing times for each gun.
- 20
22. A method of operating a plurality of seismic sources during a seismic survey, the method comprising:
- receiving a firing sequence determined according to the method of any one of the preceding claims; and
- 25
- firing the sources at respective firing times or firing positions given by the firing sequence.
23. An apparatus configured to perform the method of any one of claims 1 to 22.
- 30
24. A computer readable storage medium for storing computer executable instructions, which cause the computer to perform the method of any one of claims 1 to 22 when executed.

25. A method of determining an arrangement of a plurality of receivers for conducting a seismic survey, the method comprising:
receiving a first low discrepancy sequence;
determining for each receiver, from the first low discrepancy sequence, a
5 position in which the receiver is to be placed for the survey.
26. A method according to claim 25 and comprising receiving a second low discrepancy sequence, wherein the positions of adjacent receivers are determined from alternating first and second low discrepancy sequences.
10
27. A method according to claim 26 and comprising generating the low discrepancy sequences.
28. A method according to claim 26 or 27, wherein at least one of the first and
15 second low discrepancy sequences is a Hammersley sequence, a Halton sequence, a Faure sequence or a Sobol sequence.
29. A method according to any one of claims 26 to 28, wherein the first and second low discrepancy sequences are different types of low discrepancy sequences.
20
30. A method according to any one of claims 26 to 28, wherein the first and second low discrepancy sequences are different dimensions of the same low discrepancy sequence.
- 25 31. A method according to any one of claims 25 to 30 and comprising mapping each position onto a regular grid.
32. A method according to claim 31, wherein said mapping comprises translating each position to the nearest grid node.
30
33. A method according to any one of claims 25 to 32 and comprising calculating for each point a corresponding distance along a line.
34. A receiver arrangement comprising a plurality of receivers in an arrangement as
35 determined according to any one of claims 25 to 33.

35. A receiver arrangement for use in a seismic survey, the receiver arrangement comprising:

5 a plurality of receivers at respective positions, wherein said positions are determined from a low discrepancy sequence.

36. A receiver arrangement according to claim 35, wherein at least one coordinate of each position corresponds to a number from said low discrepancy sequence.

10 37. A receiver arrangement according to claim 35 or 36 and comprising a cable or rope to which each receiver is attached, and wherein the spacing between adjacent receivers on the cable or rope is determined from said low discrepancy sequence.

15 38. A method of determining an output signal of a continuous seismic source, the method comprising:

determining a frequency range within which said source is configured to generate output signals;

selecting a subset of frequencies corresponding to a low discrepancy sequence from said frequency range; and

20 determining an output signal having a frequency content comprising substantially only the frequencies from said subset of frequencies.

