EXPERT DECLARATION OF DR. FARAMARZ FARAHI
IN SUPPORT OF
INTER PARTES REVIEW OF U.S. PATENT NO. 7,030,971

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I. INTRODUCTION

1. I, Dr. Faramarz Farahi, submit this declaration in support of a Petition for *Inter Partes* Review of United States Patent No. 7,030,971 owned by The United States of America represented by the Secretary of the Navy. ("Patent Owner"). I have been retained in this matter by Baker Botts L.L.P. ("Counsel") on behalf of Halliburton Energy Services, Inc. ("Petitioner").

2. I make this declaration based upon my personal knowledge. I am over the age of 21 and am competent to make this declaration.

3. The statements herein include my opinions and the bases for those opinions, which relate to at least the following documents of the pending *inter partes* review petition:

- U.S. Patent No. 7,030,971 by Robert Michael Payton entitled "Natural fiber span reflectometer providing a virtual signal sensing array capability" ("the '971 Patent") (Ex. 1001).
- File History for U.S. Patent No. 7,030,971 (Ex. 1002).
- UK Patent Application No. GB 2 190 186 A by Jeremy Kenneth Arthur Everard entitled "Greatly Enhanced Spatial Detection Of Optical Backscatter For Sensor Applications," published November 11, 1987 (Ex. 1004).
- U.S. Patent No. 6,285,806 by Alan D. Kersey, et al. entitled "Coherent

Reflectometric Fiber Bragg Grating Sensor Array," filed May 31, 1998, issued September 4, 2001 (Ex. 1005).

- U.S. Patent No. 4,794,249 by Friedrich-Karl Beckmann, et al. entitled "Optical Time Domain Reflectometer With Heterodyne Reception," filed March 17, 1987, issued December 27, 1988 (Ex. 1006).
- Toshihiko Yoshino et al., "Common Path Heterodyne Optical Fiber Sensors," Journal of Lightwave Technology, Vol. 10, No. 4, April 1992, pp. 503-513 (Ex. 1007).
- U.S. Patent No. 6,606,148 by Leif Fredin, et al. entitled "Method And System For Measuring Optical Scattering Characteristics," filed April 23, 2001, issued August 12, 2003 (Ex. 1008).
- UK Patent Application No. GB 2 197 953 A by Michael Laurence Henning et al. entitled "Acoustic Sensor," published June 2, 1988 (Ex. 1009).
- U.S. Patent No. 4,596,052 by Stephen Wright et al. entitled "Coherent Optical Receiver," filed May 20, 1983, issued June 17, 1986 (Ex. 1010).
- U.S. Patent No. 6,043,921 by Robert M. Payton entitled "Fading-Free Optical Phase Rate Receiver," filed August 12, 1997, issued March 28, 2000 (Ex. 1011).
- Portions of McGraw-Hill Dictionary of Scientific and Technical Terms,

Second Edition, 1978 (Ex. 1015).

- Portions of McGraw-Hill Dictionary of Scientific and Technical Terms, Fourth Edition, 1989 (Ex. 1016).
- Portions of IEEE Standard Dictionary of Electrical and Electronics Terms (4th Ed.) (Ex. 1017).

4. I am being compensated for my time in preparing this declaration. The opinions herein are my own, and I have no stake in the outcome of the review proceeding. My compensation does not depend in any way on the outcome of the Petitioner's petition.

II. QUALIFICATIONS

5. I am qualified by education and experience to testify as an expert in the field of fiber optic measurement systems. Attached, as Attachment A, is a copy of my resume detailing my experience and education. Additionally, I provide the following overview of my background as it pertains to my qualifications for providing expert testimony in this matter.

6. I am qualified both by education and experience to testify in the field of fiber optic measurement systems, and in particular, as it pertains to the '971 Patent.

7. I have been a Professor of Physics and Optics at the University of North Carolina - Charlotte since 2002, including being chairman of Physics and

Optics from 2002-2009. I was a Professor of Physics at the same institution from 1994-2002, and an Associate Professor of Physics from 1990-1994. I mentor, teach, and supervise undergraduate and graduate physics and engineering students in the areas of fiber optic sensors and applied optics, and am a co-author of the "Handbook of Optical Sensors." I have ten patents issued over the period from 1995-2016. I am a sole- or co-author of more than two hundred publications in my field.

8. In 1988, I received my Ph.D. in Physics, Fiber Optic Sensors from University of Kent in Canterbury, England. My Ph.D. research focused on interferometric fiber optic sensors.

9. In 1976, I received a B.S. degree in Physics from Aryamehr (Sharif) University of Technology in Tehran, Iran. In 1978, I received a M.S. degree in Applied Mathematics & Theoretical Physics from University of Southampton in England.

III. PERSON OF ORDINARY SKILL IN THE ART

10. I understand that the content of a patent (including its claims) and prior art should be interpreted the way a person of ordinary skill in the art would have interpreted the material at the time of invention.

11. I understand that at this time the Petitioners make no assertion as to the proper "time of invention" as all of the cited prior art references would be

considered prior art even as to the earliest priority application (U.S. Application No. 60/599,437) in the United States Patent and Trademark Office, namely, August 6, 2004.

12. It is my opinion that one of ordinary skill in the art at the time of the filing date of the patent would have had at least (1) a Bachelor of Science in Physics or a relevant Engineering field and 4 years of fiber optics industry experience or (2) a Masters or Doctorate in Physics or a relevant Engineering field and 2 years of fiber optics industry experience.

13. In addition to my testimony as an expert, I am prepared to testify as someone who actually designed fiber optic sensor systems from 1988 to present, who actually possessed at least the knowledge of a person of ordinary skill in the art in that time period, and who actually worked with others possessing at least the knowledge of a person of ordinary skill in the art in that time period.

14. I understand that the person of ordinary skill is a hypothetical person who is assumed to be aware of all the pertinent information that qualifies as prior art. In addition, the person of ordinary skill in the art makes inferences and takes creative steps.

IV. LEGAL UNDERSTANDING

15. I have a general understanding of validity based on my experience with patents and my discussions with counsel.

16. I have a general understanding of prior art and priority date based on my experience with patents and my discussions with counsel.

17. I understand that the ’971 Patent should be evaluated under the Pre-AIA laws as the ’971 Patent was filed on February 7, 2005. I understand that the inventors are entitled to a priority date up to one year earlier than the date of filing to the extent that they can show complete possession of particular claimed inventions at such an earlier priority date and reasonable diligence to reduce the claims to practice between such an earlier priority date and the date of filing of the patent. I understand that if the patent holder contends that particular claims are entitled to an earlier priority date than the date of filing of the patent, then the patent holder has the burden to prove this contention with specificity.

18. I understand that an invention by another must be made before the priority date of a particular patent claim in order to qualify as “prior art” under 35 U.S.C. § 102 or § 103, that a printed publication or patent must be publicly available more than one year prior to the date of the application for patent in the United States in order to qualify as “prior art” under 35 U.S.C. § 102(b), or that the invention by another must be described in an application for patent filed in the United States before the priority date of a particular patent claim in order to qualify as “prior art” under 35 U.S.C. § 102(e). I understand that the Defendants have the burden of proving that any particular publication or patent is prior art.

19. I have a general understanding of anticipation based on my experience with patents and my discussions with counsel.

20. I understand that anticipation analysis is a two-step process. The first step is to determine the meaning and scope of the asserted claims. Each claim must be viewed as a whole, and it is improper to ignore any element of the claim. For a claim to be anticipated under U.S. patent law: (1) each and every claim element must be identically disclosed, either explicitly or inherently, in a single prior art reference; (2) the claim elements disclosed in the single prior art reference must be arranged in the same way as in the claim; and (3) the identical invention must be disclosed in the single prior art reference, in as complete detail as set forth in the claim. Where even one element is not disclosed in a reference, the anticipation contention fails. Moreover, to serve as an anticipatory reference, the reference itself must be enabled, *i.e.*, it must provide enough information so that a person of ordinary skill in the art can practice the subject matter of the reference without undue experimentation.

21. I further understand that where a prior art reference fails to explicitly disclose a claim element, the prior art reference inherently discloses the claim element only if the prior art reference must necessarily include the undisclosed claim element. Inherency may not be established by probabilities or possibilities. The fact that an element may result from a given set of circumstances is not

sufficient to prove inherency. I have applied these principles in forming my opinions in this matter.

22. I have a general understanding of obviousness based on my experience with patents and my discussions with counsel.

23. I understand that a patent claim is invalid under 35 U.S.C. § 103 as being obvious only if the differences between the claimed invention and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in that art. An obviousness analysis requires consideration of four factors: (1) scope and content of the prior art relied upon to challenge patentability; (2) differences between the prior art and the claimed invention; (3) the level of ordinary skill in the art at the time of the invention; and (4) the objective evidence of non-obviousness, such as commercial success, unexpected results, the failure of others to achieve the results of the invention, a long-felt need which the invention fills, copying of the invention by competitors, praise for the invention, skepticism for the invention, or independent development.

24. I understand that a prior art reference is proper to use in an obviousness determination if the prior art reference is analogous art to the claimed invention. I understand that a prior art reference is analogous art if at least one of the following two considerations is met. First a prior art reference is analogous art

if it is from the same field of endeavor as the claimed invention, even if the prior art reference addresses a different problem and/or arrives at a different solution. Second, a prior art reference is analogous art if the prior art reference is reasonably pertinent to the problem faced by the inventor, even if it is not in the same field of endeavor as the claimed invention.

25. I understand that it must be shown that one having ordinary skill in the art at the time of the invention would have had a reasonable expectation that a modification or combination of one or more prior art references would have succeeded. Furthermore, I understand that a claim may be obvious in view of a single prior art reference, without the need to combine references, if the elements of the claim that are not found in the reference can be supplied by the knowledge or common sense of one of ordinary skill in the relevant art. However, I understand that it is inappropriate to resolve obviousness issues by a retrospective analysis or hindsight reconstruction of the prior art and that the use of "hindsight reconstruction" is improper in analyzing the obviousness of a patent claim.

26. I further understand that the law recognizes several specific guidelines that inform the obviousness analysis. First, I understand that a reconstructive hindsight approach to this analysis, *i.e.*, the improper use of post-invention information to help perform the selection and combination, or the improper use of the listing of elements in a claim as a blueprint to identify selected portions of

different prior art references in an attempt to show that the claim is obvious, is not permitted. Second, I understand that any prior art that specifically teaches away from the claimed subject matter, *i.e.*, prior art that would lead a person of ordinary skill in the art to a specifically different solution than the claimed invention, points to non-obviousness, and conversely, that any prior art that contains any teaching, suggestion, or motivation to modify or combine such prior art reference(s) points to the obviousness of such a modification or combination. Third, while many combinations of the prior art might be "obvious to try," I understand that any obvious to try analysis will not show a claim to be unpatentable unless it is shown that the possible combinations are: (1) sufficiently small in number so as to be reasonable to conclude that the combination would have been selected; and (2) such that the combination would have been believed to be one that would produce predictable and well understood results. Fourth, I understand that if a claimed invention that arises from the modification or combination of one or more prior art references uses known methods or techniques that yield predictable results, then that factor also points to obviousness. Fifth, I understand that if a claimed invention that arises from the modification or combination of one or more prior art references is the result of known work in one field prompting variations of the known work for use in the same field or a different one based on design incentives or other market forces that yields predicable variations, then that factor also points to obviousness. Sixth, I understand that if a claimed invention arises from the modification or combination of one or more prior art references is the result of routine optimization, then that factor also points to obviousness. Seventh, I understand that if a claimed invention that arises from the modification or combination of one or more prior art references is the result of a substitution of one known prior art element for another known prior art element to yield predictable results, then that factor also points to obviousness.

27. I understand that a dependent claim incorporates each and every limitation of the claim from which it depends. Thus, my understanding is that if a prior art reference fails to anticipate an independent claim, then that prior art reference also necessarily fails to anticipate all dependent claims that depend from the independent claim. Similarly, my understanding is that if a prior art reference or combination of prior art references fails to render obvious an independent claim, then that prior art reference or combination of prior art references also necessarily fails to render obvious all dependent claims that depend from the independent claim.

V. THE ’971 PATENT

28. The ’971 Patent (Ex. 1001), entitled “Natural fiber span reflectometer providing a virtual signal sensing array capability” asserts that it enables virtual sensors along the span of fiber. Ex. 1001 at 1:45-46.

29. I note that the ’971 Patent claims priority to a prior provisional application, U.S. Application No. 60/599,437 filed on August 6, 2004. I am not aware at this time of any basis for an assertion of a priority date earlier than August 6, 2004.

30. The ’971 Patent includes three independent system claims. Ex. 1001 at claims 1, 21, and 22.

31. Independent reflectometer claim 1 from the ’971 Patent is presented below:

> 1. A time-domain reflectometer for sensing at a desired set of n spaced sensing positions along an optical fiber span, said sensing positions being for sensing a type of external physical signal having the property of inducing light path changes within the optical fiber span at regions there along where the signal is coupled to the span, comprising: an optical fiber span having a first end which concurrently serves as both the interrogation signal input end and the back propagating signal output end for purposes of reflectometry, and having a second remote end; a first light source for producing a coherent carrier lightwave signal of a first predetermined wavelength; a binary pseudonoise code sequence modulator modulating said carrier signal for producing a pseudonoise code sequence modulated interrogation lightwave signal which continuously reiterates the binary pseudonoise code sequence, the reiterated sequences being executed in a fixed relationship to a predetermined timing base; a lightwave heterodyner having first and second inputs for receiving a

primary signal and a local oscillator signal, respectively, and operative to produce the beat frequencies of their respective frequencies; a lightwave directional coupler having a first port which receives said binary pseudonoise code sequence modulated interrogation lightwave, a second port coupled to said first end of said optical fiber span, and a third port coupled to said primary signal input of the heterodyner; said directional coupler coupling said binary pseudonoise code sequence modulated interrogation lightwave to said second port where it is launched in a forwardly propagating direction along said optical fiber span causing the return to said second port of a composite back-propagating lightwave which is a summation of lightwave back-propagations from a continuum of locations along the length of the span, said composite back-propagating lightwave signal comprising a summation of multiple components including a first signal component comprising the summation of portions of the said pseudonoise code sequence modulated interrogation lightwave signal which the innate properties of the optical fiber cause to backpropagate at a continuum of locations along the span, and a second signal component comprising the modulation of said first signal component caused by longitudinal components of optical path changes induced into said span at a continuum of locations along said span by external physical signals, said second signal component further including a corresponding set of subcomponents comprising the modulation of said first signal component by optical path changes caused by said external signals at the respective sensing positions; said directional coupler coupling said composite back-propagating lightwave to said third port where it is applied to said first input of the heterodyner; a second light source coupled to said second input of the lightwave heterodyner, said second light source producing a coherent local oscillator lightwave signal in phase locked relation to said carrier lightwave signal, said local oscillator signal being of a second predetermined wavelength which differs from the first predetermined wavelength by an amount of difference small enough to produce at the output of the heterodyner a radio frequency (r.f.) composite difference beat signal, but by an amount large enough to cause said r.f. composite difference beat signal to have sufficient bandwidth to cause it to include r.f. counterparts of signal components and subcomponents of said composite back propagating lightwave signal; said r.f. composite difference beat frequency signal being coupled to an n-way splitter providing a corresponding set of n output channels, each transmitting said r.f. composite difference beat signal; a corresponding set of n correlation-type binary pseudonoise code sequence demodulators having their respective inputs connected to the corresponding output channels of said n-way splitter through a corresponding set of time delay circuits which respectively provide a corresponding set of predetermined time delays in relation to said predetermined timing base of the binary pseudonoise code sequence modulator, to establish said n desired sensing positions along said optical fiber span; and said set of correlation-type binary pseudonoise code sequence demodulators serving to conjunctively temporally and spatially de-multiplex said r.f. composite difference beat signal to provide at their respective outputs r.f. counterparts of the subcomponents of said second signal component of said composite back-propagating lightwave signal caused by changes in the optical path within said optical fiber span induced by external physical signals respectively coupled to the corresponding sensing positions.

32. Independent system claim 21 from the ’971 Patent is presented below:

> 21. A system wherein, at respective sensing stations of a plurality of sensing stations along a span of optical fiber, the system senses input signals of a type having a property of inducing light path changes at regions of the span influenced by such input signals, comprising: means for illuminating an optical fiber span with a CW optical signal; means for retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span; means for modulating said CW optical signal with a reiterative autocorrelatable form of modulation; means for picking off a radio frequency (r.f.) counterpart of the retrieved signal, wherein the r.f. counterpart is in phase locked synchronism with the CW optical signal; means for performing a corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal wherein said performing of the respective autocorrelation detections of the plurality of autocorrelation detection by said means for performing autocorrelation-detections are done in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal.

33. Independent apparatus claim 22 from the ’971 Patent is presented below:

> 22. Signal sensing apparatus for sensing input signals at an array of a plurality of sensing stations along an optical fiber span, wherein at respective sensing station of the array the apparatus senses input signals of a type having the property of inducing light path changes within regions influenced by such input signals, said apparatus comprising: an optical wave network comprising a transmitter laser and a lightwave directional coupler, said network being operative to illuminate an optical fiber span with a CW optical signal and to retrieve portions of the illumination back-propagating from a continuum of locations along the fiber span; a modulator operative to modulate the CW optical signal in accordance with a reiterative autocorrelatable form of modulation code; a heterodyner which, in phase locked synchronism with said transmitter laser, receives said retrieved back-propagated portions of illumination and derives therefrom a radio frequency (r.f.) counterpart; and a corresponding plurality of autocorrelation detectors operative upon said r.f. counterpart of the retrieved optical signal in respective timed relationships of a corresponding plurality of different timed relationsips with respect to said reiterative autocorrelatable form of modulation code.