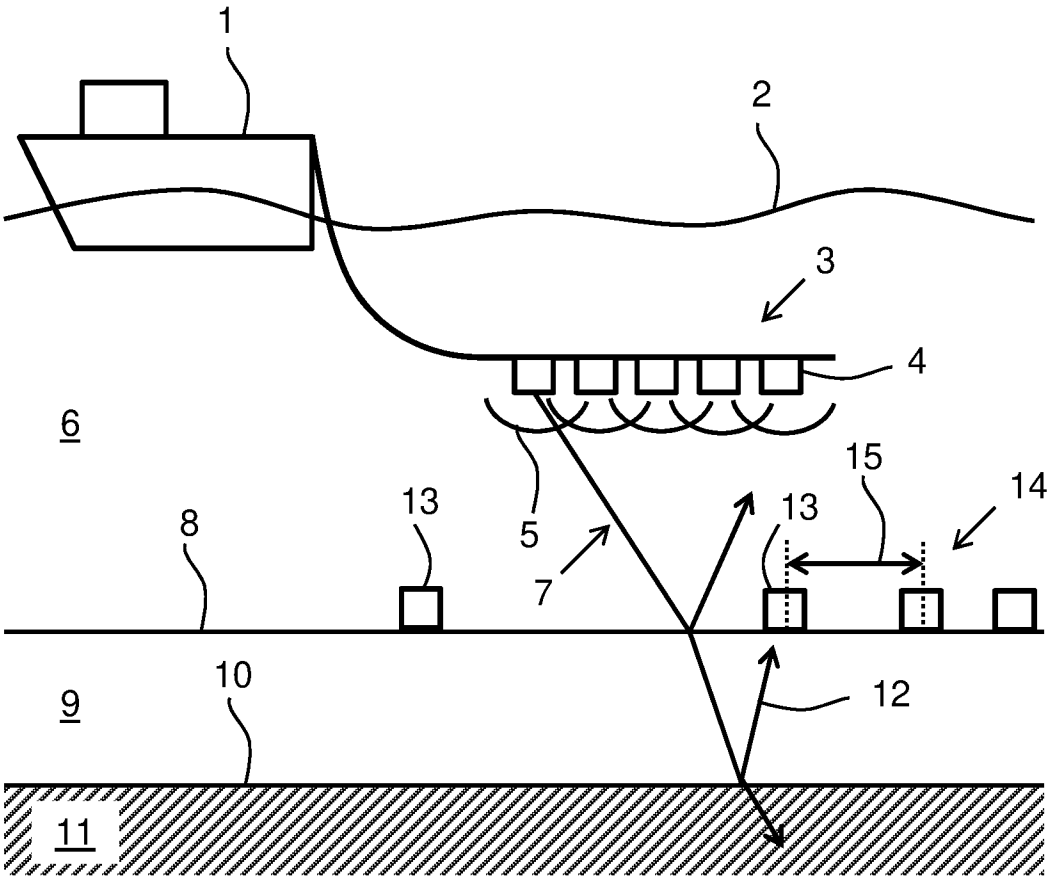


Figure 1

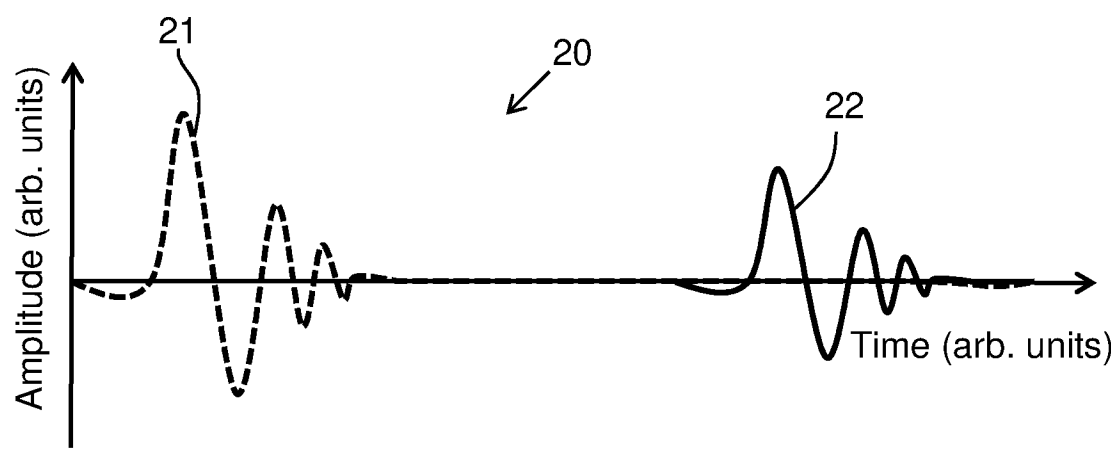


Figure 2a

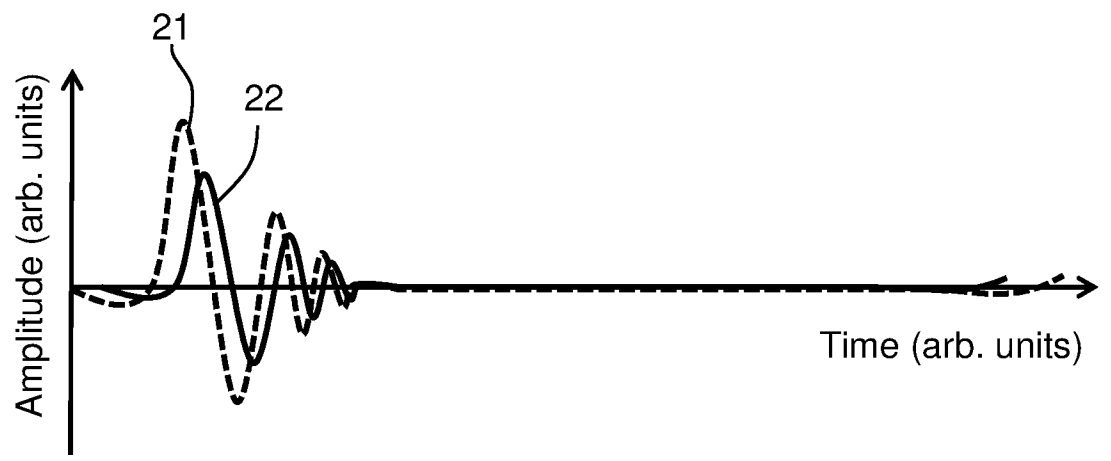


Figure 2b

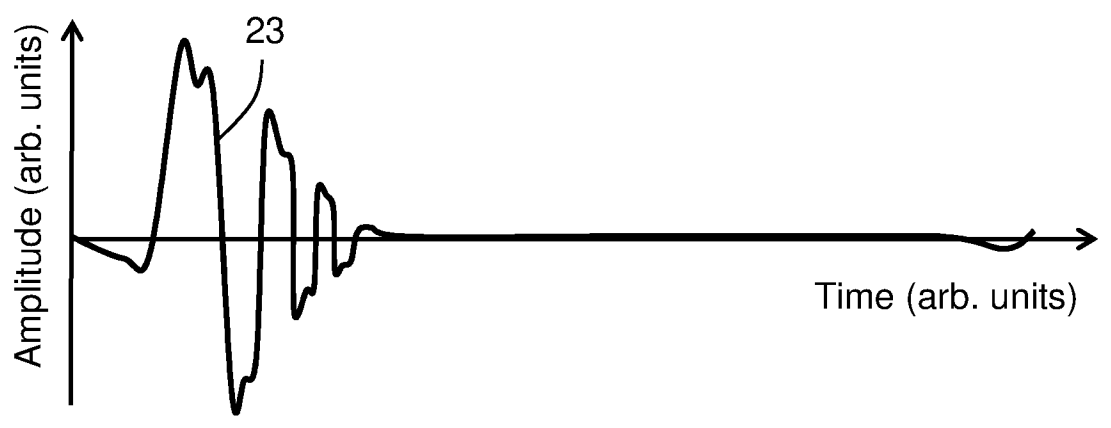


Figure 2c

3/13

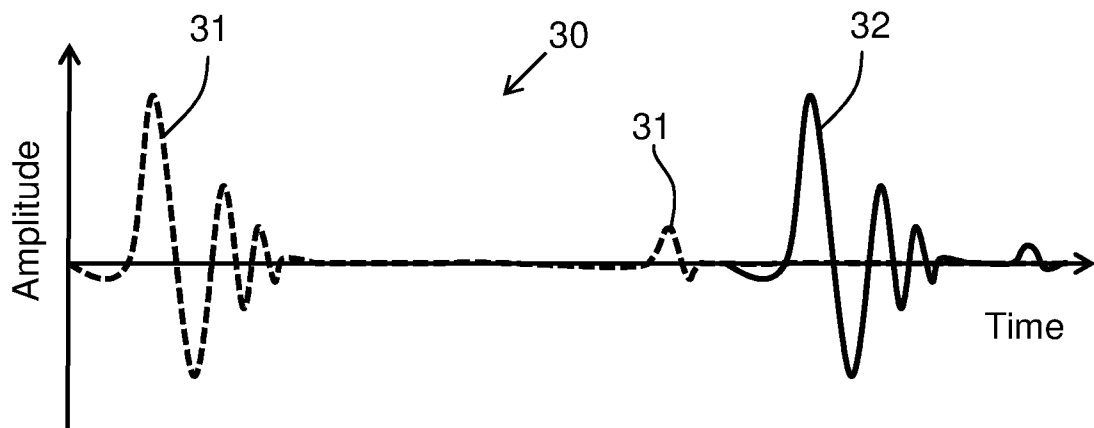


Figure 3a

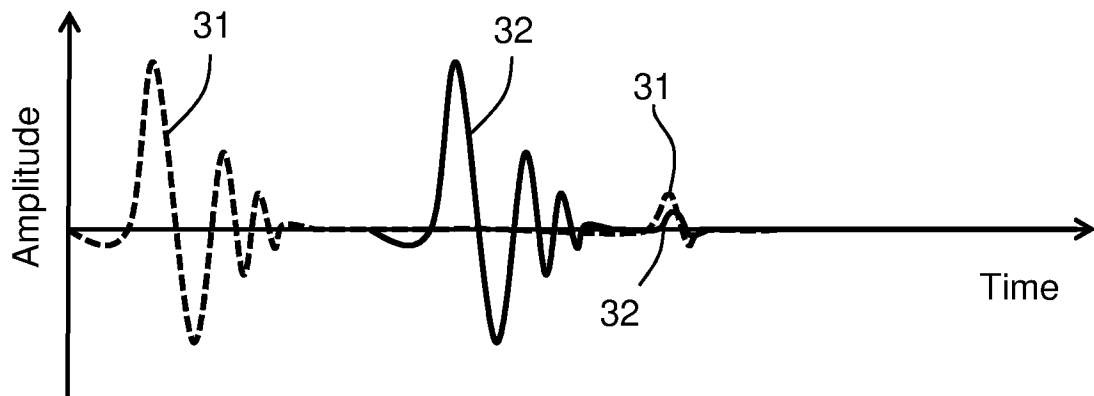


Figure 3b

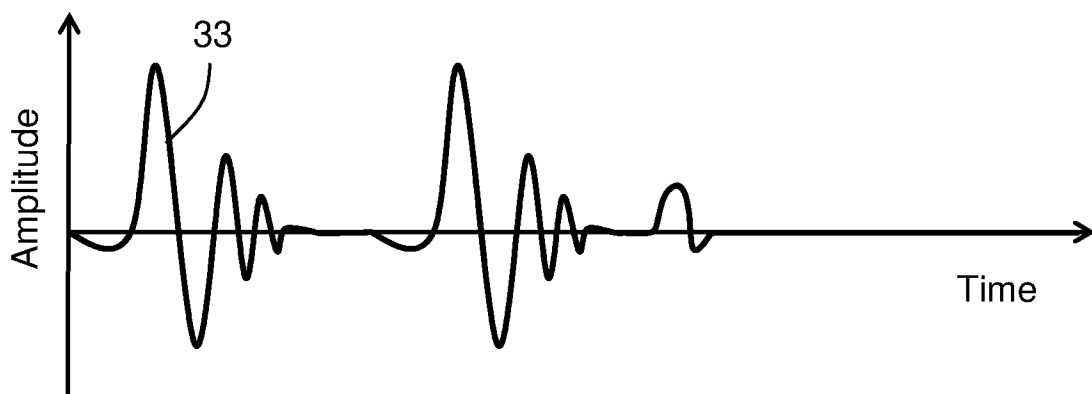


Figure 3c

4/13

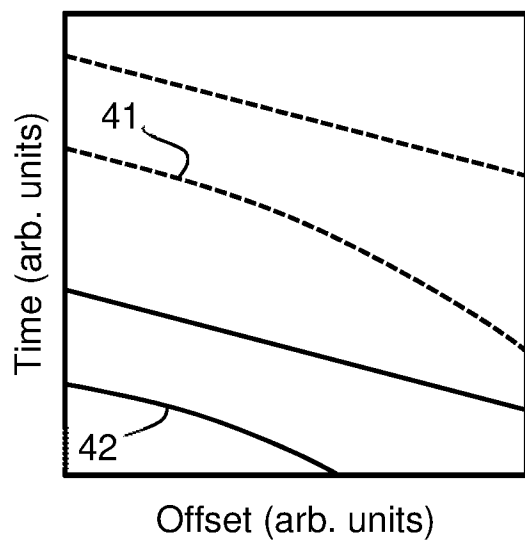


Figure 4a

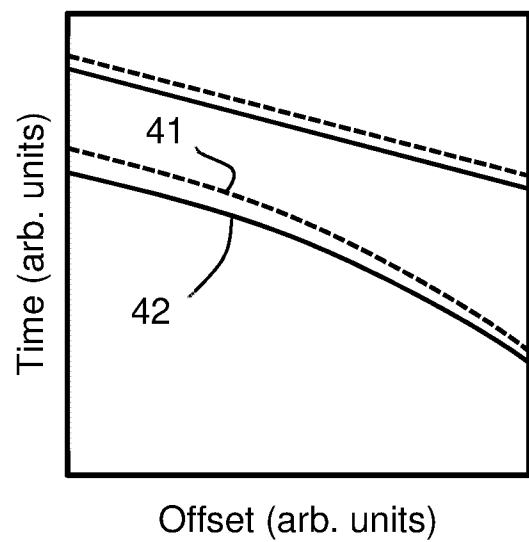


Figure 4b