34. The ’971 Patent specification includes 13 figures. The ’971 Patent describes Figure 1 and Figure 2 as helpful in depicting concepts and underlying mechanisms of optical systems. Ex. 1001 at 4:25-31.

35. The ’971 Patent describes Figure 3 as “a block diagram of a natural fiber span time-domain reflectometer system in accordance with the present

invention." Ex. 1001 at 4:32-34. It also describes Figure 12 as "a block diagram of a programmable routing and phase signal switching network which provides selective pairing of the outputs of the set of phase demodulators of FIG. 7 to provide differential phase signals across pairs of virtual sensors along the fiber span in accordance with the present invention" and Figure 13 as "a diagrammatic depiction of embodiment of invention [sic] of FIG. 3 in which portions of the optical fiber span are wound around a hollow mandrel." *Id*. at 4:65-67. Those are the only three figures that are described with respect to the invention, though other figures reference particular portions of Figure 3. Figure 3 is reproduced below.

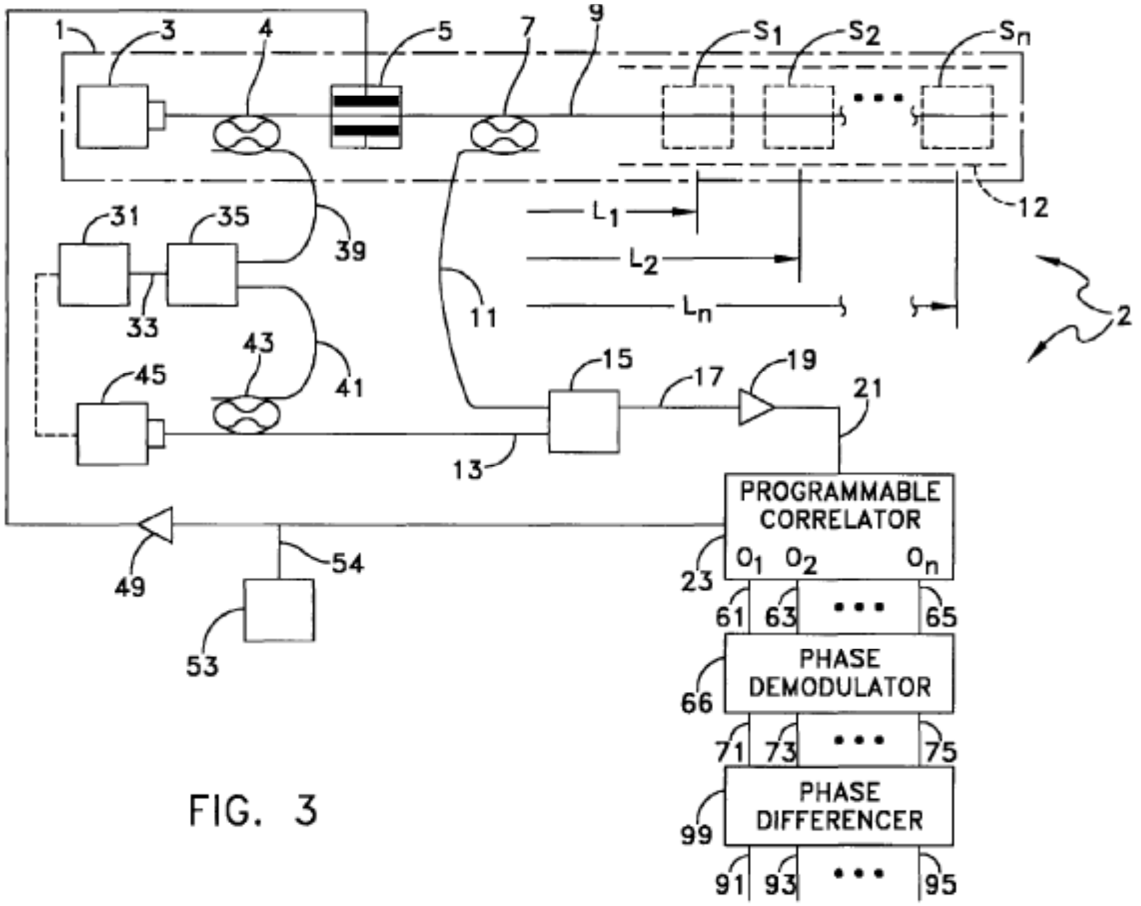


FIG. 3

36. The ’971 Patent provides a “Description of the Preferred Embodiment” that includes the components of Figure 3. The transmitter laser (3), in the upper left, projects light through optical coupler or beamsplitter (4) and into optical modulator (5). The modulated light moves through optical coupler, beamsplitter, or circulator (7) and into optical fiber (9). *Id*. at 15:53-55; 15:58-61; and 16:1-5. The type of modulation applied is determined by master correlation code generator (53), which is connected to the modulator (5) by an amplifier 49. *Id*. at 15:62-63.

37. The ’971 Patent explains that sending modulated light down an optical fiber span “causes a back-propagating composite optical signal, which is a linear summation, or integration spatially, of all the individual, continuous, or continuum of back-reflections along the span of fiber.” *Id*. at 16:21-24. That “composite signal” has several components according to the ’971 Patent, including at least the “naturally occurring continuum of optical back reflections” and “the continuum of modulations at locations along the span of the reflected signals due to longitudinal components of optical path length change.” *Id*. at 16:26, 36-38. The second component can be caused by many conditions along the fiber including acoustic pressure waves, mechanical strain or pressure, and thermal strain or pressure. *Id*. 16:40-45. Put another way, there is always some backscattering, but the exact type of backscattering received can vary based on fiber conditions such as temperature

and pressure. The ’971 Patent considers those variations separately though it is always the composite signal, including the natural continuum, that is received in any system.

38. The system depicted in Figure 3 connects an optical pathway (11) to optical coupler, beamsplitter, or circulator (7) to receive the backscattered light from fiber (9) and relay it to optical receiver (15). Ex. 1001 at 17:10-14. Figures 4 and 5 are schematics showing alternative arrangements of the internal components of the optical receiver (15). *Id.* at 4:36-39. Figure 4 shows the use of two photodetectors (111) and (113), while in Figure 5 the optical receiver shows only one photodetector (111). *Id.* at Figs. 4 & 5. The optical receiver (15) also receives an input from local oscillator laser (45). *Id*. at 18:64-19:8. The transmitter laser (3) and local oscillator laser (45) are also connected to optical receiver (35) through optical couplers or beamsplitters (4) and (43) and optical pathways (49) and (41), respectively. *Id.* at 15:55-58, 18:67-19:4. Optical receiver (35) is then connected back to local oscillator laser (45) through phase locking circuitry (31), which employs “a conventional phase locked loop mechanism.” *Id.* at 19:14-22.

39. Figure 3 of the ’971 patent also shows that the optical receiver (15) is connected through an amplifier (19) to a programmable correlator (23), which also receives an input from the master correlation code generator (53). Figure 6 shows

a block diagram of the components inside programmable correlator (23). Ex. 1001 at 4:40-42. Figure 6 is reproduced below:

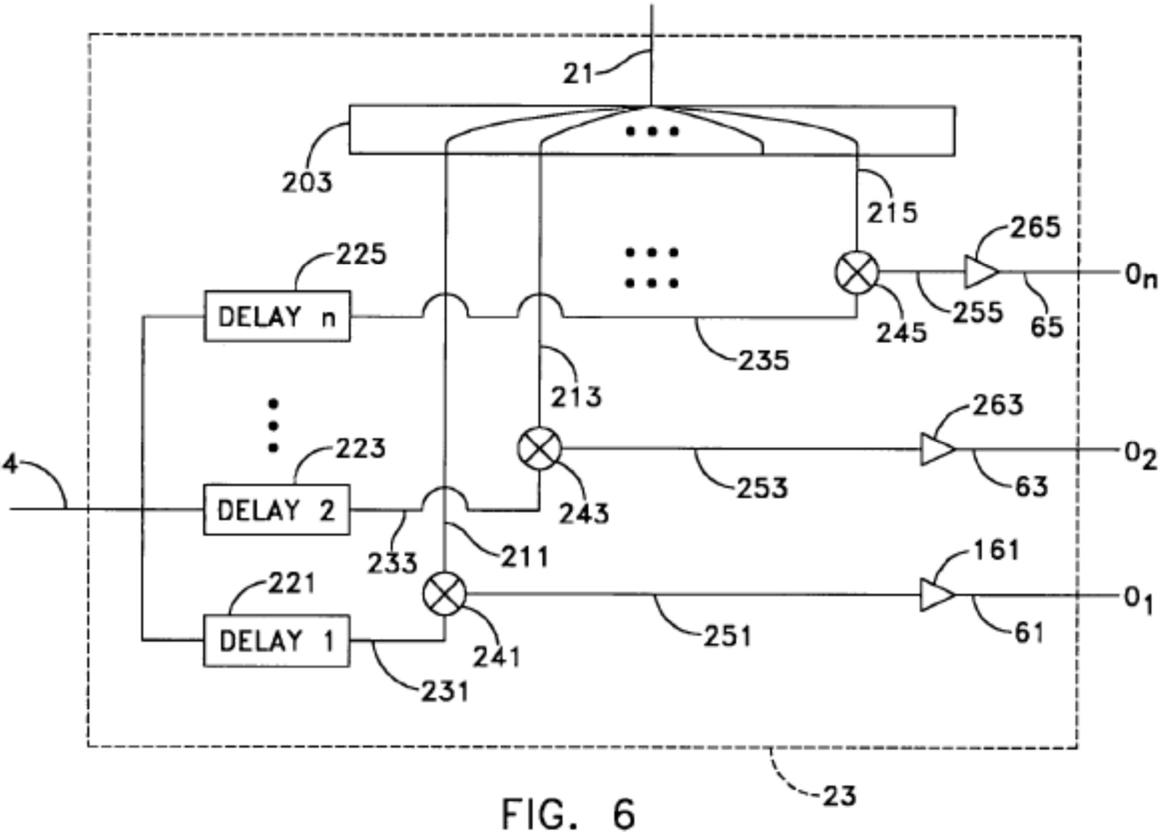


FIG. 6

40. The input from the master correlation code generator (53) is provided to multiple programmable delay circuits (221), (223), and (225), while the output of the optical receiver (15) is provided to a power splitter (203). Ex. 1001 at 25:18-25. Each delayed correlation code (231), (233), and (235) is provided to one of the "multipliers (or balanced mixers)" (241), (243), and (245) along with one of the power splitter outputs (211), (213), and (215) and the results are amplified at (261), (263) and (265) and outputted. *Id*. at 25:27-40. Figure 7 shows that the

outputs are demodulated at (81), (83), and (85). *Id.* at 26:12-15. Figure 8 provides a block diagram of a demodulator, *e.g.*, (81). *Id.* at 4:47-48.

41. Figure 9 provides a block diagram of a component of a demodulator. Ex. 1001 at 4:49-51.

42. Figures 10 and 11 provide block diagrams of digital and analog phase demodulator circuits, respectively. Ex. 1001 at 4:52-57.

43. Figure 12 illustrates one example implementation of the phase detection in which a "programmable phase differencer" embodiment is provided. Ex. 1001 at 29:12-14.

44. Figure 13 illustrates an embodiment in which the fiber optic span "is to be immersed in a liquid medium." Ex. 1001 at 31:58-60.

45. After describing the embodiments and figures, the '971 Patent states that "Many modifications in these are possible by those skilled in the art within the teachings herein of the invention." Ex. 1001 at 33:12-14. It then describes one such specific modification. In that embodiment the local oscillator laser (45) is replaced by a "Bragg cell" from which a "Bragg shifted-diffracted optical wave will exit the acousti-optical modudulator [sic] with an optical frequency equivalent to the phase locked laser 45." Ex. 1001 at 33:20-28.

46. The '971 Patent includes 22 claims. I have been informed by counsel that claims 1-3, 6-16, and 18-22 are the subject of the *Inter Partes* Review petition.

VI. CLAIM CONSTRUCTION

47. I understand that claim construction is a matter of law. I understand that in an *Inter Partes* Review proceeding the claims are to be given their broadest reasonable interpretation consistent with the Patent's specification, and that specific claim terms are given their ordinary and customary meaning, as would be understood by a person of ordinary skill in the art in the context of the entire disclosure. I also understand that limitations from the specification are not to be read into the claims. The specification, however, can inform a person of ordinary skill in the art as to the broadest reasonable interpretation of the claims. In addition, I understand that a person of ordinary skill in the art would look to explanations and arguments made by the applicants during prosecution history to inform as to the broadest reasonable interpretation of the claims.

48. I understand that a court has not construed the claims of the '971 Patent.

"light source"

49. In my opinion and based on my interactions with those of skill in 2003-2004, a person of ordinary skill in the art in that timeframe would have used and understood "light" in "light source" to refer to electromagnetic radiation in wavelengths from near-ultraviolet to mid-infrared, which is consistent with the definition of the IEEE Dictionary for the laser field. Ex. 1017 at 521 ("light . . . (2)

In the laser and optical communication fields, custom and practice have extended usage of the term to include the much broader portion of the electromagnetic spectrum that can be handled by the basic optical techniques used for the visible spectrum. This region has not been clearly defined but, as employed by most workers in the field, may be considered to extend from the near-ultraviolet region of approximately 0.3 um, through the visible region, and into the mid-infrared region to 30um.”). Any range of or difference in frequencies is directly related to a range of or difference in wavelengths due to the fixed speed of light.

50. Based on my review of the ‘971 Patent specification and figures, in my opinion, a person of ordinary skill in the art would not modify their usual understanding of those terms in the context of the embodiments and description of the patent.

“radio frequency (r.f.)”

51. The ’971 Patent uses “radio frequency,” “r.f.” and “RF” interchangeably. Ex. 1001 at 19:57, 34:37 (radio frequency and r.f.); 17:39 (RF). In my opinion and based on my interactions with those of skill in 2003-2004, a person of ordinary skill in the art in that timeframe would have also used and understood those terms interchangeably to refer to a range of frequencies from the low kilohertz to the high gigahertz. At that time such use and understanding of the RF terms was long established. The McGraw-Hill Dictionary of Scientific and

Technical Terms in both 1978 and 1989 defined a range for radio frequency of "roughly the range from 10 kilohertz to 100 gigahertz." Ex. 1013 at 1316; Ex. 1014 at 1553. That range is consistent with the definition of the IEEE Dictionary. Ex. 1017 at 775-76. That range is also consistent with my understanding of how people of ordinary skill in the art used and understood the term across a long timeframe including during the time of the priority date.

52. Based on my review of the '971 Patent specification and figures, in my opinion, a person of ordinary skill in the art would not modify their usual understanding of those terms in the context of the embodiments and description of the patent.

VII. STATE OF THE ART

53. As of August 6, 2004, the state of the art in the field of optical sensors fully encompassed the concepts of and the implementation for a system for sensing external physical signals based on light path changes within an optical fiber as claimed in the '971 Patent.

54. Ex. 1004 ("Everard") discloses a distributed sensor system. The system includes modulating a light source using a repeating pseudo random bit sequence (PRBS), transmitting the modulated light down an optical fibre, and detecting the backscattered signal. Everard discloses "Optical Time domain reflectometry techniques, hereafter defined as OTDR, are used in which a pulse is

launched into the fibre and a photodetector, amplifier, and sampling gate combination are used to measure the backscatter," where "[t]he time delay between the transmitted pulse and the sampling gate being fired, defines the slot in the fibre over which the backscatter is measured." Ex. 1004, 1:16-21. Alternatively, Everard indicates "FMCW [frequency modulated continuous waveforms] can be used, however spectral analysis is required in the receiver after the detector." *Id*., 1:43.

55. The backscattered signal is "incident on the photo-detector with an optical local oscillator. A constant local oscillator signal similar to the transmitted optical signal without any modulation on it is applied with the optical backscattered light from the fibre to the input of the photodetector." *Id.* , 4:10-13. "The measurement of the amplitude, spectra, phase, and polarisation of the backscatter can also be used to characterise the properties of the material and the influence of any external parameters which influence the properties of the materials producing the backscatter." *Id*., 1:10-13. "Spacing information is obtained by multiplying the detected backscattered signal with a delayed version of the pseudo random bit sequence. . . . By varying the delay[,] the backscatter from different points can be measured." *Id*., 1:62-64. Alternatively, the backscattered signal may be demodulated "using multiple correlators to give simultaneous

information from different spatial positions using multiple delays of the pseudo random sequences." *Id*., 6:17-18; Fig. 9.

56. Ex. 1005 ("Kersey") discloses a sensor system for detecting a physical condition such as an acoustic wave. The system uses fiber optic Bragg gratings to reflect portions of input light representing the effects of a physical condition on segments of the fiber. Ex. 1005, Abstract. Kersey discloses a laser light source which is passed to a modulator that modulates the light using a pseudo-random bit sequence (PRBS) generator to produce a PRBS optical signal. Ex. 1005, 3:28-37. The sum of reflected light from each Bragg grating reflector is received by a coupler. *Id.*, 3:56-57. A delay circuit coupled to the PRBS generator is used to "ensure[] that the demodulated signal reflecting from [a] grating 216[], and the modulation signal delayed by [the delay circuit], will both arrive at correlator 230 within the time window." *Id.*, 4:44-50. The correlation circuit is used to correlate n pairs of backscatter signals and delay signals. *Id.*, Fig. 3. The system may then determine the phase difference between the two signals to determine the change in optical path of a given segment of the fiber. *Id.*, 4:54-5:6.

57. Ex. 1006 ("Beckmann") discloses "an optical time-domain reflectometer (OTDR) using heterodyne reception" that measures the "backscattered portion of light pulses sent into the measuring waveguide." Ex. 1006, Abstract. "The structure is comprised of a modulated laser light source" and

"a laser light source which constitutes a local oscillator and transmits continuous light." *Id*., Abstract; 1:10-13. The modulated laser light source and the local oscillator light source "differ[] by an intermediate frequency." *Id.*, Abstract; 1:14. "[T]he back-scattered light of the transmission light source is superposed and applied to a photodetector whose intermediate-frequency electric output signal is filtered and evaluated." *Id*., Abstract; 1:14-18. "[I]t is advantageous that the intermediate frequency f_{ZF} has a value between 0.5 and 15 GHz. *Id*., 3:15-17.

58. Ex. 1007 ("Yoshino") discloses a differential heterodyne fiber-optic sensing scheme using a dual-frequency dual-polarization laser beam and a polarization-maintaining fiber as a sensor element. Ex. 1007, 503. The sensors may measure "temperature, strain, force, pressure, rotation rate (gyroscope), magnetic and electric fields, displacement, and film thickness." *Id.* The system uses a light source to emit "orthogonally linearly polarized two modes having a frequency separation from 300 to 400 kHz." *Id.*, 504. The system uses a signal fiber and a reference fiber aligned close to each other, where the phase difference between the two beat signals is detected by a phasemeter. *Id.*

59. Ex. 1008 ("Fredin") discloses a method and system for measuring optical scattering characteristics and determining the temperature of a specific portion of a fiber by using backscattered radiation. Ex. 1008, Abstract. A continuous wave laser excitation signal is coupled to an optical fiber. *Id.* The

excitation signal is amplitude modulated at variable frequencies and enters the optical fiber. *Id.*, 2:48-51. Radiation backscattered by the optical fiber is used to produce backscattered radiation signal, which is mixed with the excitation signal. *Id.*, 2:59-63. The mixed signal is filtered and digitized to determine the magnitude of backscattered radiation from a specific portion of the fiber, which allows determination of a temperature associated with that specific portion of the fiber. *Id.*, 2:63-3:4. Fredin discloses using an optical fiber that is a single mode optical fiber. *Id.*, 2:55-56.

60. Ex. 1009 ("Henning") discloses an acoustic sensor comprising "an optical fibre core surrounded by a jacket of plastics material" that is "suitable for a linear or a planar optical fibre senor array." Ex. 1009, Abstract. The jacket has "low Young's modulus and low Poisson's ratio for high sensitivity to hydrostatic stress." *Id.*, 4. A laser is launched into an optical fibre subject to acoustic waves and backscattered light pulses reaches a photo detector and the signal is demultiplexed to produce output signals indicating acoustic signals. *Id.*, 7-8, Figure 7.

61. Ex. 1010 ("Wright") discloses a receiver with inputs for an input signal and a local oscillator, which are both applied to a "beam splitter/combiner" to produce two combined signals. Ex. 1010, Abstract. Those signals are applied to

"substantially identical photodetectors" whose current difference comprises the balanced detection output. *Id.*

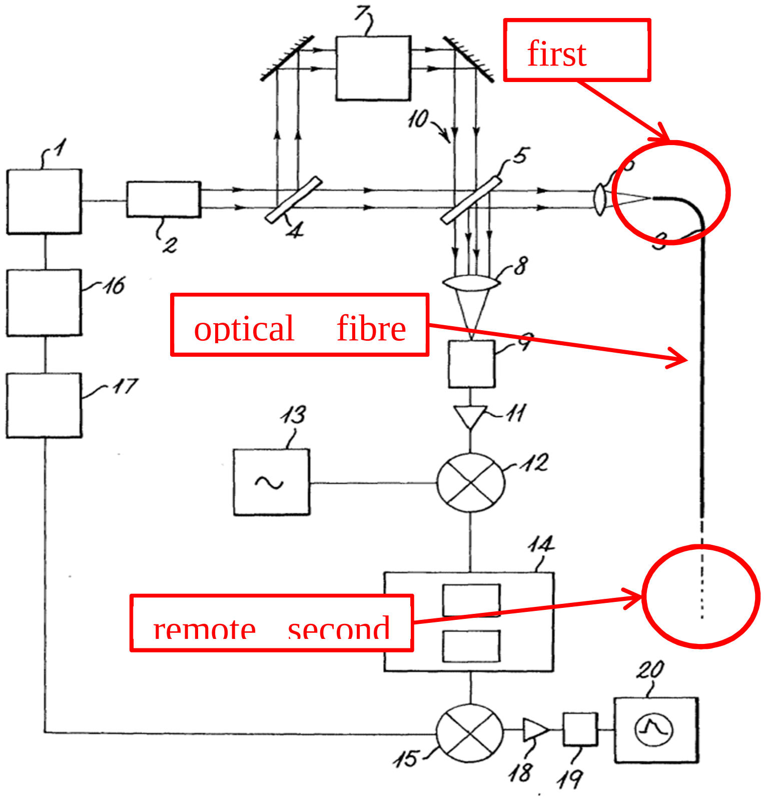
62. Ex. 1011 ("Payton '921") discloses a receiver for optical input signals with varying phase. Ex. 1011, Abstract. A signal decoding module detects the phase rate of the optical input signal, while maintaining a constant signal to noise ratio. *Id.* at Abstract, Fig. 7, and 3:5-7.

VIII. UNPATENTABILITY ANALYSIS OF THE '971 PATENT

63. In my opinion, Everard anticipates claims 1-3, 6, 12, 14, 15, and 18-22 of the '971 Patent for at least the reasons described herein.

64. Claim 1 is anticipated by Everard.

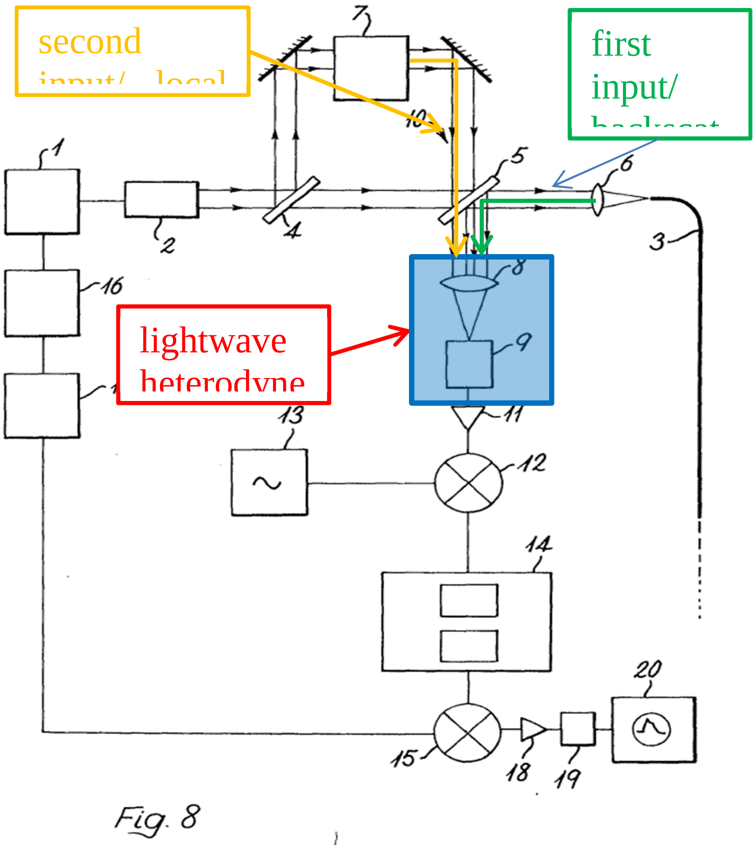
1[p]. A time-domain reflectometer for sensing at a desired set of n spaced sensing positions along an optical fiber span, said sensing positions being for sensing a type of external physical signal having the property of inducing light path changes within the optical fiber span at regions there along where the signal is coupled to the span, comprising:	To the extent the preamble may be limiting, a person of ordinary skill would understand it is disclosed by Everard. To a person of ordinary skill Everard discloses a "system described in (1) can be used to perform optical time domain reflectometry on fibre systems" for sensing at a desired set of n spaced sensing positions along an optical fiber span (Figure 8, fibre 3), said sensing positions being for sensing a type of external physical signal having the property of inducing light path changes within the optical fiber span at regions there along where the signal is coupled to the span ("The measurement of the amplitude, spectra, phase and polarisation of the scatter can also be used to characterise the properties of the material and the influence of any external parameters which influence the properties of the materials producing the backscatter."). Ex. 1004, 8:42-45, 6:31-35.

1[a]. an optical fiber span, having a first end which concurrently serves as both the interrogation signal input end and the back propagating signal output end for purposes of reflectometry and having a remote second end:	To a person of ordinary skill Everard discloses that "light out of the laser (2) is coupled into an optical fibre (3) via beam splitters (4) and (5) and a lens (6)" and the back propagating signal output end for purposes of reflectometry ("The backscattered signal from the fibre is deflected by the beam splitter (5) via a lens (8) onto the photodetector (9)") and having a remote second end. Ex. 1004 at Fig. 8, 5:39-45.  Fig. 8

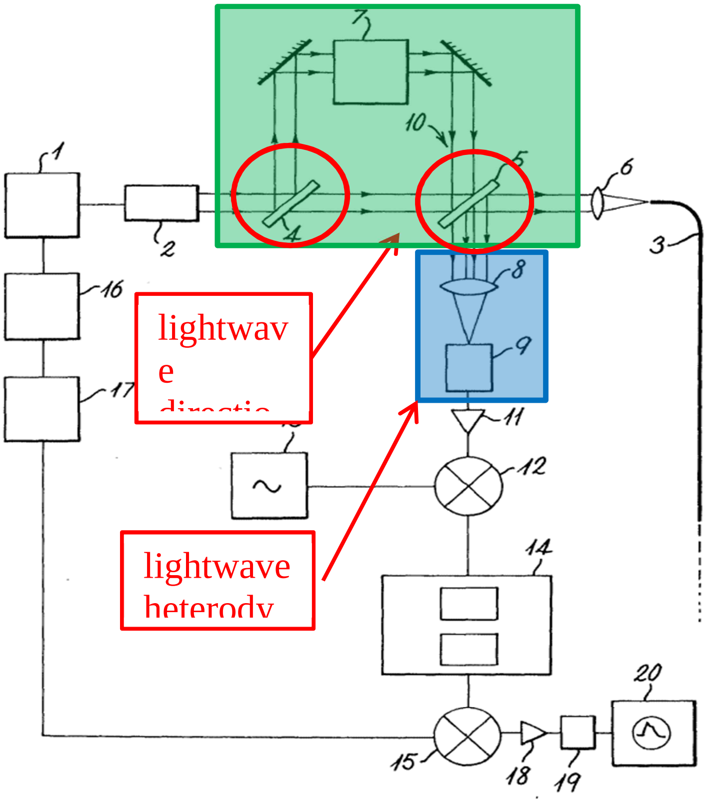
1[b]. a first light source for producing a coherent carrier lightwave signal of a first predetermined wavelength;	To a person of ordinary skill Everard discloses a first light source for producing a coherent carrier lightwave signal of a first predetermined wavelength (laser 2). Ex. 1004, 3:51-52, 4:10-13, 5:37-40. Payton admits that lasers produce coherent light "laser 42 functions as the source of coherent light." Ex. 1001 at 2:18-25, discussing U.S. Patent No. 5,194,847, 3:62-63.

1[c]. a binary pseudonoise code sequence modulator modulating said carrier signal for producing a pseudonoise code sequence modulated interrogation lightwave signal which continuously reiterates the binary pseudonoise code sequence, the reiterated sequences being executed in a fixed relationship to a predetermined timing base;	To a person of ordinary skill Everard discloses a "digital pseudo random generator is built using digital circuits," which modulates the carrier signal for producing a pseudonoise code sequence modulated interrogation lightwave signal and continuously reiterates the sequence in a fixed relationship to a predetermined timing base ("the time taken before the sequence starts to repeat (hereafter called the sequence repeat time)"). Ex. 1004, 1:55-64, 5:37-40, 6:14-15. Everard discloses using a predetermined timing base because "[s]patial information is obtained by multiplying the detected backscattered signal with a delayed version of the pseudo random bit sequence, the delay being implemented digitally. By varying the delay[,] the backscatter from different points can be measured."). Ex. 1004, 1:62-63.

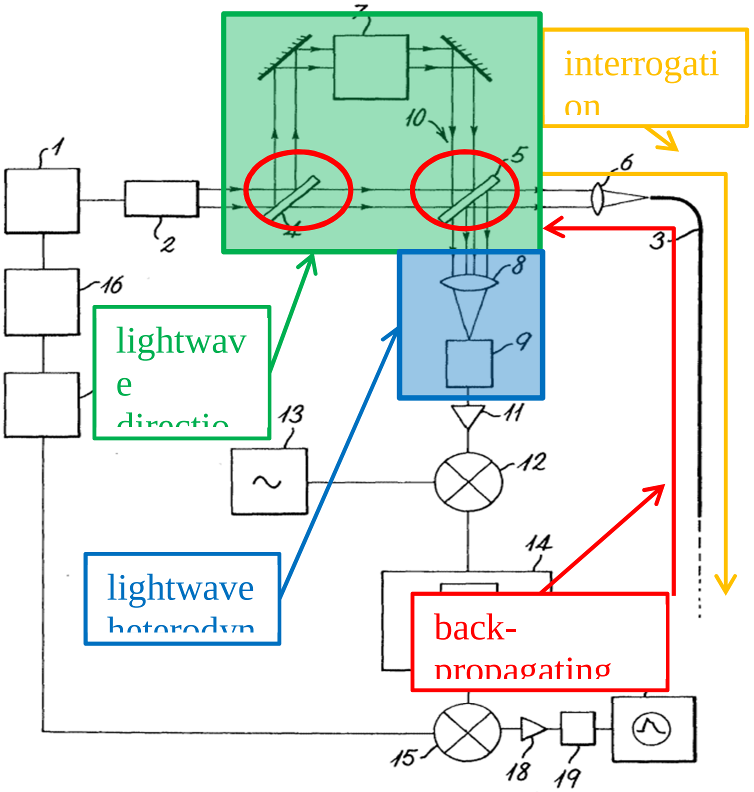
1[d]. a lightwave heterodyner having first and second inputs for receiving a primary signal and a local oscillator signal, respectively, and operative to produce the beat frequencies of their respective frequencies;	To a person of ordinary skill Everard discloses a lightwave heterodyner having first and second inputs ("The backscattered signal from the fibre is deflected by the beam splitter (5) via a lens (8) onto the photodetector (9). The frequency shifted optical local oscillator beam (10) is derived from the other reflection from the beam splitter (4) and photodetector/amplifier (11) this is arranged to be incident onto the photo-detector (9) via a lens (8) simultaneously with the optical backscatter.") for receiving a primary signal ("backscattered signal from the fibre") and a local oscillator signal ("frequency shifted optical local oscillator"), respectively, and operative to produce the beat frequencies of their respective frequencies. Ex. 1004, 5:44-53. Because a lightwave heterodyner outputs the beat frequencies of its inputs, one of ordinary skill in the art would understand Everard's disclosure of the incidence of the frequency shifted local oscillator beam 10 "simultaneously with the optical backscatter" on the photo detector operates as lightwave heterodyner and would produce "beat

	frequencies of their respective frequencies." Ex. 1004, 5:45-48.  Fig. 8

1[e]. a lightwave directional coupler having a first port which receives said binary pseudonoise code sequence modulated interrogation lightwave, a second port coupled to said first end of said optical fiber span, and a third port coupled to said primary signal input of	To a person of ordinary skill Everard discloses beam splitters 4 and 5, and lenses 6 and 8, which "can be replaced by optical fibre couplers" having a first port which receives the modulated interrogation lightwave, a second port coupled to an end of the fiber, and a third port coupled to the heterodyner input. Ex. 1004, 5:37-40, 5:44-49, 5:54, 7:17-18.