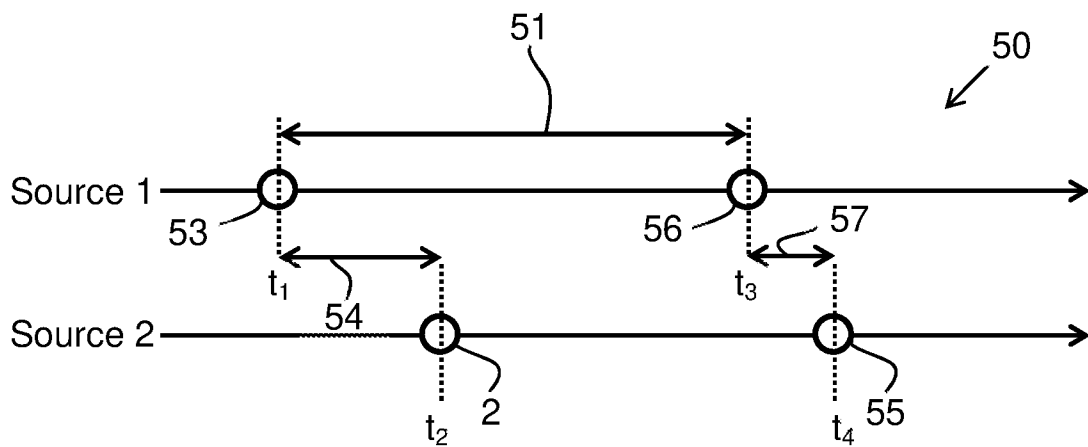


Figure 5

5/13

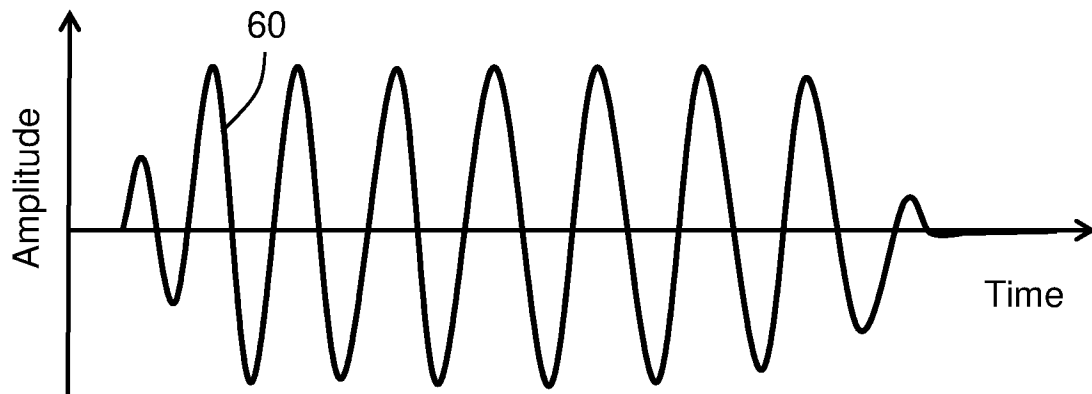


Figure 6a

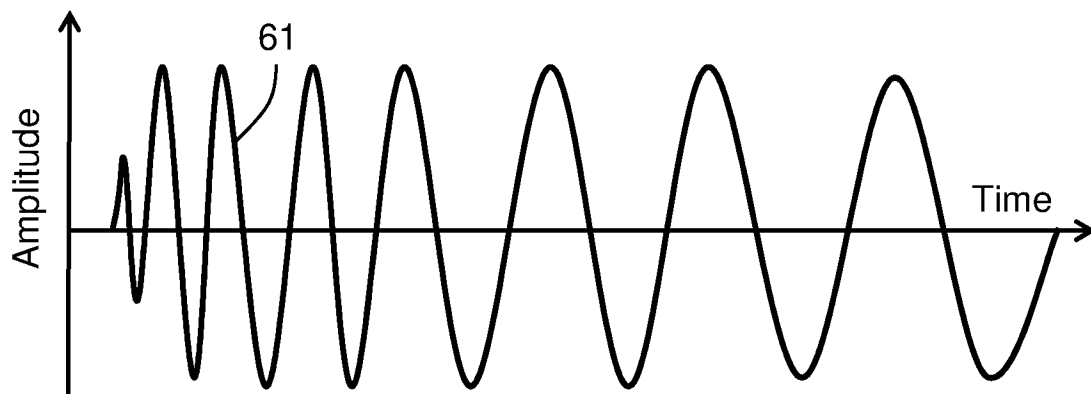


Figure 6b

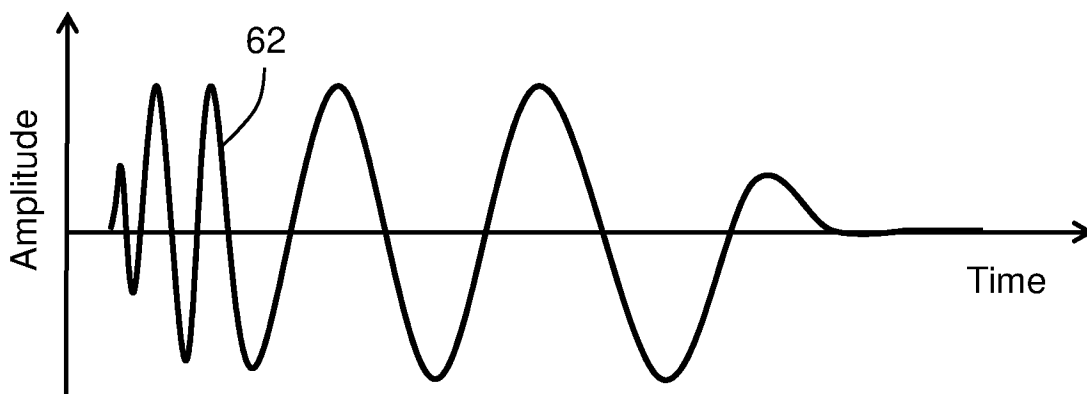


Figure 6c

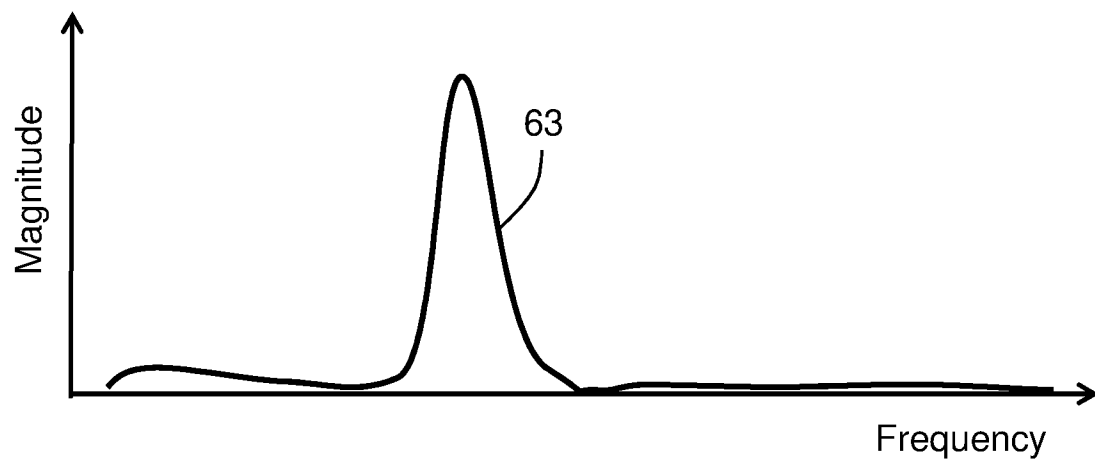