the heterodyner	 Fig. 8

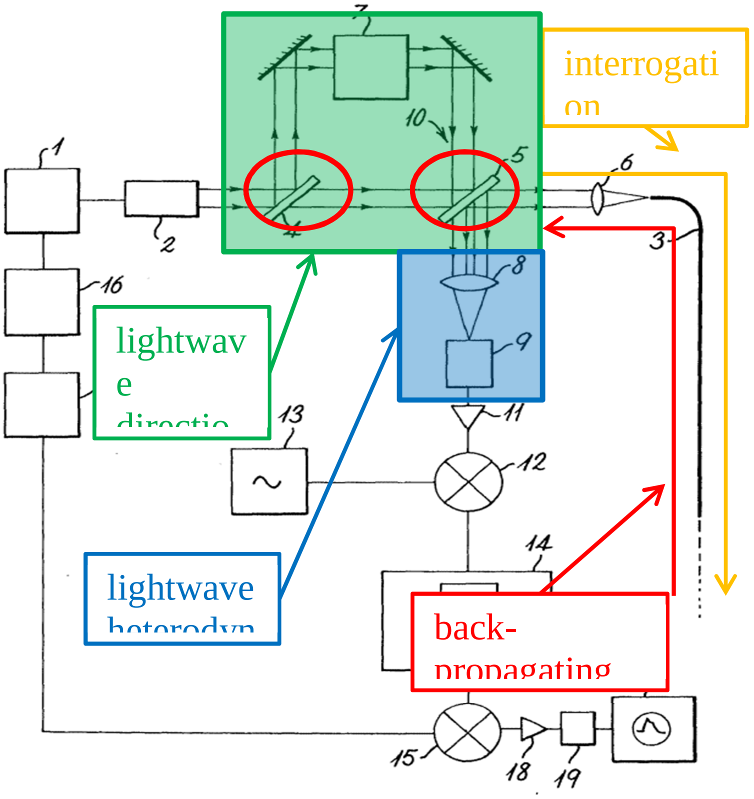
1[f]. said directional coupler coupling said binary pseudonoise code sequence modulated interrogation lightwave to said second port where it is launched in a forwardly propagating direction along said optical fiber span causing the return to said second port of a composite back-propagating lightwave which is a summation of lightwave back-propagations from a	To a person of ordinary skill Everard discloses that the directional coupler directs the modulated lightwave into the fiber causing a composite back-propagating lightwave to return. Ex. 1004 at 5:37-45. The back-propagating lightwave is generated at locations along the length of the span and has a summation of multiple components, including components that "characterise the properties of the material" and components based on "external parameters which influence the properties of the materials." Ex. 1004, 3:11-14; 6:31-35. A person of ordinary skill would understand Payton to confirm that backscatter inherently includes multiple components. Ex. 1001 at 16:18-24.

continuum of locations along the length of the span, said composite back-propagating lightwave signal comprising a summation of multiple components including	 Fig. 8

1[g]. a first signal component comprising the summation of portions of the said pseudonoise code sequence modulated interrogation lightwave signal which the innate properties of the optical fiber cause to backpropagate at a continuum of locations along the span, and a second signal component comprising the modulation of said first signal component	To a person of ordinary skill Everard discloses a first signal component comprising backscatter from along the fiber produced by innate properties of the optical fiber, "properties of the material," and a second signal component comprising changes to the first based on longitudinal components of optical path changes from external physical signals, "external parameters." Ex. 1004, 6:12-14, 6:31-35. A person of ordinary skill would understand Payton to confirm that backscatter inherently includes those two components. Ex. 1001 at 16:18-24; 16:25-39.

caused by longitudinal components of optical path changes induced into said span at a continuum of locations along said span by external physical signals, said second signal component further including a corresponding set of subcomponents comprising the modulation of said first signal component by optical path changes caused by said external signals at the respective sensing positions;	

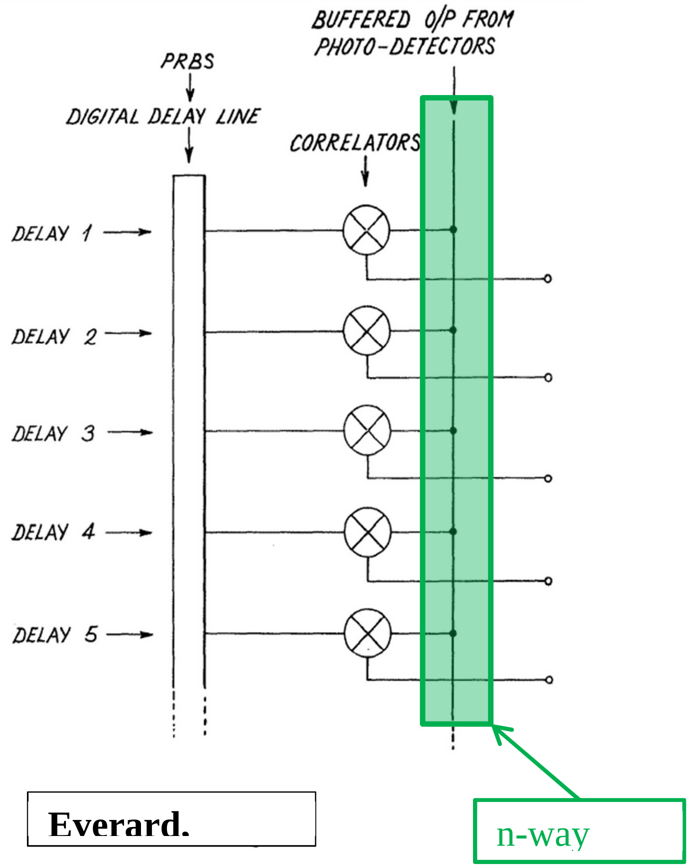
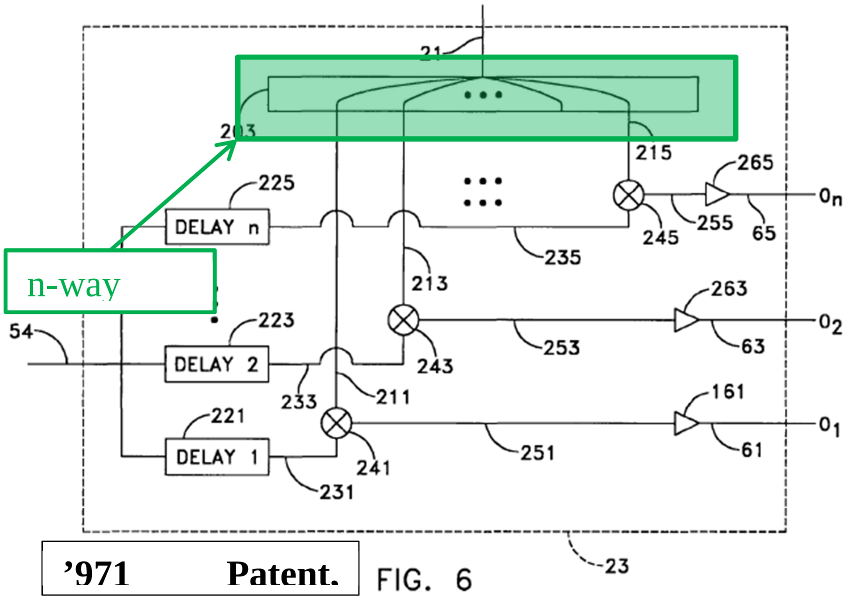
1[h]. said directional coupler coupling said composite back-propagating lightwave to said third port where it is applied to said first input of the heterodyner	To a person of ordinary skill Everard discloses the directional coupler coupling the backscatter (identified by red line) to the third port (facing lens 8) where it is applied to said first input of the heterodyner (at lens 8). Ex. 1004, 5:44-45, 7:17-18.

	 Fig. 8

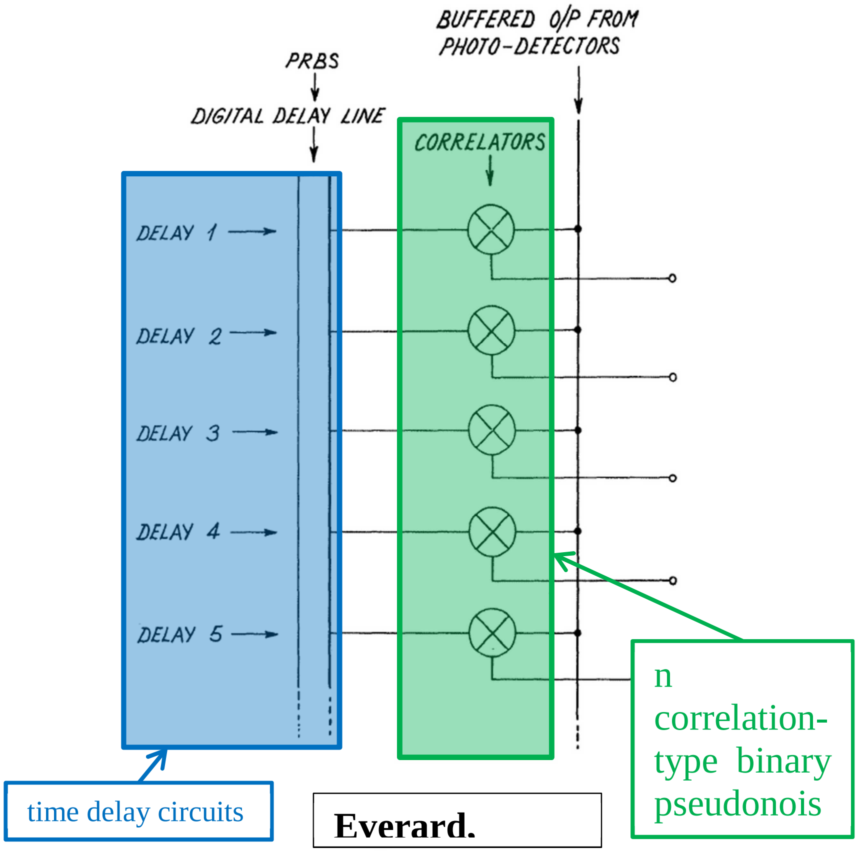
1[i]. a second light source coupled to said second input of the lightwave heterodyner, said second light source producing a coherent local oscillator lightwave signal in phase locked relation to said carrier lightwave signal, said local oscillator signal being of a second predetermined wavelength which differs from the first predetermined	To a person of ordinary skill Everard discloses a "optical local oscillator" coupled to a input of the lightwave heterodyner (facing lens 8), and producing a coherent lightwave in phase locked relation to the carrier lightwave signal with a second predetermined wavelength which differs from the first predetermined wavelength by an amount of difference small enough to produce at the output of the heterodyner an RF composite difference beat signal (for RF mixer 12) with sufficient bandwidth to include the components and subcomponents of the backscatter signal so that "output which when integrated or averaged would produce spatial information about the amplitude, spectrum, phase and polarisation of the backscatter". Ex. 1004, 5:3-5, 34-41, 48-51; 6:26-28. To a person of ordinary skill Everard's use of frequency shifting for one of the heterodyner inputs to produce at

wavelength by an amount of difference small enough to produce at the output of the heterodyner a radio frequency (r.f.) composite difference beat signal, but by an amount large enough to cause said r.f. composite difference beat signal to have sufficient bandwidth to cause it to include r.f. counterparts of signal components and subcomponents of said composite back propagating lightwave signal;	the heterodyner output an RF signal for the RF mixer equates to the ’971 patent’s “alternative to the previously described mechanism for phase locking laser 3 and 45, the laser optical wave on an optical path 39 can be passed through an acoustic-optic modulator, sometimes called a Bragg Cell. . . . with an optical frequency equivalent to the phase locked laser 45.” “An acousto-optically frequency shifted version of the light in optical path 39 can therefore replace the phase locked light of coherent optical source 45.” Ex. 1001 at 33:19-34.

1[j]. said r.f. composite difference beat frequency signal being coupled to an n-way splitter providing a corresponding set of n output channels, each transmitting said r.f. composite difference beat signal	To a person of ordinary skill Everard discloses r.f. composite difference beat frequency signal being coupled to an n-way splitter (“using multiple correlators”) providing a corresponding set of n output channels, each transmitting said r.f. composite difference beat signal (Figure 9). Ex. 1004, 6:16-23.

	 **Everard.**  **’971 Patent.** FIG. 6

1[k]. a corresponding set of n correlation-	To a person of ordinary skill Everard discloses “using multiple correlators” and “using multiple delays of the

type binary pseudonoise code sequence demodulators having their respective inputs connected to the corresponding output channels of said n-way splitter through a corresponding set of time delay circuits which respectively provide a corresponding set of predetermined time delays in relation to said predetermined timing base of the binary pseudonoise code sequence modulator, to establish said n desired sensing positions along said optical fiber span; and	original pseudo random sequences" to establish said n desired sensing positions along said optical fiber span that "give simultaneous information from different spatial positions." Ex. 1004, Fig. 6, 6:16-23. 

1[l]. said set of correlation-type binary pseudonoise code sequence demodulators serving to conjunctively temporally and spatially de-multiplex said r.f. composite difference beat signal to provide at their respective outputs r.f.	To a person of ordinary skill Everard's Fig. 9 discloses a set of correlation-type binary pseudonoise code sequence demodulators that conjunctively temporally and spatially de-multiplex the RF output of the heterodyner with "output which when integrated or averaged would produce spatial information about the amplitude, spectrum, phase and polarisation of the backscatter." "The spatial position being probed by each correlator is set by the delay between the transmitted PRBS and the PRBS applied to the correlators via the delay circuitry." Ex. 1004, 6:24-35.

counterparts of the subcomponents of said second signal component of said composite back-propagating lightwave signal caused by changes in the optical path within said optical fiber span induced by external physical signals respectively coupled to the corresponding sensing positions.	

65. Claim 2 is anticipated by Everard.

2. The reflectometer of claim 1 wherein: said innate properties of the said optical fiber material include the generation of Rayleigh optical scattering effects at a continuum of locations along said optical fiber span in response to said forwardly propagating binary pseudonoise code sequence modulated interrogation lightwave.	To a person of ordinary skill Both Everard and the '971 Patent disclose that the innate properties of an optical fiber include the generation of Rayleigh optical effects. Ex. 1001, Abstract; Ex. 1004, 1:8-9, 5:34-36.

66. Claim 3 is anticipated by Everard.

3. The reflectometer	To a person of ordinary skill Everard discloses a system

of claim 1 wherein said type of external physical signal which induces light path changes in said optical fiber span is an acoustic pressure wave signal.	measuring characteristics that influence backscatter from an optical fiber. A person of ordinary skill would understand the ’971 Patent to confirm that acoustic pressure waves inherently influence fiber backscatter. Ex 1001, Abstract and 16:40-45; Ex. 1004, 6:64-7:1.

67. Claim 6 is anticipated by Everard.

6. The reflectometer of claim 3 wherein: said optical fiber span is of a length L; and said first light source is a laser having the performance capability to generate a lightwave signal with sufficient phase stability to substantially retain coherency in propagation along said optical fiber span for a distance at least equal to 2 L.	To a person of ordinary skill Everard discloses an optical fiber having a length and that backscattered light from along that fiber is coherently detected, indicating that coherency was retained for twice the length of the fiber. Ex. 1004, 4:10-13.

68. Claim 12 is anticipated by Everard.

12. The reflectometer of claim 1 wherein: said lightwave heterodyner is of the photodetector type.	To a person of ordinary skill Everard discloses that its heterodyner uses a photodetector. Ex. 1004, 1:16-19; 5:44-45.

69. Claim 14 is anticipated by Everard.

14. The reflectometer of claim 1 wherein the continuously reiterated binary pseudonoise code sequences are binary pseudonoise sequences wherein shifts between binary states of the signal alternatingly shift the radian phase of the carrier between substantially 0° and substantially 180°.	To a person of ordinary skill Everard discloses the use of on and off pulses, which will shift the carrier phase from 0° to 180°. A person of ordinary skill would understand that the phase is 0° as the carrier shifts from off to on and is 180° as the carrier shifts from on to off. Ex. 1004, 1:55-56.

70. Claim 15 is anticipated by Everard.

The reflectometer of claim 1 wherein said pseudonoise code sequence is a pseudorandom number (PN) code sequence generated by a shift-register type PRN code generator.	To a person of ordinary skill Everard discloses the use of shift registers to generate pseudo random bit sequences. Ex. 1004, Fig 5, 2:63-64, 6:1-8.

71. Claim 18 is anticipated by Everard.

The reflectometer of claim 1, wherein: a time period TP is required for forward propagation of said autocorrelatable spectrum spreading signal from the output	To a person of ordinary skill Everard teaches varying bit sequences and, specifically, lengthening sequences to improve dynamic range, resulting in a sequence having a temporal length greater than total propagation time period of interrogation light into the fiber and backscatter returning through the fiber, labeled TP. Ex. 1004, 1:58-61, 6:14-15.

of the source of the spectrum spreading signal to where said first light source is modulated, and then for the forward propagation of the derivative spread spectrum modulated interrogation lightwave signal to the second remote end of the fiber optical span, plus the time period required for the back propagation of a subcomponent of said composite back-propagating CW lightwave signal produced at the remote end of the span to the input of the heterodyner, and then for the back propagation of the derivative counterpart subcomponent of the r.f. composite difference beat signal from the output of the heterdyner to the input of a corresponding de-spreader and de-multiplexer of said set of n de-spreader and de-multiplexers; and the temporal length of a single autocorrelatable	

spectrum spreading signal sequence of the continuously reiterated code sequences is one of one and the other of less than the time period TP, and greater than the time period TP.	