Figure 7a

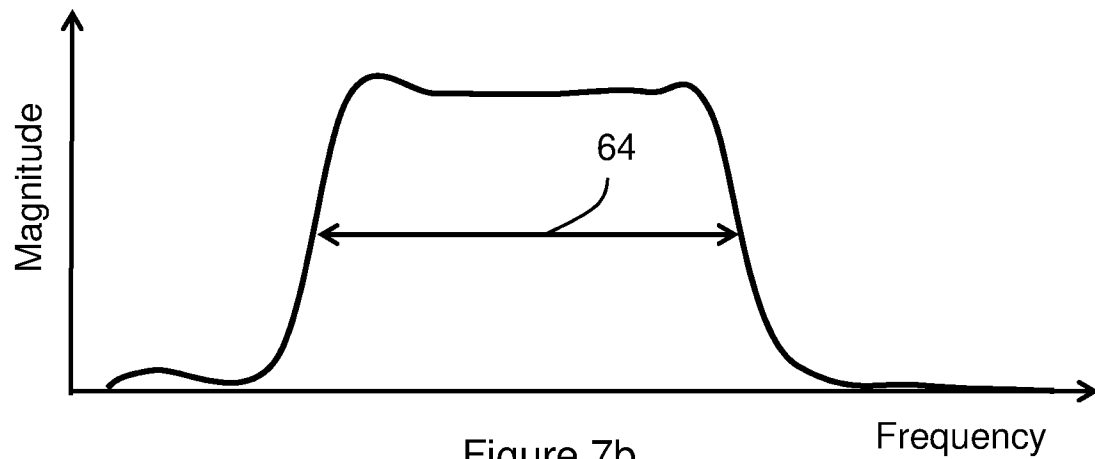


Figure 7b

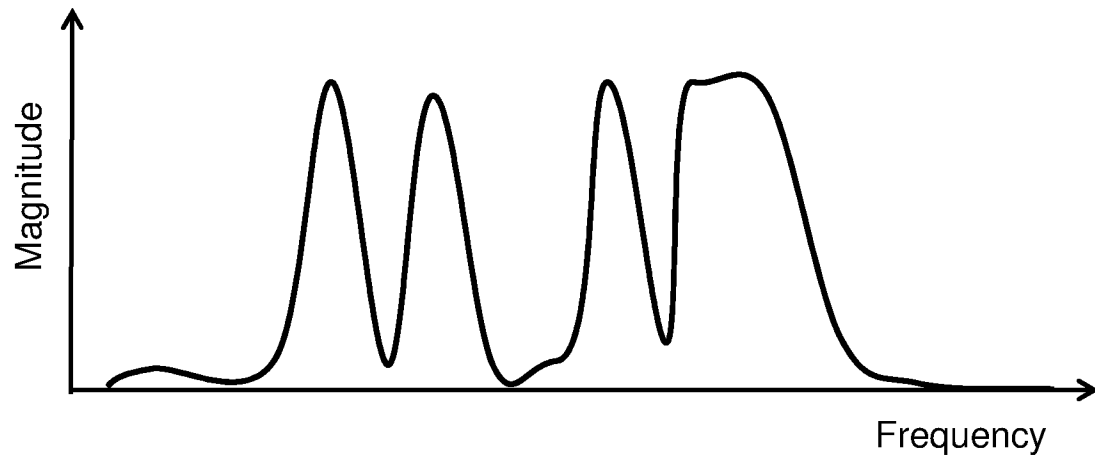


Figure 7c

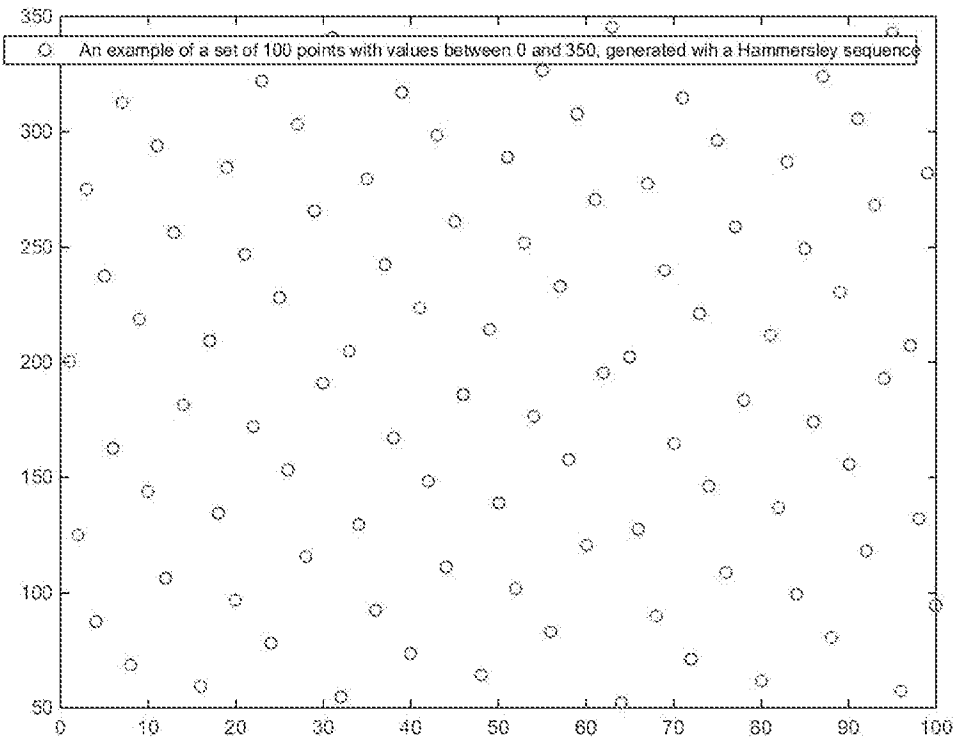


Figure 8

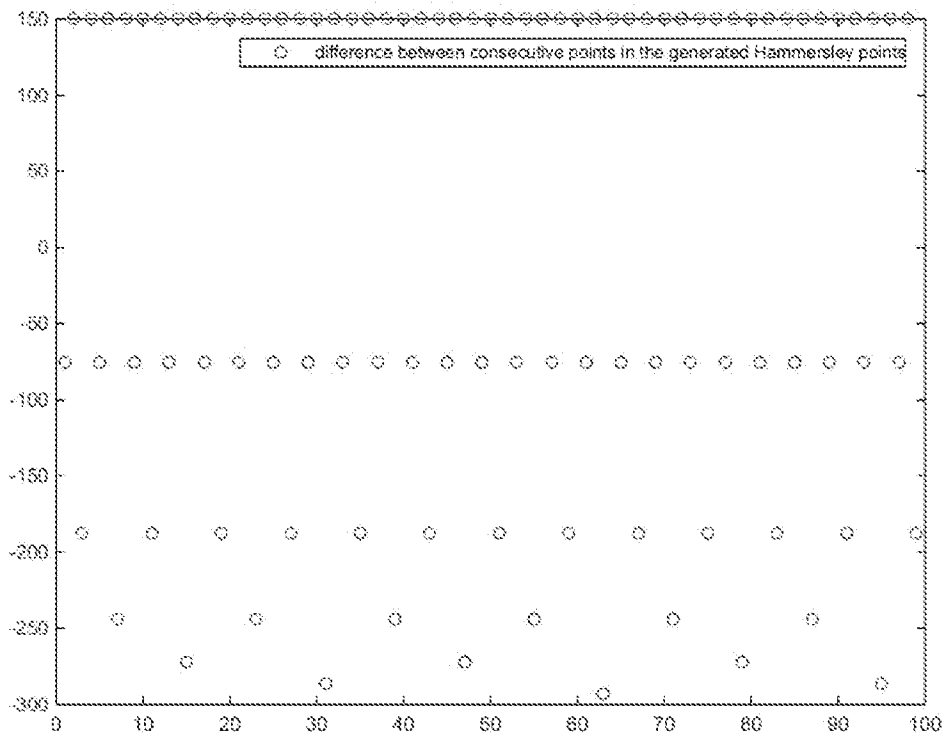


Figure 9

8/13

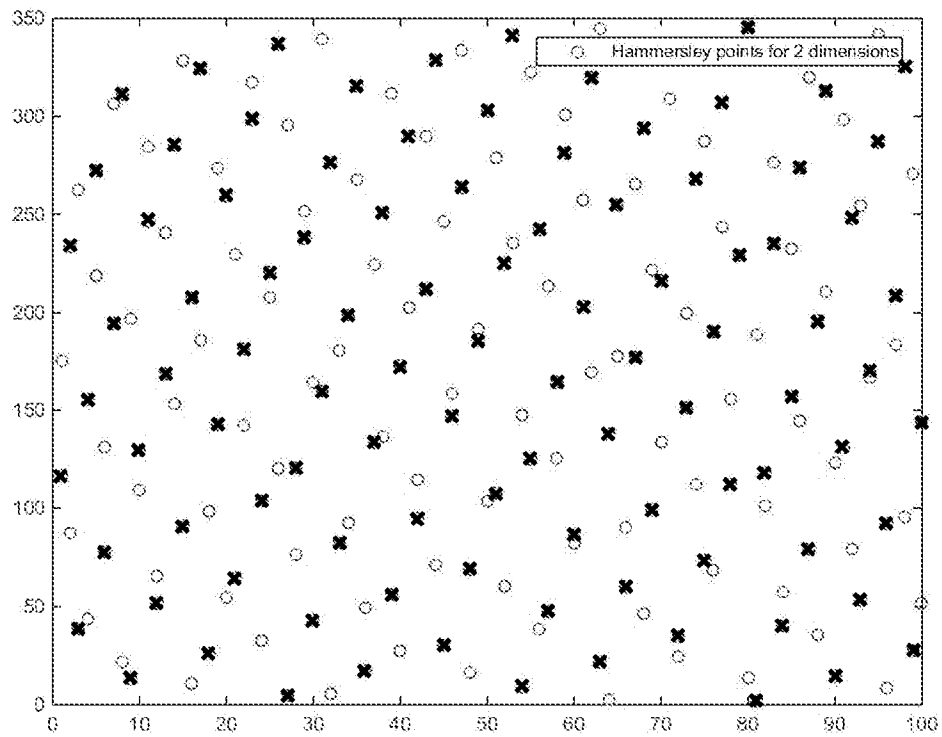


Figure 10

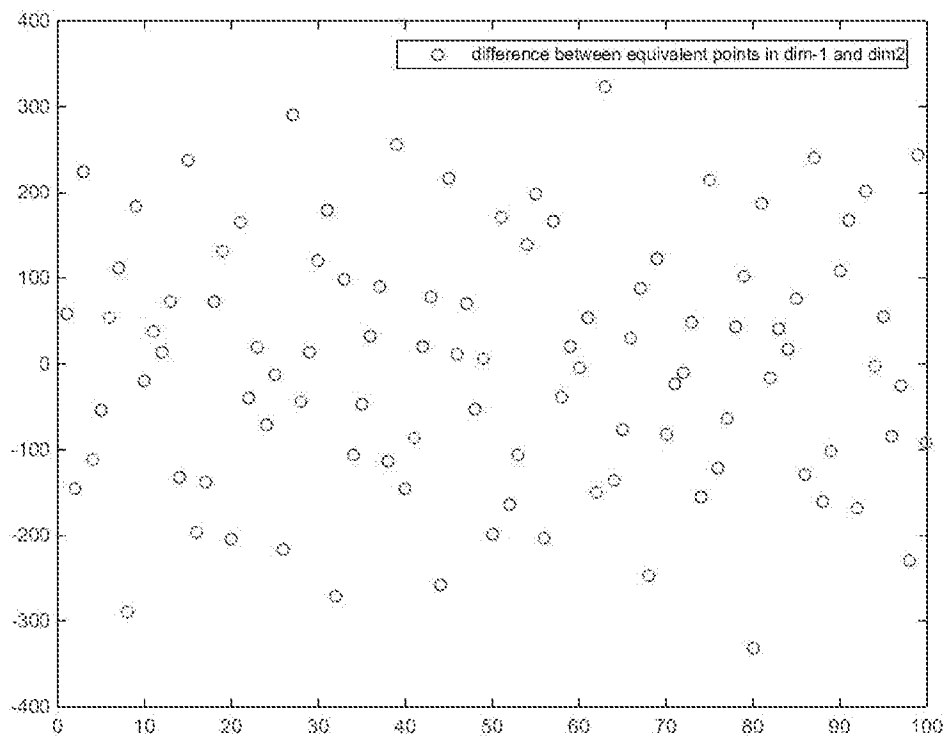


Figure 11

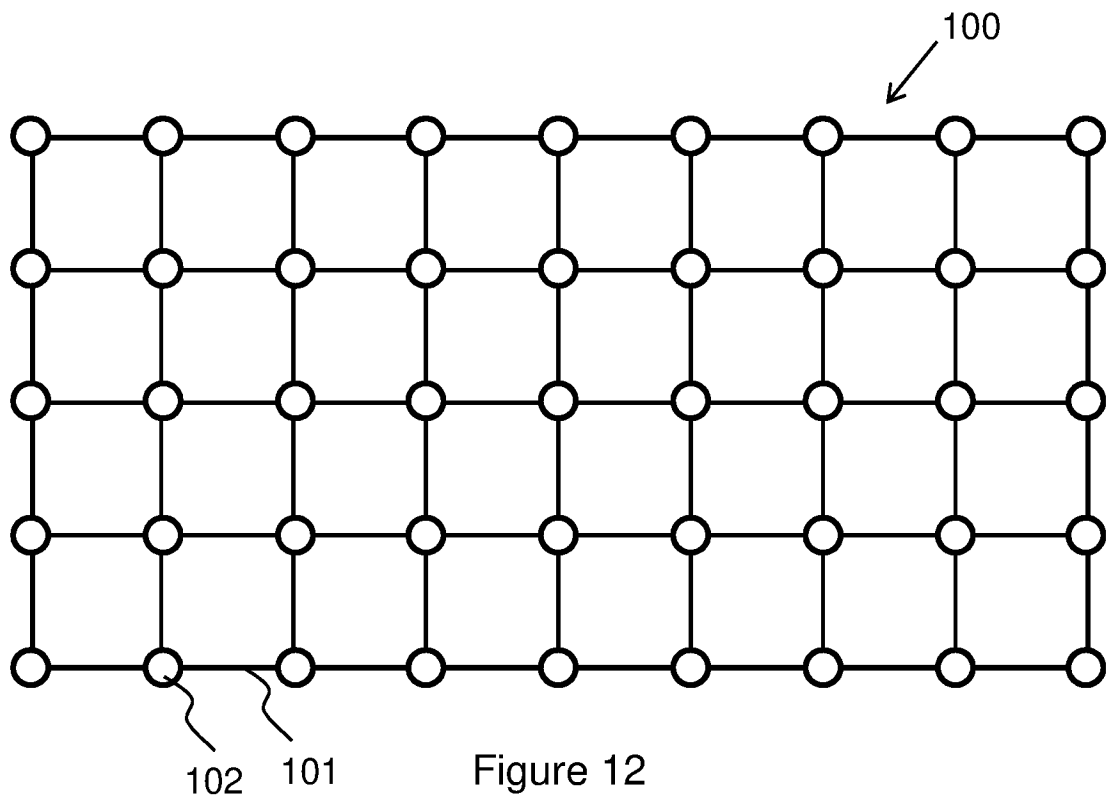


Figure 12

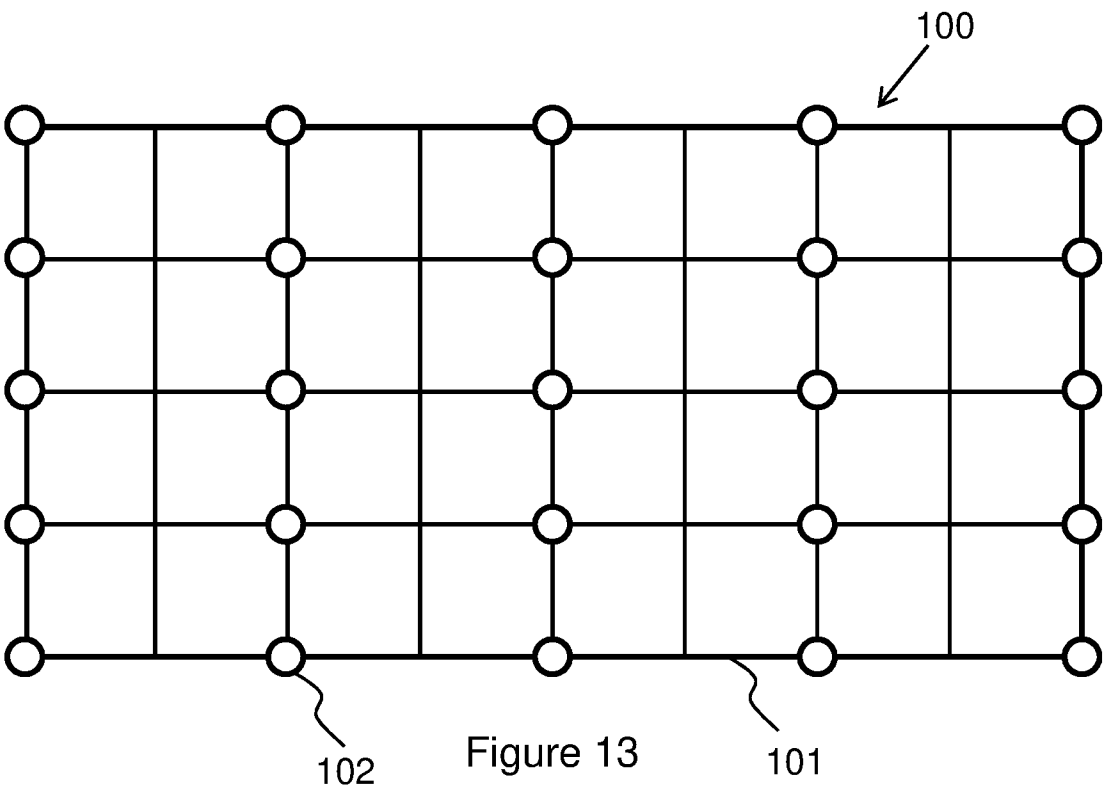


Figure 13

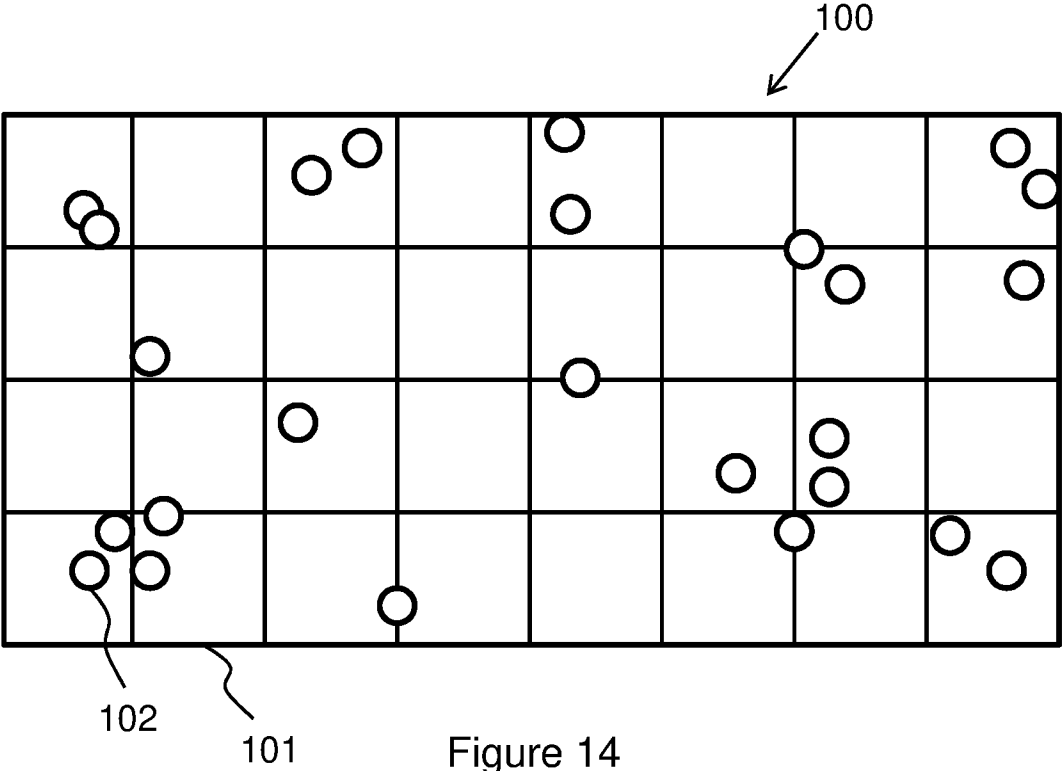