72. Claim 19 is anticipated by Everard.

The reflectometer of claim 1, wherein said type of external physical signal which induces light path changes in said optical fiber span is a selected one of a group consisting of: (i) a seismic signal wherein with the media which couples the signal to said optical fiber span includes at least in part the ground in which the fiber optic span is buried; (ii) an underwater sound signal wherein the media which couples the signal to said optical fiber span includes at least in part a body of water in which the fiber optic span is immersed; (iii) an electromagnetic force field coupled to	To a person of ordinary skill Everard discloses several of the alternative external physical signals, including at least temperature variations coupled to the optical fiber span. Ex. 1004, 1:11-13, 3:28-30.

the optical fiber span; (iv) a signal comprising temperature variations coupled to the optical fiber span; and (v) at least one microphonic signal which is coupled to said optical fiber span at an at least one of said set of n sensing positions along the optical fiber span.	

73. Claim 20 is anticipated by Everard.

20. The reflectometer of claim 1, wherein each of: (i) said coherent carrier lightwave signal; (ii) said coherent local oscillator lightwave signal; (iii) said spread spectrum modulated interrogation lightwave signal; (iv) said composite back-propagating lightwave signal; (v) said radio frequency (r.f.) composite difference beat signal; and (vi) each counterpart of said r.f. counterpart of the subcomponents of said second signal component of said composite back-	To a person of ordinary skill Everard discloses use of a CW signal. Specifically a Frequency Modulated Continuous Wave (FMCW) as the source of the downstream resulting signals such that each of those signals, including those identified as ii-vi in claim 20, are continuous wave (CW) signals. Everard also instructs selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications, like the laser identified by the '971 patent. Ex. 1001, 20:12-21; Ex. 1004, 1:43-44, 5:37-40.

propagating lightwave signal, is a continuous wave (CW) signal.	

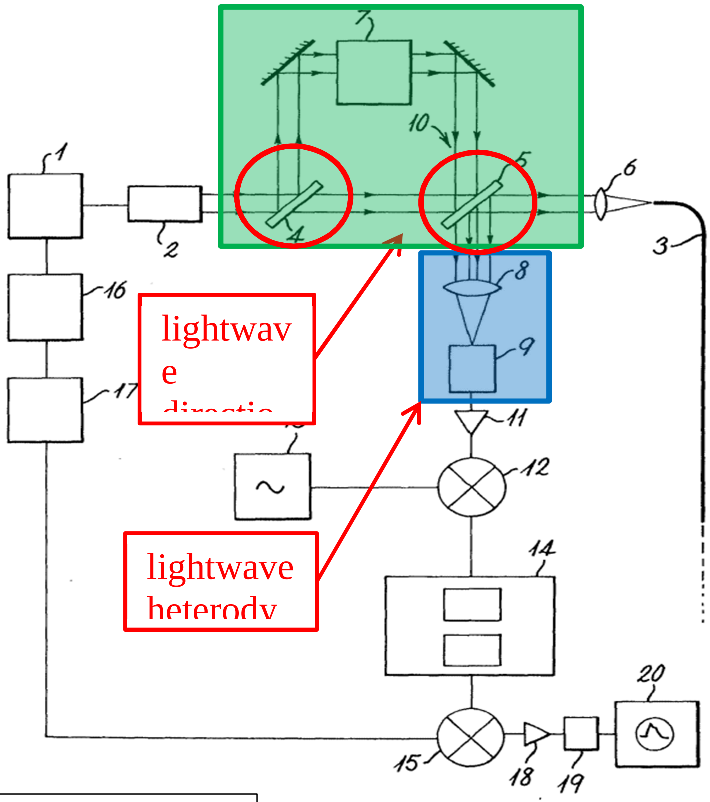
74. Claim 21 is anticipated by Everard.

21[p]. A system wherein, at respective sensing stations of a plurality of sensing stations along a span of optical fiber, the system senses input signals of a type having a property of inducing light path changes at regions of the span influenced by such input signals, comprising:	To the extent the preamble may be limiting, to a person of ordinary skill it is disclosed by Everard. To a person of ordinary skill Everard discloses a "system described in (1) can be used to perform optical time domain reflectometry on fibre systems" for sensing at a desired set of n spaced sensing positions along an optical fiber span (Figure 8, fibre 3), said sensing positions being for sensing a type of external physical signal having the property of inducing light path changes within the optical fiber span at regions there along where the signal is coupled to the span ("The measurement of the amplitude, spectra, phase and polarisation of the scatter can also be used to characterise the properties of the material and the influence of any external parameters which influence the properties of the materials producing the backscatter."). Ex. 1004, 8:39-45, 6:16-35.

21[a]. means for illuminating an optical fiber span with a CW optical signal;	To a person of ordinary skill Everard discloses a means for illuminating (laser 2). Ex. 1004, 3:51-52, 4:10-13, 5:37-40. One of ordinary skill in the art would understand Everard's teaching that "FMCW can be used" to suggest that a frequency modulated continuous wave (FMCW) laser may be used in this invention. Ex. 1004, 1:43-44. Everard also instructs selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications, like the laser identified by the '971 patent. Ex. 1001, 20:12-21.

21[b]. means for	To a person of ordinary skill Everard discloses means for

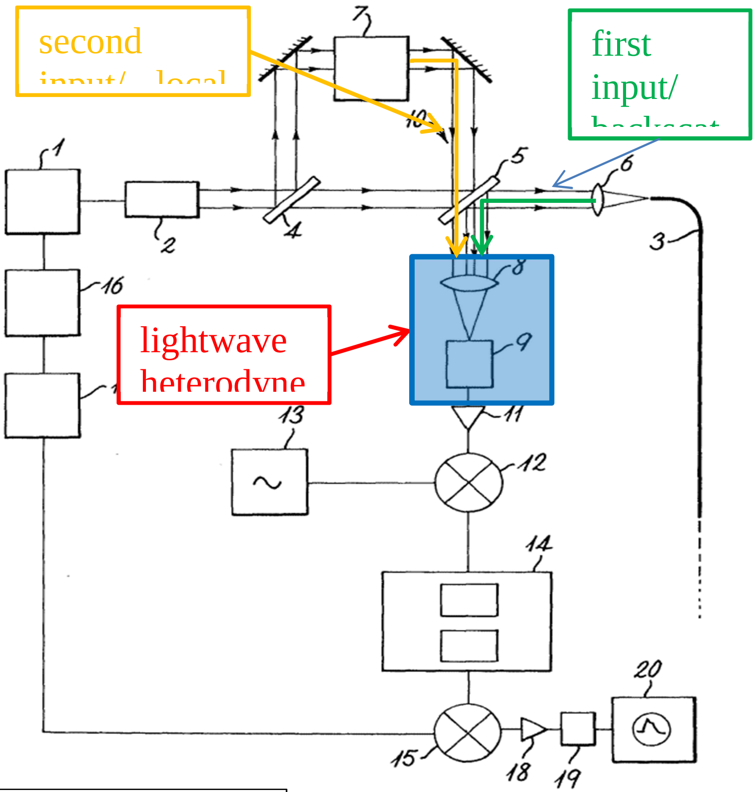
<table>
<tr><td>retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span;</td><td>retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span ("The light out of the laser (2) is coupled into an optical fibre (3) via beam splitters (4) and (5) and a lens (6). . . . The backscattered signal from the fibre is deflected by the beam splitter (5) via a lens (8) onto the photodetector (9)." "The beam splitter arrangements described in Figs. 4, 6, 7, 8 and 10 can be replaced by optical fibre couplers."). Ex. 1004 at 5:37-45, 7:17-18.



Everard.</td></tr>
</table>

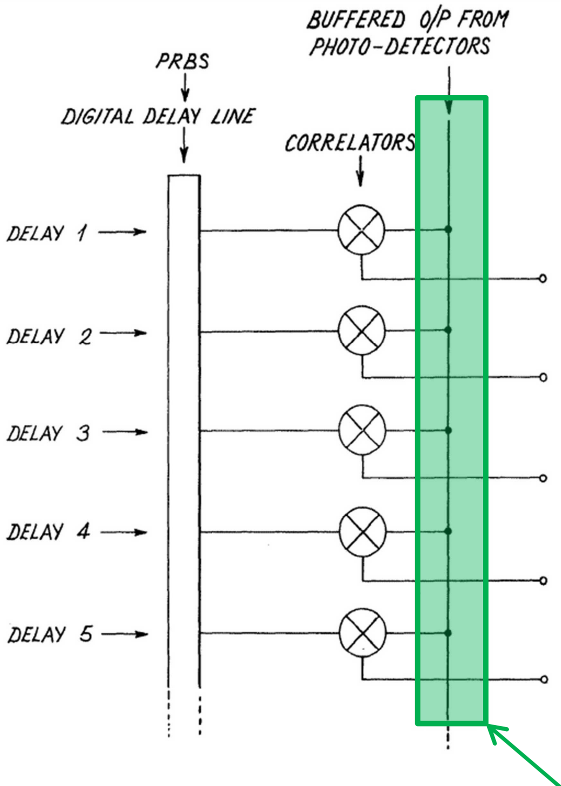
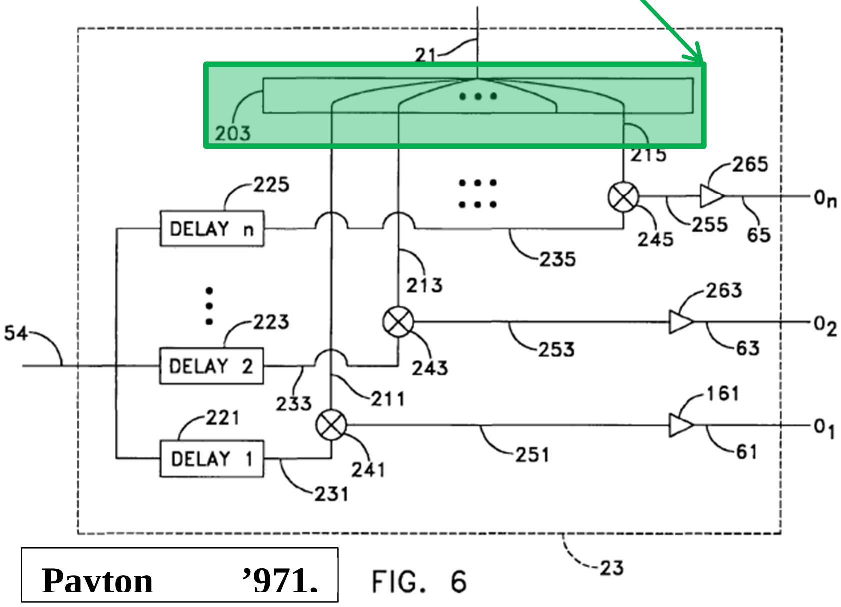
<table>
<tr><td>21[c]. means for modulating said CW optical signal with a reiterative autocorrelatable form of modulation;</td><td>To a person of ordinary skill Everard discloses means for modulating said CW optical signal with a form of modulation, Ex. 1004, 5:37-40, that is reiterative and autocorrelatable. Ex. 1004, 1:57-64, 6:14-15.</td></tr>
</table>

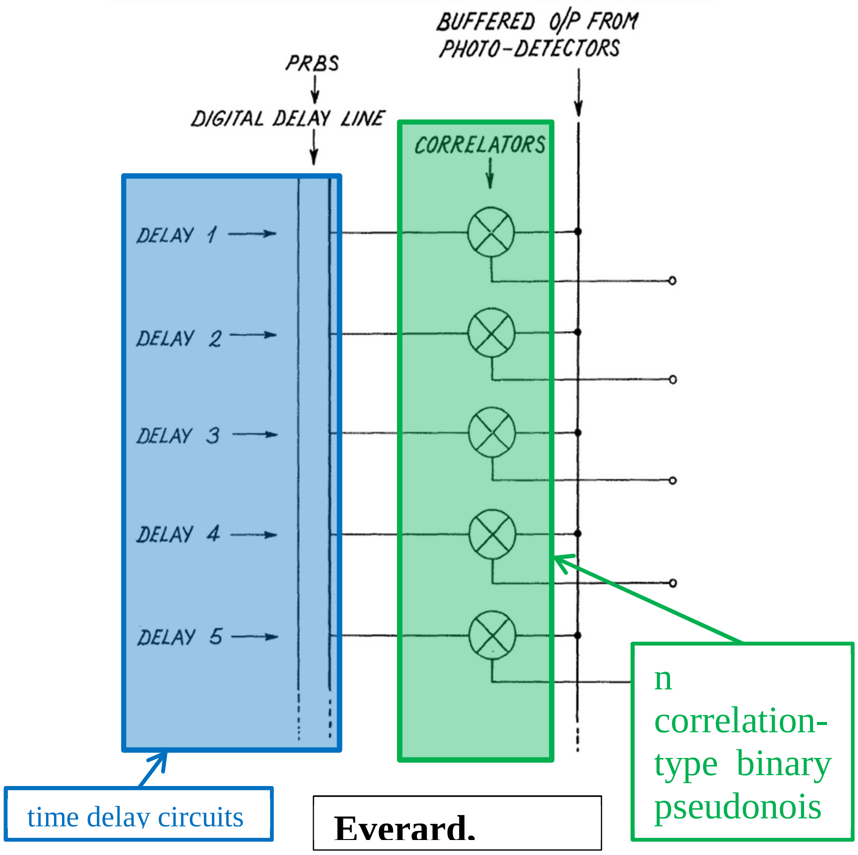
<table>
<tr><td>21[d]. means for</td><td>To a person of ordinary skill Everard discloses means for</td></tr>
</table>

picking off a radio frequency (r.f.) counterpart of the retrieved signal, wherein the r.f. counterpart is in phase locked synchronism with the CW optical signal;	picking off a radio frequency (r.f.) counterpart of the retrieved signal, wherein the r.f. counterpart is in phase locked synchronism with the CW optical signal. Ex. 1004, 5:44-53. A person of ordinary skill in the art would understand the photodetector is structure used for picking off a radio frequency (r.f.) counterpart of the retrieved signal, because output provided by the photodetector into the RF mixer must be an radio frequency signal. *Id*. Everard's phase locked synchronism equates to the '971 Patent's "alternative to the previously described mechanism for phase locking laser 3 and 45" where an "acousto-optically frequency shifted version of the light in optical path 39 can therefore replace the phase locked light of coherent optical source 45." Ex. 1001, 33:19-34; Ex. 1004, 5:40-53.  **Everard.**

21[e]. means for performing a	To a person of ordinary skill Everard discloses a means for performing a corresponding plurality of

corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal wherein said performing of the respective autocorrelation detections of the plurality of autocorrelation detection by said means for performing autocorrelation-detections are done in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal.	autocorrelation detections. "In other words a number of pseudo random bit sequences with different delays between them would be separately multiplied with the received signal to produce simultaneous output of the backscatter from different positions along the fibre Fig. 9." Ex. 1004, 6:16-23, 24-30.

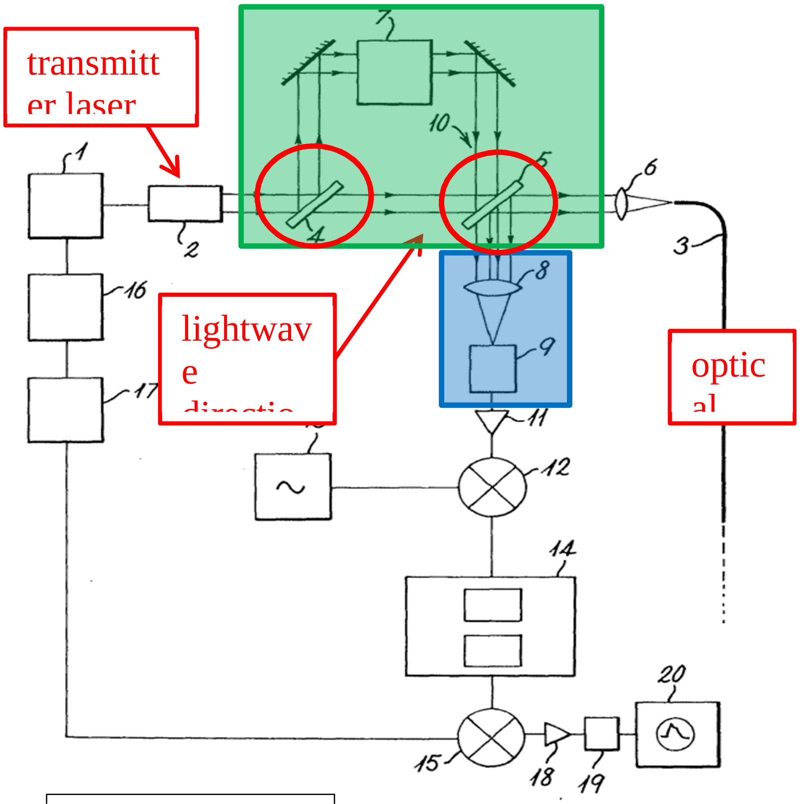
	 **Everard.** n-way  **Pavton ’971.** FIG. 6

	 time delay circuits **Everard.** n correlation-type binary pseudonois

75. Claim 22 is anticipated by Everard.

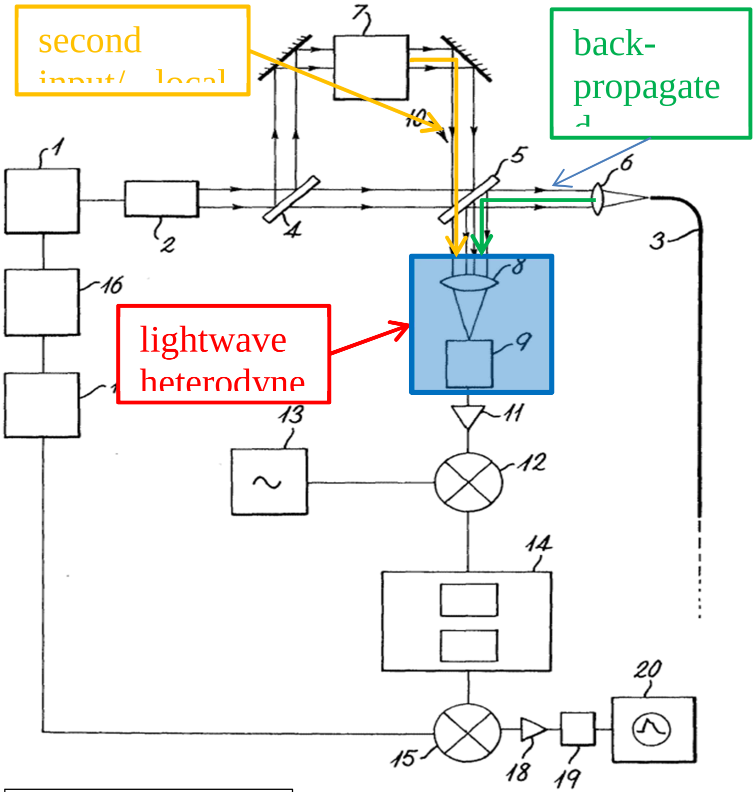
22[p]. Signal sensing apparatus for sensing input signals at an array of a plurality of sensing stations along an optical fiber span, wherein at respective sensing station of the array the apparatus senses input signals of a type having the property of inducing light path changes within regions influenced by such	To the extent the preamble may be limiting, to a person of ordinary skill is disclosed by Everard. To a person of ordinary skill Everard discloses a signal sensing apparatus for sensing input signals at an array of a plurality of sensing stations along an optical fiber span to produce "output which when integrated or averaged would produce spatial information about the amplitude, spectrum, phase and polarisation of the backscatter." Ex. 1004, 6:24-35, 8:29-41.