Figure 14

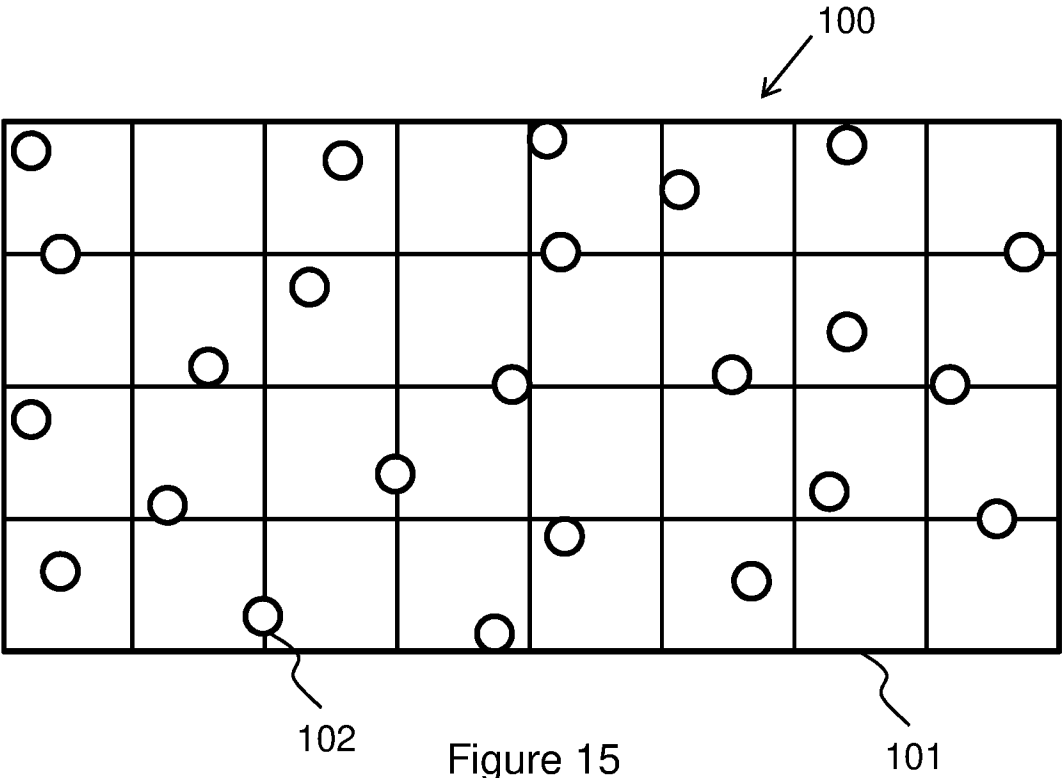


Figure 15

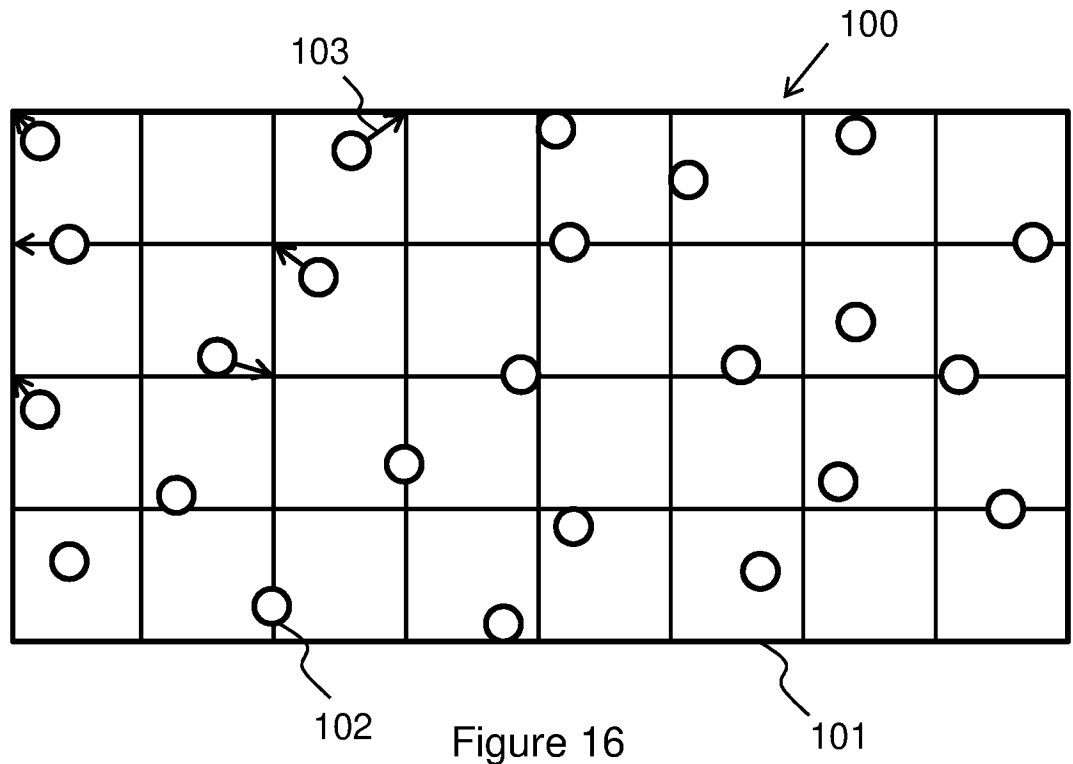


Figure 16

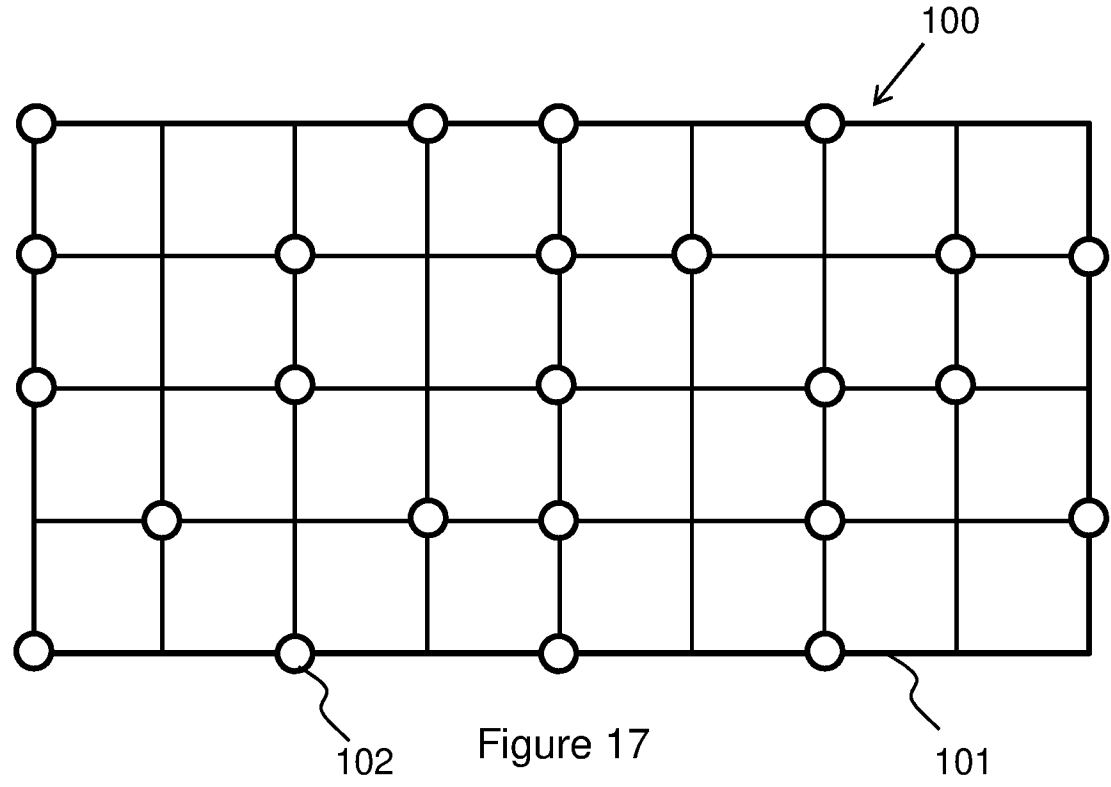
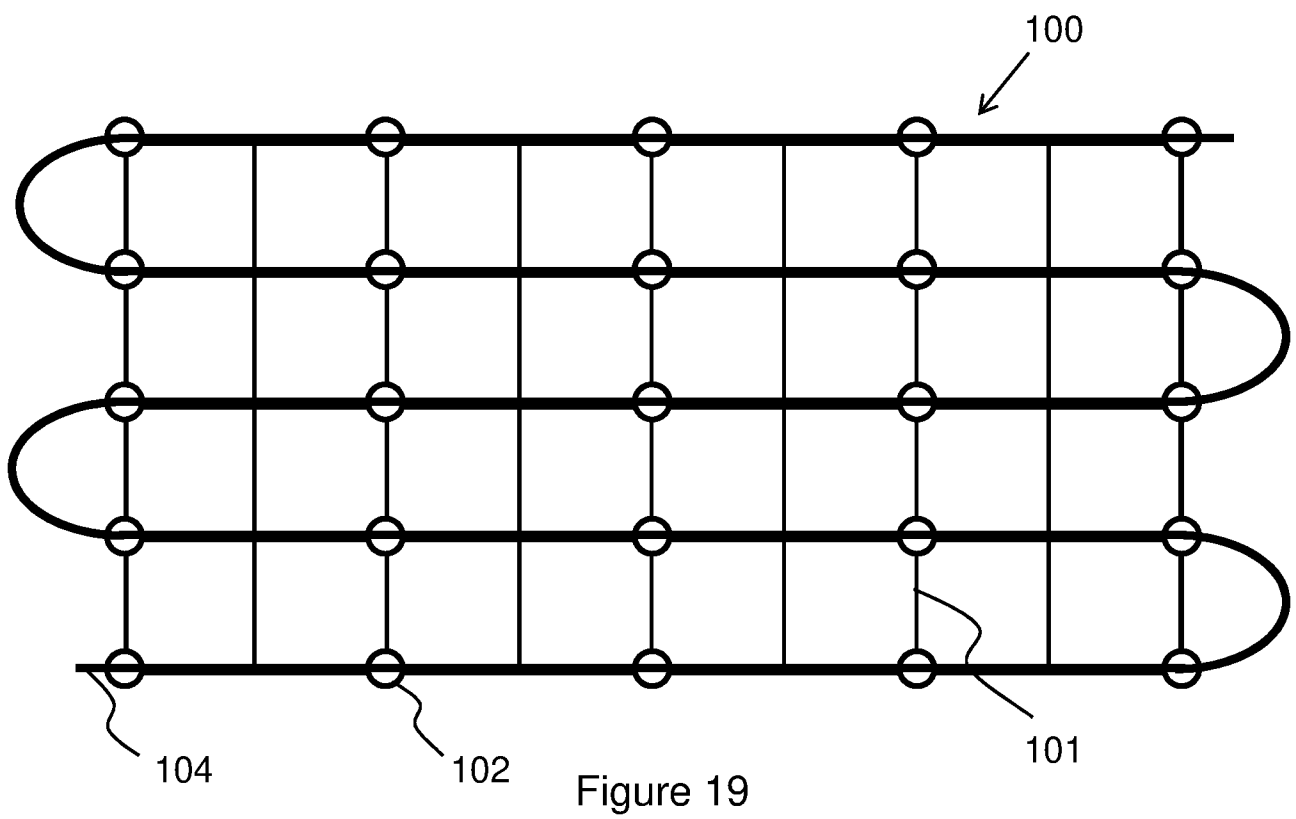
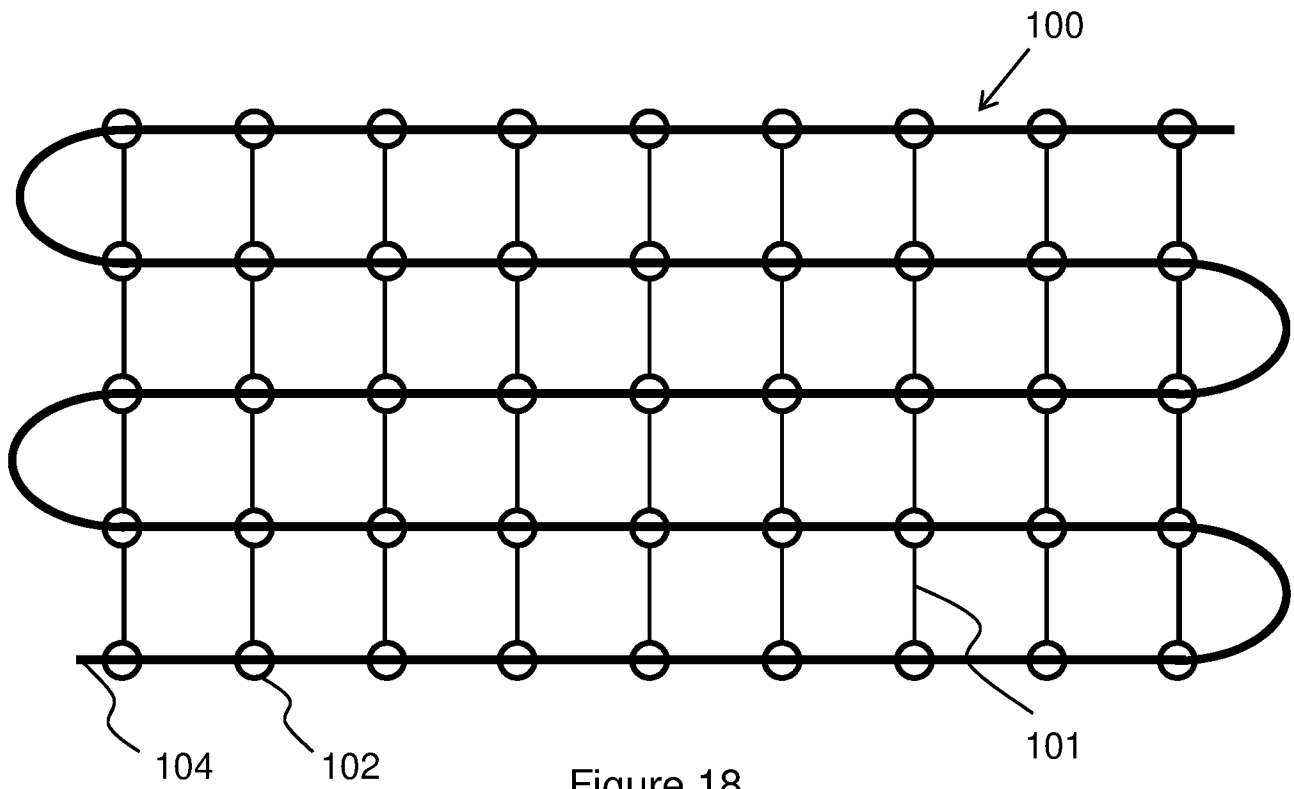