input signals, said apparatus comprising:	

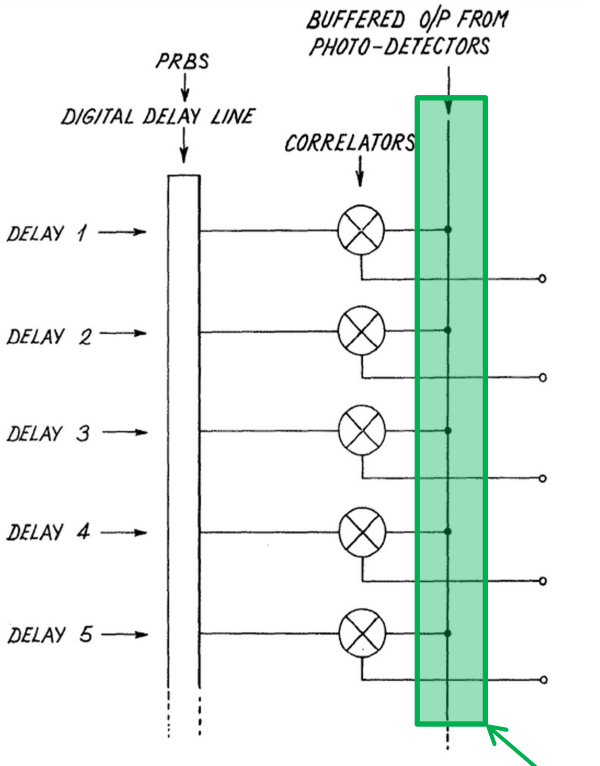
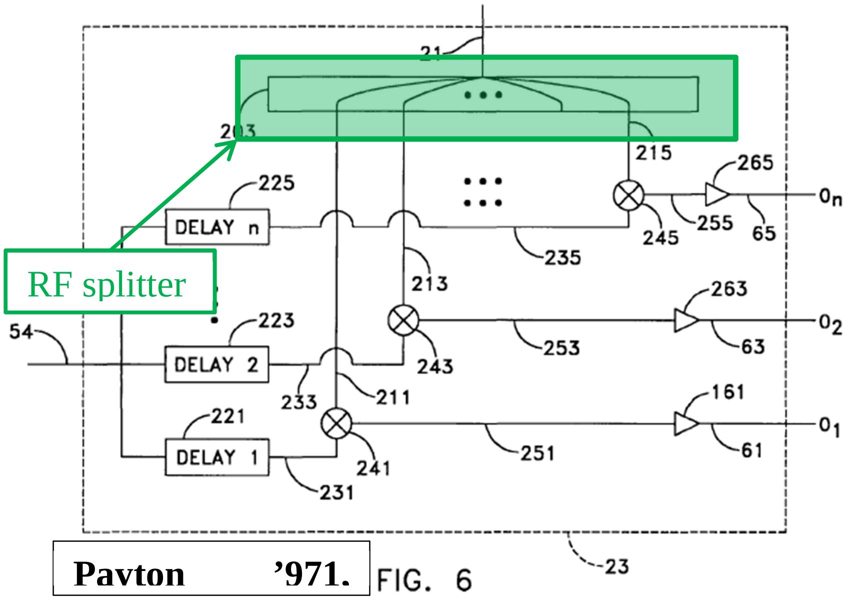
22[a]. an optical wave network comprising a transmitter laser and a lightwave directional coupler, said network being operative to illuminate an optical fiber span with a CW optical signal and to retrieve portions of the illumination back-propagating from a continuum of locations along the fiber span;	To a person of ordinary skill Everard discloses an optical wave network comprising a transmitter laser (2) and a lightwave directional coupler ("[t]he beam splitter arrangements described in Figs. 4, 6, 7, 8 and 10 can be replaced by optical fibre couplers.") The network illuminates a fiber with a CW optical signal and to retrieve portions of the illumination back-propagating from a continuum of locations along the fiber span. One of ordinary skill in the art would understand Everard's teaching that "FMCW can be used" to suggest that a frequency modulated continuous wave (FMCW) laser is included in an embodiment. Ex. 1004 at 1:43-44. Everard instructs selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications, like the laser identified by the '971 patent. Ex. 1001, 20:12-21.  **Everard.**

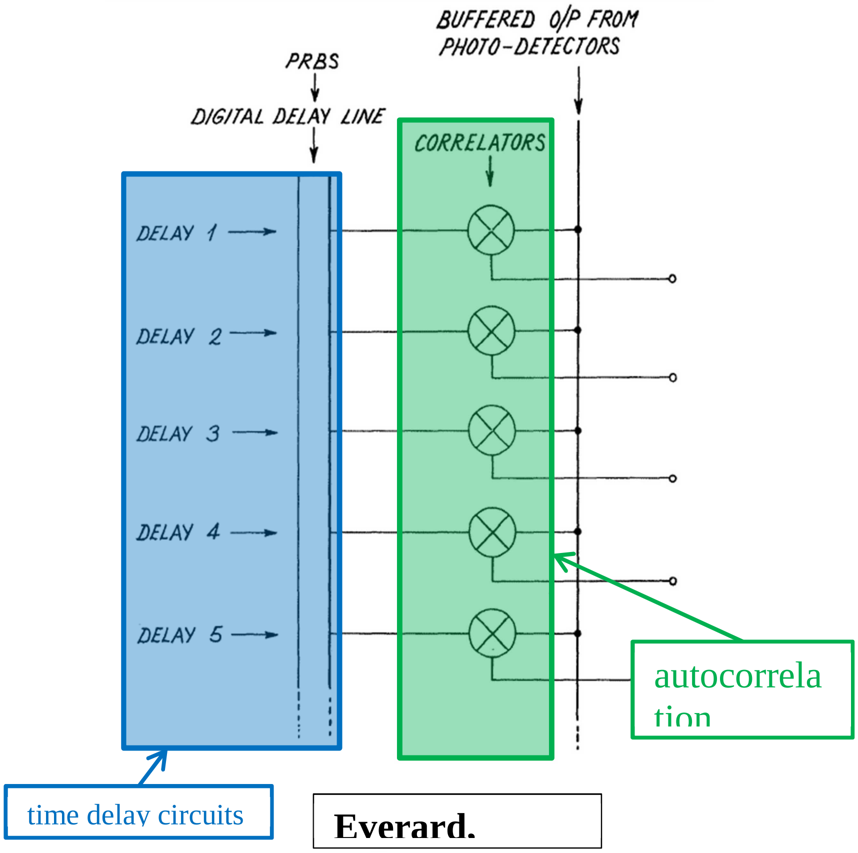
22[b]. a modulator operative to modulate the CW optical signal in accordance with a reiterative autocorrelatable form of modulation code;	To a person of ordinary skill Everard discloses that "[t]he output of (1) is amplitude modulated onto a laser (2)" in accordance with a reiterative autocorrelatable form of modulation code. "The pseudo random sequence is also designed to have specific autocorrelation properties. The number of bits in the pseudo random sequence before the sequence repeats and the time taken before the sequence starts to repeat (hereafter called the sequence repeat time) can be varied according to the specifications of the sensor system." Ex. 1004, 1:57-64, 5:37-40.

22[c]. a heterodyner which, in phase locked synchronism with said transmitter laser, receives said retrieved back-propagated portions of illumination and derives therefrom a radio frequency (r.f.) counterpart; and	To a person of ordinary skill Everard discloses a heterodyner (lens 8, photodetector 9) which, in phase locked synchronism, based on the local oscillator input, with said transmitter laser, receives back-propagated illumination and derives an RF counterpart that then goes to RF mixer 12. Ex. 1004 at 5:40-41, 44-53.

	 **Everard.**

22[d]. a corresponding plurality of autocorrelation detectors operative upon said r.f. counterpart of the retrieved optical signal in respective timed relationships of a corresponding plurality of different timed relationships with respect to said reiterative autocorrelatable form of modulation code.	To a person of ordinary skill Everard discloses "multiple correlators" receiving the heterodyner RF output a well as timed delayed versions of the modulation code. Ex. 1004, 1:58-64, 6:16-30.

	 **Everard.** RF splitter  RF splitter **Pavton ’971.** FIG. 6

76. In my opinion Claims 7 and 8 would have been obvious over Everard.

77. Claim 7 would have been obvious over Everard.

7. The reflectometer of claim 6, wherein: said the length L of said optical fiber span is at least 5.0 km.	To a person of ordinary skill in the art Everard discloses the reflectometer of claim 6 as discussed above with respect to claims 1, 3 and 6. A person of ordinary skill would understand Everard to further suggest selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications. Ex. 1004 at 1:43-44. The '971 patent confirms that components such as the Lightwave Electronics Corp. Model 125 laser were commercially

	available which meet the requirements of claim 7. Ex. 1001 at 20:12-16. A person of ordinary skill would have been motivated by the suggestion in Everard to use components such as the Model 125 laser because such components had sufficiently narrow spectral width, as shown by their coherence over a long distance, to achieve good spatial resolution and would have had a reasonable expectation of success. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available lasers with coherence sufficient to be substantially retained in backscatter from an optical span of at least 5.0 km would have provided predictable results to address the design goal identified in Everard of coherent detection.

78. Claim 8 would have been obvious over Everard.

8. The reflectometer of claim 7 wherein said first light source is a planar, ring-type laser.	To a person of ordinary skill in the art Everard discloses and motivates claim 7's subject matter as discussed above with respect to claim 7. While Claim 8 refers to a "planar" laser, the written description of the '971 patent only refers to "non-planar" lasers. Ex. 1001 at 20:12. To the extent that the broadest reasonable interpretation of claim 8 is determined to cover non-planar lasers, the '971 patent confirms that components such as the Lightwave Electronics Corp. Model 125 laser were commercially available which meet the requirements of claims 7 and 8. Id. Everard further suggests selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications. Ex. 1004 at 1:43-44. A person of ordinary skill would have been motivated by the suggestion in Everard to use components such as the Model 125 laser because such components had sufficiently narrow spectral width, as shown by their coherence over a long distance, to achieve good spatial resolution and would have had a reasonable expectation of success. Based on

	my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available non-planar lasers would have provided predictable results to achieve the design goal identified in Everard of coherent detection.

79. In my opinion Claim 9 would have been obvious over Everard in view of Fredin (Ex. 1008)

9. The reflectometer of claim 3 wherein said optical fiber span comprises a single-mode fiber optic cable.	To a person of ordinary skill in the art Everard discloses the reflectometer of claim 3 as discussed above with respect to claims 1 and 3. To a person of ordinary skill in the art Everard teaches the reflectometer of claim 3, but does not specify whether a single mode or multi-mode fiber is employed. A person of ordinary skill in the art implementing Everard's system would be motivated to look to similar optical fiber measurement systems to decide on what type of fiber to use. Fredin is a similar system which teaches the technical advantage of using a single mode fiber. Ex. 1008, 2:55-56, 3:31-33. Based on the Everard and Fredin systems a person of ordinary skill would have had a reasonable expectation of success in implementing the single mode fiber suggested by Fredin in the Everard system. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available single-mode fiber optic cable would have provided predictable results to achieve the design goal identified in Everard of measuring measurands along the fiber. The conventionality of single mode (and multimode) fiber is confirmed by the '971 Patent. Ex. 1001: 17:15-16 ("low cost, conventional single-mode or multimode, fiber cable types").

80. In my opinion Claim 10 would have been obvious over Everard in view of Yoshino (Ex. 1007).

10. The reflectometer of claim 3 wherein said optical fiber span comprises a fiber optic cable of the polarization preserving type.	Everard as discussed above with respect to claims 1 and 3. To a person of ordinary skill in the art Everard teaches the reflectometer of claim 3, but does not specify whether the employed fiber is polarization preserving. A person of ordinary skill in the art implementing Everard's system would be motivated to look to similar optical fiber measurement systems to decide on what type of fiber to use. Yoshino is a similar system which teaches the advantages, such as "a stable and precise fiber sensing scheme," of using a polarization preserving fiber. Ex. 1007, 503. Based on the Everard and Yoshino systems a person of ordinary skill would have been motivated to use and had a reasonable expectation of success in implementing the polarization preserving fiber suggested by Yoshino in the Everard system. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available polarization preserving fiber optic cable would have provided predictable results to achieve the design goal identified in Everard of measuring measurands, including the use of "polarisation detectors" along the fiber. E.g., Ex.1004, 3:31-32.

81. In my opinion Claim 11 would have been obvious over Everard in view of Henning (Ex. 1009)

11. The reflectometer of claim 3, wherein: said optical fiber span	Everard as discussed above with respect to claims 1 and 3.

has a coating made of a thermoplastic material having the combined characteristics of a low Young's modulus and a Poisson's ratio below that of natural rubber; and said coating serving to enhance the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the span from a direction at least in part having a lateral component in the direction along which the wave front propagates	To a person of ordinary skill in the art Everard teaches the reflectometer of claim 3, but does not specify the coating for the optical fiber. A person of ordinary skill in the art implementing Everard's system would be motivated to look to similar optical fiber measurement systems to decide on what type of coating to use. Henning is a similar system which teaches the advantages, such as sensitivity, of using a low Young's Modulus and low Poisson's ratio coating. Ex. 1009 at 3-4 ("an encapsulant with low Young's Modulus and low Poisson's ratio produces high sensitivity to hydrostatic stress"). Based on the Everard and Henning systems a person of ordinary skill would have been motivated to use and had a reasonable expectation of success in implementing the fiber coating suggested by Henning in the Everard system. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a fiber optic cable coating known to increase sensitivity to certain measurands would have provided predictable results to better achieve the design goal expressed in Everard of measuring "any external parameters." Ex. 1004, 1:11-13.

82. In my opinion Claim 13 would have been obvious over Everard in view of Wright (Ex. 1010)

13. The reflectometer of claim 12 wherein: said lightwave heterodyner of the photodetector type is a balanced optical detector circuit including a matched pair of photodetectors with the composite back-propagating	To a person of ordinary skill in the art Everard teaches the reflectometer of claim 12, but does not require a balanced circuit with two detectors. Everard does suggest that either one or two detectors can be used. Ex. 1004, 4:58 ("2 detectors could be used"). Wright teaches a balanced optical detector circuit with identical photodetectors 11 and 12. Ex. 1010 at Fig. 1 and 1:42-45 ("second identical photodetector"). Wright also teaches applying the input signal to each photodetector and producing a differential current output in the same manner as Figure 4 of the '971 Patent. Compare Ex. 1010

lightwave signal applied to each photodetector of the pair; and said balanced optical detection circuit produces said r.f. composite difference beat signal as a differential current from the matched pair of photodetectors.	at Fig. 1 with Ex. 1001 at Fig. 4. Wright teaches that use of the balanced detector circuit with fibre optic systems having an "optical fibre coupler" like the "optical coupler 105" used in Fig. 4 will result in advantages of "low noise" and "efficient use" of the available power. Ex. 1010 at 2:6-15. Based on Everard's suggestion of using two detectors, a person of ordinary skill would be motivated to achieve the advantages taught by Wright by replacing the single detector with Wright's balanced detector circuit and would have had a reasonable expectation of success. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a balanced heterodyner design would have provided predictable results of lower noise to better achieve the design goal expressed in Everard of measuring "any external parameters." Ex. 1004, 1:11-13.

83. In my opinion Claim 16 would have been obvious over Everard in view of Payton '921 (Ex. 1011)

16. The reflectometer of claim 1, and: a fixed frequency reference oscillator which produces a reference phase signal; each phase demodulator including an I & Q quadrature demodulator having a first input for receiving said reference phase signal and a second input for receiving an r.f. counterpart of the corresponding subcomponent of said	To a person of ordinary skill in the art Everard teaches the reflectometer of claim 1, but does not require a particular receiver structure for detecting phase variance. Everard does suggest measuring the phase and polarisation of backscatter, including specific suggestion of "polarisation detectors". Ex. 1004, 1:11-13, 3:31-32, 3:62-4:1. To a person of ordinary skill Payton '921 teaches a receiver for detecting an optical phase signal having varying polarization with signal to noise advantage. Ex. 1011, 1:11-14, 2:7-20. Payton '921 teaches producing a reference phase signal and feeding that signal to phase demodulators, including I & Q quadrature demodulators that also receive the RF counterpart of the backscatter, including the portion indicating changes in characteristics along the fiber. *Id.*, Fig. 7, 12:23-39. The output includes two phase signals mixed to provide output signals. *Id.*, Fig. 7, 12:40-53.

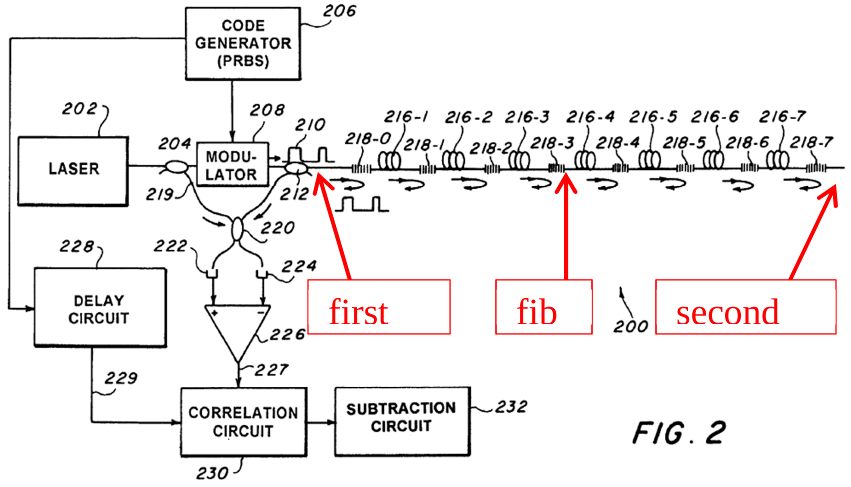
second signal component of said composite back-propagating lightwave signal, said I & Q demodulator being operative to derive from said reference phase signal an interim in phase signal and an interim quadrature phase signal and to split the signal received at its second input and mix one part thereof with the interim in phase signal and another part thereof with the interim quadrature phase signal to provide a pair of output signals; and each phase demodulator further including a phase detector having a pair of inputs for receiving respectively one and the other of said outputs of the I & Q demodulator and operative to provide at the output of the phase demodulator said signal representative of the radian phase of the respective subcomponent of said set of n subcomponents.	Phase detectors then receive the demodulator outputs to produce outputs that “provide power proportional to the external optical signal power over all phase and polarization values.” *Id.*, Fig. 7, 12:58-63. Based on either Everard’s suggestion of using polarisation detectors or Payton ’921’s teaching that its detector has the advantages of consistent signal to noise ratio and unlimited electronic output voltages, a person of ordinary skill would be motivated to achieve the advantages taught by Payton ’921 by using its signal decoding module detector with Everard’s system for spatial detection of backscatter and would have had a reasonable expectation of success. The ’971 Patent confirms the motivation and expectation. Ex. 1001, 23:34-53. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a reference frequency driven phase demodulator to isolate signal indicating fiber characteristics would have provided predictable results to address Everard’s suggestion of ”measurement of . . . phase . . . of the backscatter” to determine external parameters. Ex. 1004, 1:11-13.

84. In my opinion Claims 1-3, 6-10, 12, 14 and 18-22 would have been obvious over Kersey in view of Yoshino or Beckmann.

85. Claim 1 would have been obvious over Kersey in view of Yoshino or Beckmann.

1[p]. See VI.A.1	To the extent the preamble may be limiting, a person of ordinary skill would understand it is disclosed by Kersey. To a person of ordinary skill Kersey discloses a system that is "capable of detecting a physical condition such as an acoustic wave" for multiple segments of a fiber. Ex. 1005, Abstract. Kersey discloses sensing positions that sense external physical signals that induce light path changes within the fiber such as "sensing segments" that "undergo a change in refractive index in response to a physical condition." *Id.* at 1:13-18.

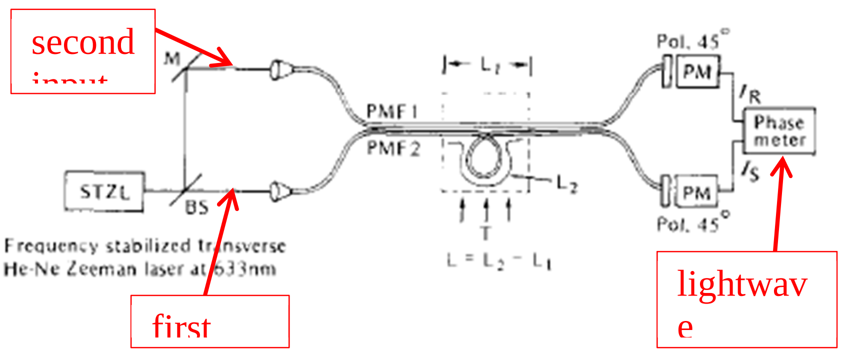
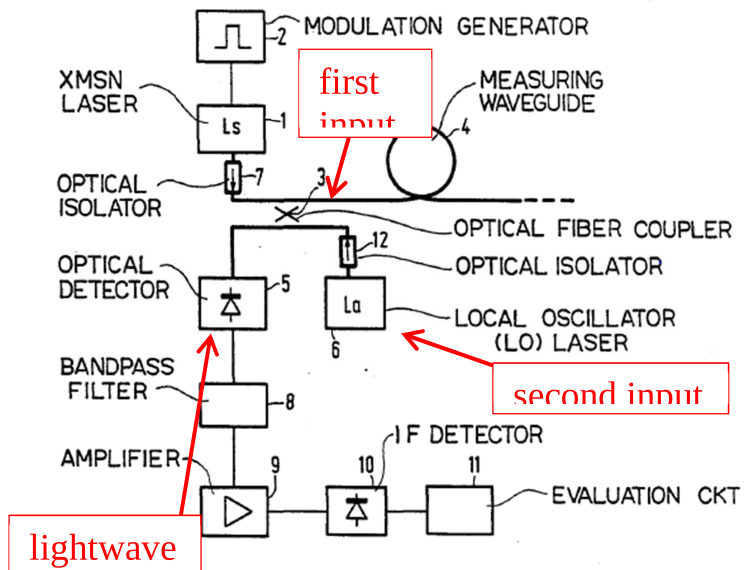
1[a]. See VI.A.1	To a person of ordinary skill Kersey discloses an optical fiber span (fiber 214), having a first end which handles the interrogation signal input and the back propagating signal output because "the invention need not employ an additional return line" there is a second remote end as well. Ex. 1005, 2:52-61, Fig. 2.

	 FIG. 2

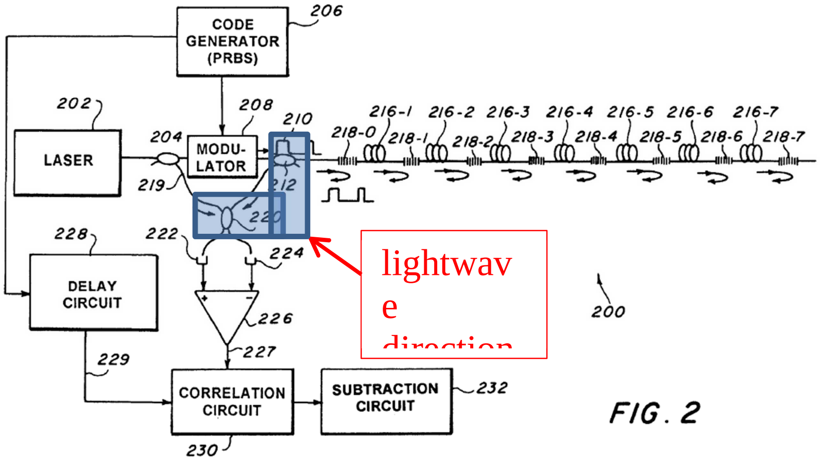
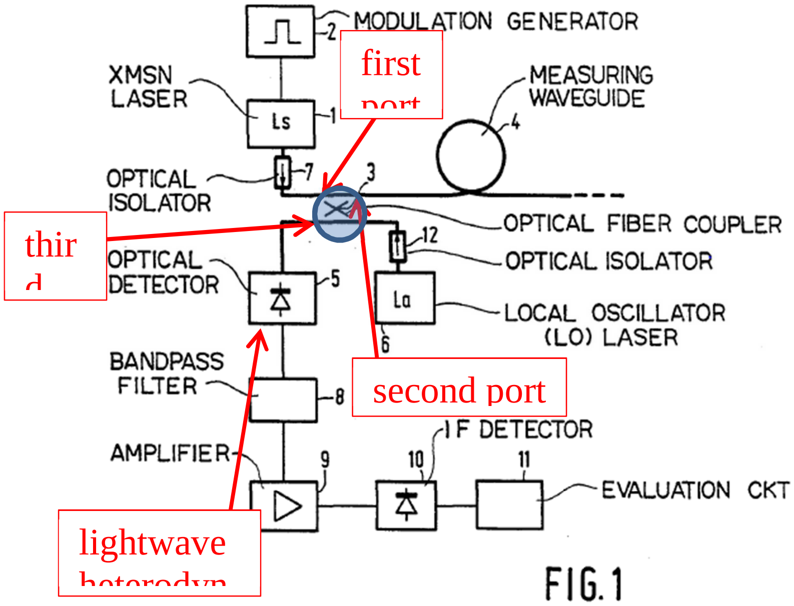
1[b]. See VI.A.1	To a person of ordinary skill Kersey discloses a first light source that produces a coherent carrier lightwave signal of a predetermined wavelength (laser 202). Ex. 1005 at 3:28-31.

1[c]. See VI.A.1	To a person of ordinary skill Kersey discloses a binary pseudonoise code sequence modulator (pulse modulator 208 coupled to PRBS generator 206) modulating said carrier signal for producing a pseudonoise code sequence modulated interrogation lightwave signal (PRBS optical signal 210) with continuously reiterates the binary pseudonoise code sequence (known properties of a PRBS generator), the reiterated sequences being executed in a fixed relationship to a predetermined timing base ("time delay circuit 136 receives the PRBS from PRBS generator 104 and applies a time delay to the PRBS corresponding to the time delay of each PRBS output signal."). Ex. 1005 at 1:46-51, 58-62, 2:22-28, 3:35-38.

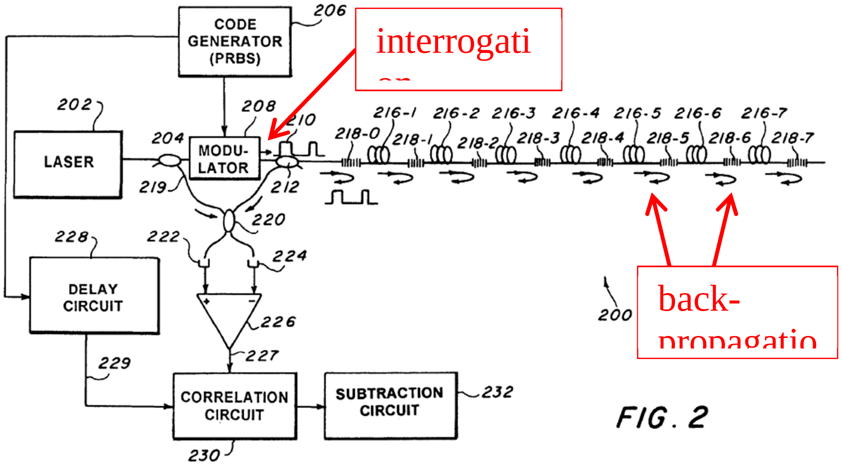
1[d]. See VI.A.1	One of ordinary skill would have been motivated to combine Kersey with the lightwave heterodyner of either Yoshino or Beckmann with a reasonable expectation of success based at least on Kersey's explicit suggestion to incorporate that structure. Ex. 1005, 5:7-11. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a heterodyner, such as the ones suggested in Yoshino or Backmann would have provided predictable results to address the suggestion in Kersey of producing an accurate electronic signal containing information on the backscatter. *Id*. To a person of ordinary skill Yoshino discloses a lightwave heterodyner (phase meter of Fig. 2(a)), having a first input (line BS) for receiving a primary signal, and a second input (line M) for receiving a local oscillator signal, operative to produce the beat frequency of their respective frequencies ("typical beat signals (300 kHz) of the sensing and reference fibers."). Ex. 1007 at 504. To a person of ordinary skill Beckmann discloses a lightwave heterodyner (optical detector 5) having a first input (for backscattered light from measuring waveguide 4) for receiving a primary signal and a second input (for local oscillator 6) for receiving a local oscillator signal, operative to produce the beat frequency of their respective frequencies ("intermediate-frequency portions"). Ex. 1006, 3:57-58.

	  FIG.1

1[e]. See VI.A.1	To a person of ordinary skill Kersey discloses a lightwave directional coupler (212 and 220) having a first port which receives said binary pseudonoise code sequence modulated interrogation lightwave (shown as an arrow from 208 to 212). Kersey also discloses a second port coupled to said first end of said optical fiber span. Combining the lightwave heterodyner of Yoshino or Beckmann as discussed above discloses a third port coupled to said primary signal input of the heterodyner (balanced PMs of Yoshino or optical detector 5 of Beckmann). Beckmann explicitly discloses a directional coupler (optical coupler 3) having a third port coupled to

	primary signal input of the heterodyner (balanced PMs of Yoshino or optical detector 5 of Beckmann). Ex. 1005 at 3:56-61.  FIG. 2  FIG.1

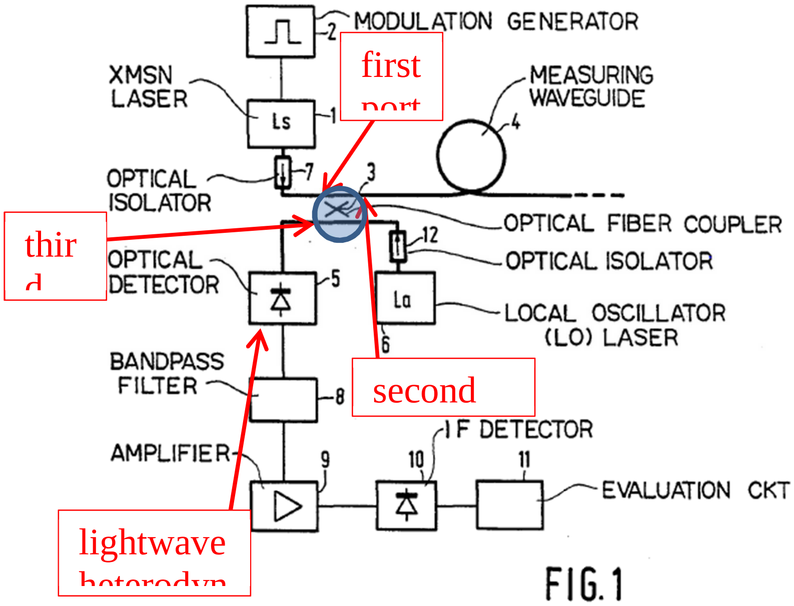
1[f]. See VI.A.1	To a person of ordinary skill Kersey discloses said directional coupler (212 and 220) coupling said binary pseudonoise code sequence modulated interrogation

	lightwave (PRBS optical signal 210) to said second port where it is launched in a forwardly propagating direction along said optical fiber (214) causing the return to said second port of a composite back-propagating lightwave which is a summation of lightwave back-propagations from a continuum of locations (fiber segments 216) along the length of the fiber (214), said composite back-propagating lightwave signal comprising a summation of multiple components (innate properties of light propagating through a fiber). Ex. 1005, 3:40-41, 56-57, 6:1-15. A person of ordinary skill would understand the '971 Patent to confirm that backscatter inherently includes multiple components. Ex. 1001, 16:18-24.  FIG. 2

1[g]. See VI.A.1	A person of ordinary skill would understand the '971 Patent to confirm that the backscatter components are an inherent result of propagating light through an optical fiber span, rather than a result of the particular invention claimed. Specifically, the '971 Patent states, "the

	propagation of the optical spread-spectrum interrogation signal down the continuous full span of the optical fiber span, signal launch end to remote end, causes a back-propagating composite optical signal, which is the linear summation, or integration spatially, of all of the individual, continuous, or continuum of back-reflections along the span of the optical fiber." Ex. 1001, 16:18-39. To a person of ordinary skill Kersey discloses a first signal component comprising the summation of portions of the said pseudonoise sequence modulated interrogation lightwave signal which the innate properties of the optical fiber cause to back-propagate at a continuum of locations along the span (innate properties of light propagating through the fiber 214). Kersey discloses a second signal component comprising the modulation of said first signal component caused by longitudinal components of optical path changes induced into said span at a continuum of locations along said span by external physical signals, said second signal component further including a corresponding set of subcomponents comprising the modulation of said first signal component by optical path changes caused by said external signals at the respective sensing positions. Ex. 1005 at Abstract, 1:16-18, 3:44-49.