Figure 17

12/13



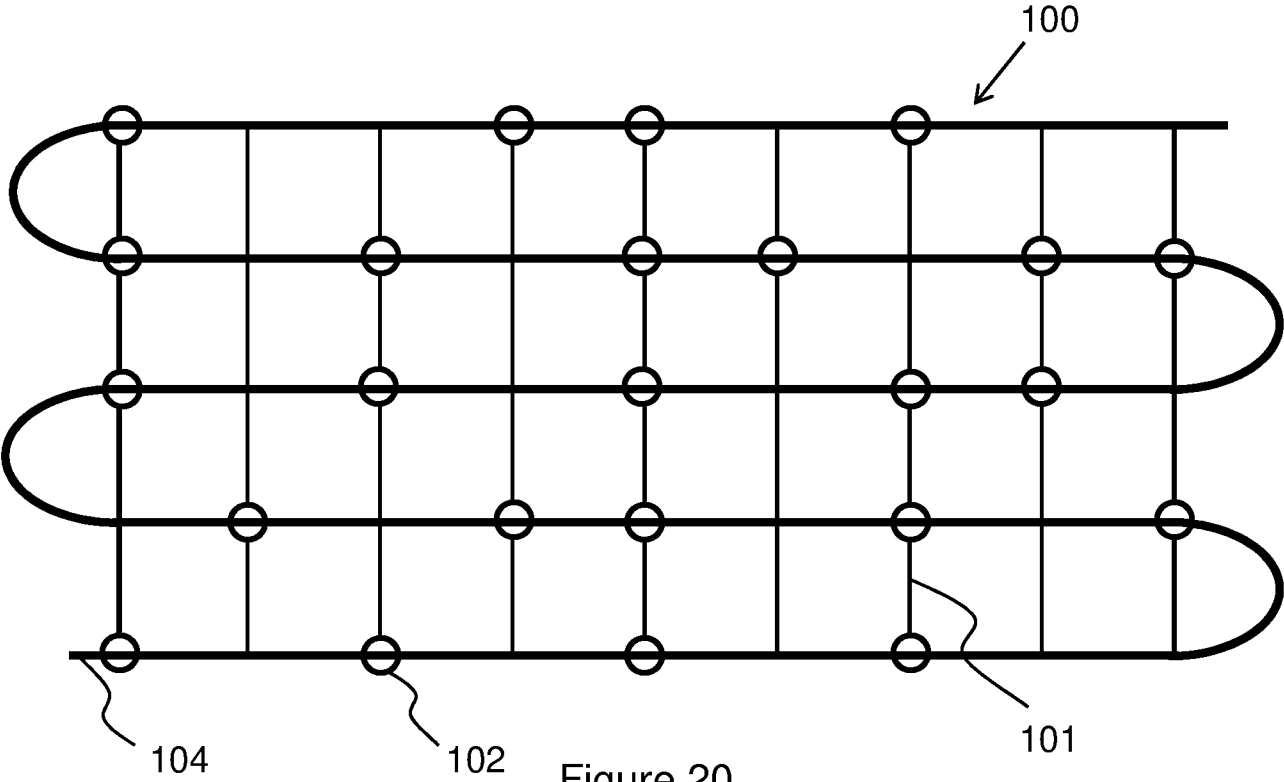


Figure 20

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2019/050038

A. CLASSIFICATION OF SUBJECT MATTER		
G01V 1/00 (2006.01), G01V 1/20 (2006.01), G01V 1/38 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) G01V		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched DK, NO, SE, FI: Classes as above.		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC, WPI, INSPEC, COMPENDEX, ELSEVIER, FULL TEXT: ENGLISH		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011158041 A1 (MOLDOVEANU, N. et al.) 2011.06.30	25, 31, 34-37
Y	paragraphs [0031]; [0054]; [0080]; [0094]; [0096]; [0100]; [0101]; [0103]	38
A		1-24, 26-30, 32, 33
Y	US 2009010103 A1 (SALLAS, J.; GIBSON, J.) 2009.01.08	38
	paragraphs [0003]; [0015]-[0019]; claim 1	
A	EP 3206052 A1 (CGG SERVICES SAS) 2017.08.16	1-38
	paragraphs [0061]-[0063]; claim 11	
A	US 2015131409 A1 (ABMA, R.; ROSS, A.) 2015.05.14	1-38
	paragraphs [0011]; [0047]	
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
"A" document defining the general state of the art which is not considered to be of particular relevance		
"E" earlier application or patent but published on or after the international filing date		
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
12/04/2019	23/04/2019	
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. -	Authorized officer Margrethe Stange Overå Telephone No. + 47 22 38 73 11	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2019/050038

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-37
Claims 1-37 describes using low discrepancy sequences to determine firing sequence and the arrangement of receivers and sources.

2. Claim 38
Claim 38 discloses determining an output signal of a continuous seismic source.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/NO2019/050038

Patent document cited in search report / Publication date		Patent family member(s) / Publication date	
US 2011158041 A1	2011.06.30	US 2011158042 A1	2011.06.30
		US 8681581 B2	2014.03.25
		US 8711654 B2	2014.04.29
		WO 2011082259 A2	2011.07.07
		WO 2011082259 A3	2011.11.17
		MX 2012007769 A	2012.08.01
		EP 2519844 A2	2012.11.07
		EP 2519844 A4	2015.03.25
US 2009010103 A1	2009.01.08	US 7859945 B2	2010.12.28
		CA 2693394 A1	2009.01.15
		CA 2693394 C	2014.08.05
		AU 2008275375 A1	2009.01.15
		AU 2008275375 B2	2013.10.24
		WO 2009009334 A1	2009.01.15
		MX 2010000218 A	2010.06.01
		ZA 201000059 B	2010.09.29
		TN 2009000543 A1	2011.03.31
EP 3206052 A1	2017.08.16	US 2017235003 A1	2017.08.17
US 2015131409 A1	2015.05.14	NONE	