1[h]. See VI.A.1	To a person of ordinary skill Kersey in combination with Yoshino and Beckmann discloses a directional coupler (212 and 220 in Kersey, optical coupler 3 in Beckmann) coupling said composite back-propagating lightwave to said third port where it is applied to said first input of the heterodyner (balanced PMs of Yoshino, optical detector 5 of Beckman). Ex. 1006 at 47-52, 57-58, Fig. 1; Ex. 1007 at 504.

	 FIG. 1

1[i]. See VI.A.1	To a person of ordinary skill Beckmann discloses a second light source (local oscillator laser 6) coupled to said second input of the lightwave heterodyner (optical detector 5), said second light source producing a coherent local oscillator lightwave signal in phase locked relation to said carrier lightwave signal ("a laser light source which constitutes a local oscillator and transmits continuous light"), said local oscillator signal being of a second predetermined wavelength which differs from the first predetermined wavelength by an amount of difference small enough to produce at the output of the heterodyner a radio frequency (r.f.) composite difference beat signal, but by an amount large enough to cause said r.f. composite difference beat signal to have sufficient bandwidth to cause it to include r.f. counterparts of signal components and subcomponents of said composite back propagating lightwave signal ("it is advantageous that the intermediate frequency f_{ZF} has a value between 0.5 and 15 GHz"). Ex. 1006, 1:43-52, 2:38-45, 3:12-17. To a person of ordinary skill Yoshino also discloses a

difference in lightwave frequencies in the r.f. range. “The laser emits orthogonally linearly polarized two modes having a frequency separation from 300 to 400 kHz.” “Fig. 2(b) shows typical beat signals (300 kHz) of the sensing and reference fibers.” Ex. 1007 at 504.

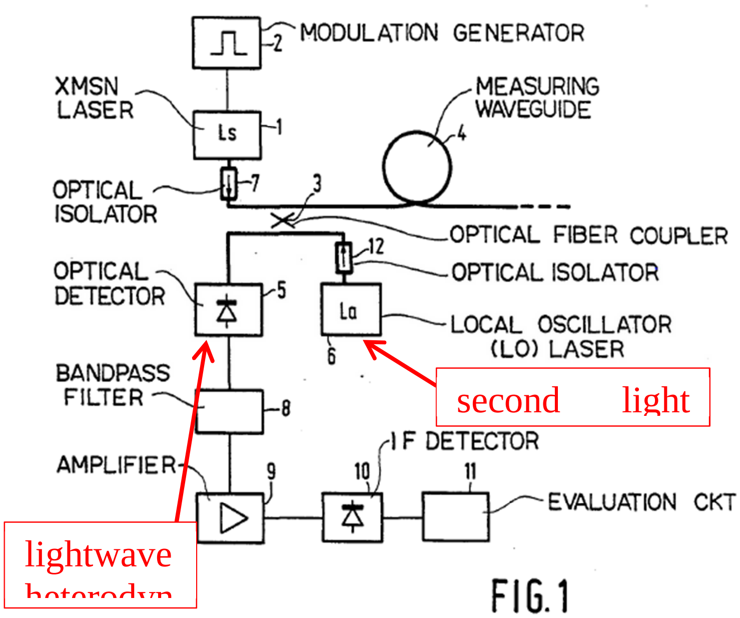
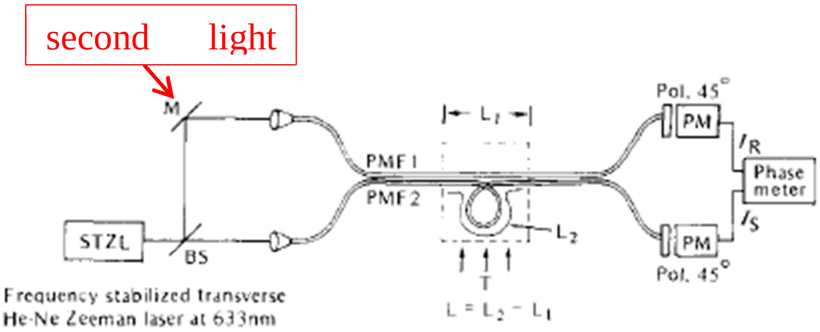
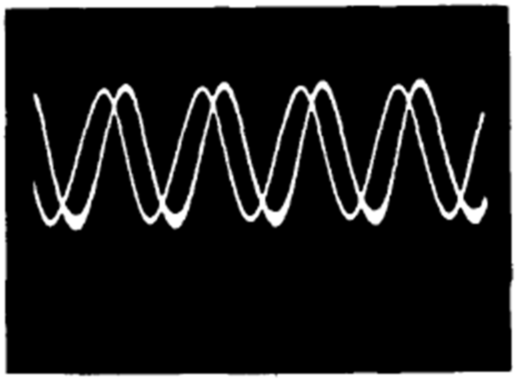
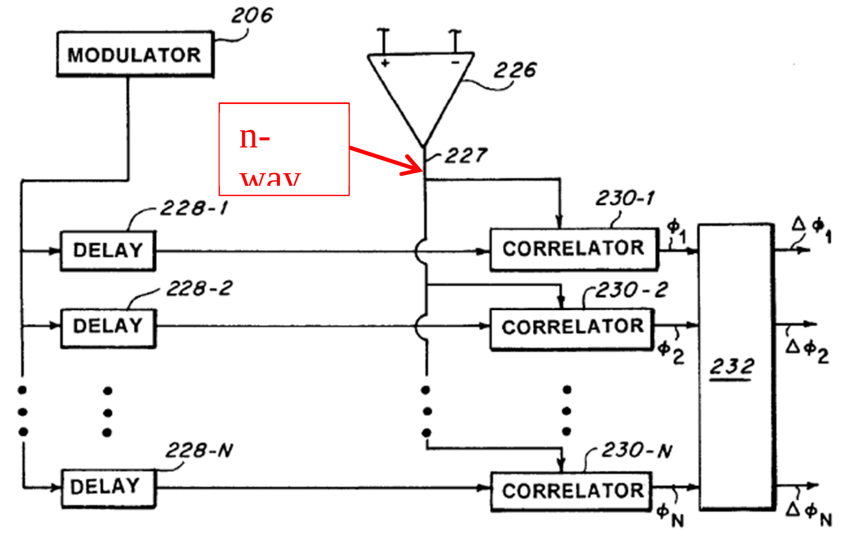


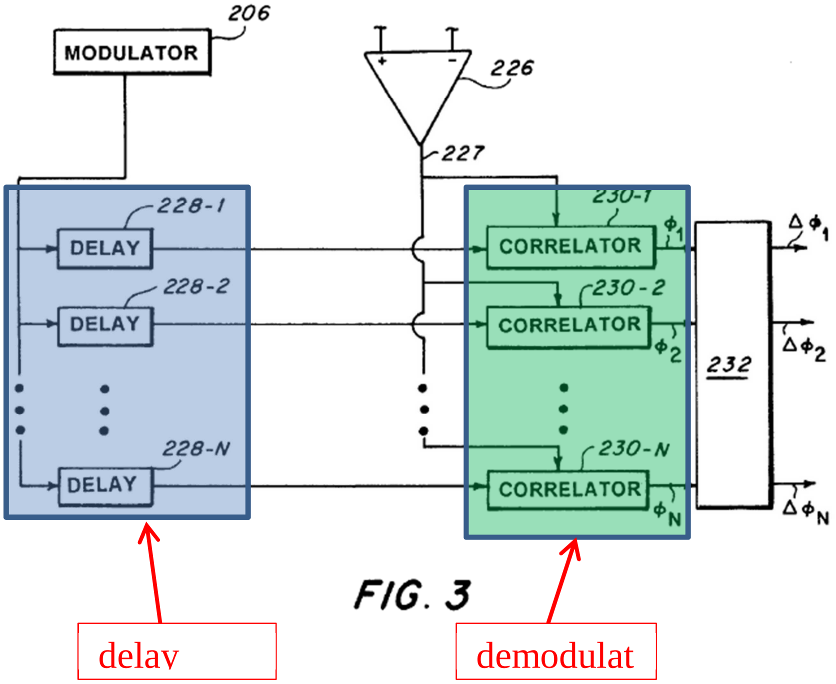
FIG. 1

	  (b)

1[j]. See VI.A.1	To a person of ordinary skill Kersey discloses a composite difference beat signal being coupled to an n-way splitter (227) providing a corresponding set of n output channels, each transmitting said composite difference beat signal (Δϕ1, Δϕ2, . . . , Δϕn). Beckmann and Yoshino disclose an r.f. composite difference beat signal as discussed above. Ex. 1005, 4:59-5:6.

	 FIG. 3

1[k]. See VI.A.1	To a person of ordinary skill Kersey discloses a corresponding set of n correlation-type pseudonoise code sequence demodulators (correlators 230) having their inputs connected to the corresponding output channels of said n-way splitter (227) through a corresponding set of time delay circuits (delays 228) which respectively provide a corresponding set of predetermined time delays in relation to said predetermined timing base of the binary pseudonoise code sequence modulator, to establish said n desired sensing positions along said optical fiber span ("there are N delay-correlator pairs denominated 228-n and 230-n, n=l, 2, ... , N, having corresponding outputs ϕ_1 , ϕ_2, . . . , ϕ_N, in which ϕ_n is the cumulative phase induced on a signal reflected from the nth Bragg grating. Subtractor 232 receives this phase information, and determines $\Delta\phi_n=\phi_n-\phi_{n-l}$, i.e. the phase 5 shift induced by fiber segment 218-n alone."). Ex. 1005

	at 4:44-50, 4:64-5:6, 6:23-33.  FIG. 3

1[l]. See VI.A.1	To a person of ordinary skill Kersey discloses a set of correlation-type binary pseudonoise code sequence demodulators (correlators 230) serving to conjunctively temporally and spatially de-multiplex said r.f. composite difference beat signal to provide at their respective outputs r.f. counterparts of the subcomponents of said second signal component of said composite back-propagating lightwave signal caused by changes in the optical path within said optical fiber span induced by external physical signals respectively coupled to the corresponding sensing positions ("there are N delay-correlator pairs denominated 228-n and 230-n, n=l, 2, ... , N, having corresponding outputs ϕ_1 , ϕ_2, . . . , ϕ_N, in which ϕ_n is the cumulative phase induced on a signal reflected from the nth Bragg grating. Subtractor 232

	receives this phase information, and determines $\Delta\phi_n=\phi_n-\phi_{n-l}$, i.e. the phase 5 shift induced by fiber segment 218-n alone.”). Ex. 1005, 4:64-5:6.

86. Claim 2 would have been obvious over Kersey in view of Yoshino or Beckmann.

2. See VI.A.2	To a person of ordinary skill both Kersey and the ’971 Patent disclose that the innate properties of an optical fiber include the generation of Rayleigh optical effects. Ex. 1005, 5:22-25.

87. Claim 3 would have been obvious over Kersey in view of Yoshino or Beckmann.

3. See VI.A.3	To a person of ordinary skill Kersey discloses a system that measures acoustic waves changing backscatter from an optical fiber. Ex. 1005, Abstract. The ’971 Patent admits that acoustic pressure waves influence backscatter in an optical fiber. Ex 1001, Abstract, 16:40-45.

88. Claim 6 would have been obvious over Kersey in view of Yoshino or Beckmann.

6. See VI.A.4	To a person of ordinary skill Kersey discloses an optical fiber having a length and that backscattered light from along that fiber is coherently detected, indicating that coherency was retained for twice the length of the fiber. Ex. 1005, 3:59-61.

89. Claim 7 would have been obvious over Kersey in view of Yoshino or Beckmann.

7. See VI.B.1	To a person of ordinary skill Kersey discloses all the limitations of claim 6, as discussed above, and suggests using a laser "having a long coherence length and a narrow wavelength range." Ex. 1005, 3:29-30. and a narrow wavelength range." Ex. 1005, 3:29-30. The '971 patent confirms that components such as the Lightwave Electronics Corp. Model 125 laser were commercially available which meet the requirements of claim 7. Ex. 1001 at 20:12-16. A person of ordinary skill would have been motivated by the suggestion in Everard to use components such as the Model 125 laser because such components had sufficiently narrow spectral width, as shown by their coherence over a long distance, to achieve good spatial resolution and would have had a reasonable expectation of success. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available lasers with coherence sufficient to be substantially retained in backscatter from an optical span of at least 5.0 km would have provided predictable results to address the design goal identified in Kersey of being able to coherently mix the backscatter. Ex. 1005, 3:60.

90. Claim 8 would have been obvious over Kersey in view of Yoshino or Beckmann.

8. See VI.B.2	To the extent that the broadest reasonable interpretation of claim 8 is determined to cover non-planar lasers, the '971 patent confirms that components such as the Lightwave Electronics Corp. Model 125 laser were commercially available which meet the requirements of claims 7 and 8. Id. Everard further suggests selection of a laser with "narrow spectral width for good spatial resolution" for FMCW applications. Ex. 1004 at 1:43-44. A person of ordinary skill would have been motivated by the suggestion in Everard to use components such as the Model 125 laser because such

	components had sufficiently narrow spectral width, as shown by their coherence over a long distance, to achieve good spatial resolution and would have had a reasonable expectation of success. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of commercially available non-planar lasers would have provided predictable results to achieve the design goal identified in Kersey of being able to coherently mix the backscatter.

91. Claim 9 would have been obvious over Kersey in view of Yoshino or Beckmann.

9. See VI.C.1	To a person of ordinary skill Kersey discloses all the limitations of claim 6, as discussed above and Yoshino teaches the advantages, such as "a stable and precise fiber sensing scheme," of using a single-mode fiber. Ex. 1007 at 503.

92. Claim 10 would have been obvious over Kersey in view of Yoshino or Beckmann.

10. See VI.D.1	To a person of ordinary skill Kersey discloses claim 3's limitations, as discussed above, and Yoshino teaches the advantages, such as "a stable and precise fiber sensing scheme," of using a polarization preserving fiber. Ex. 1007 at 503.

93. Claim 12 would have been obvious over Kersey in view of Yoshino or Beckmann.

12. See VI.A.5	To a person of ordinary skill Beckmann discloses that its heterodyner uses a photodetector. Ex. 1006, Fig. 1,

	optical detector 5.

94. Claim 14 would have been obvious over Kersey in view of Yoshino or Beckmann.

14. See VI.A.6	To a person of ordinary skill Kersey discloses the use of on and off pulses, using the switch 208, which will shift the carrier phase from 0° to 180° resulting in 50% duty cycle. Ex. 1005, 3:36-37, 5:17-18. A person of ordinary skill would understand that the phase is 0° as the carrier shifts from off to on and is 180° as the carrier shifts from on to off.

95. Claim 18 would have been obvious over Kersey in view of Yoshino or Beckmann.

18. See VI.A.8	To a person of ordinary skill Kersey discloses using a maximal code which results in a sequence having a temporal length greater than total propagation time period of interrogation light into the fiber and backscatter returning through the fiber, labeled TP. Ex. 1005, 3:37-39.

96. Claim 19 would have been obvious over Kersey in view of Yoshino or Beckmann.

19. See VI.A.9	To a person of ordinary skill Kersey discloses several of the alternative external physical signals, including at least vibrations and temperature variations coupled to the optical fiber span. Ex. 1005, 1:5-9, 2:6-10.

97. Claim 20 would have been obvious over Kersey in view of Yoshino or Beckmann.

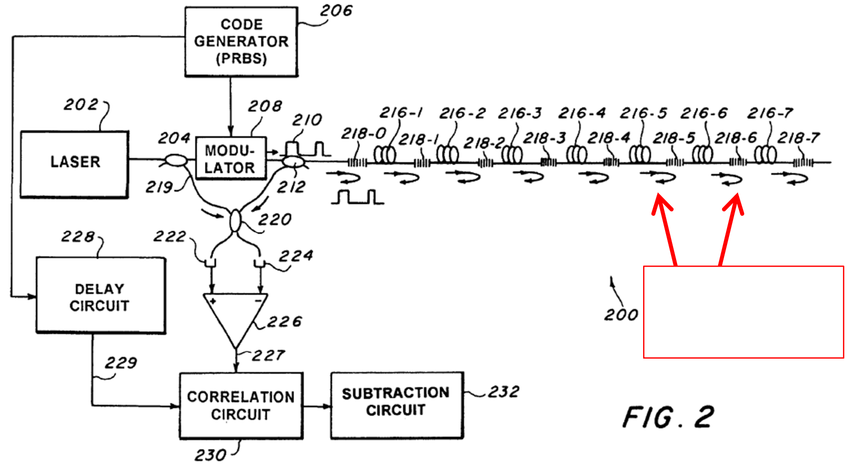
20. See VI.A.10	To a person of ordinary skill Kersey discloses use of a CW laser signal, described as “light having long coherence length,” which it contrasts with the prior art use of pulses. Ex. 1005, 1:16-17, 3:29. Specifically, the light having a long coherence length and a narrow wavelength range is the source of the downstream resulting signals such that each of those signals, including those identified as ii-vi in claim 20, is continuous wave. Ex. 1005 Abstract, 3:29-30.

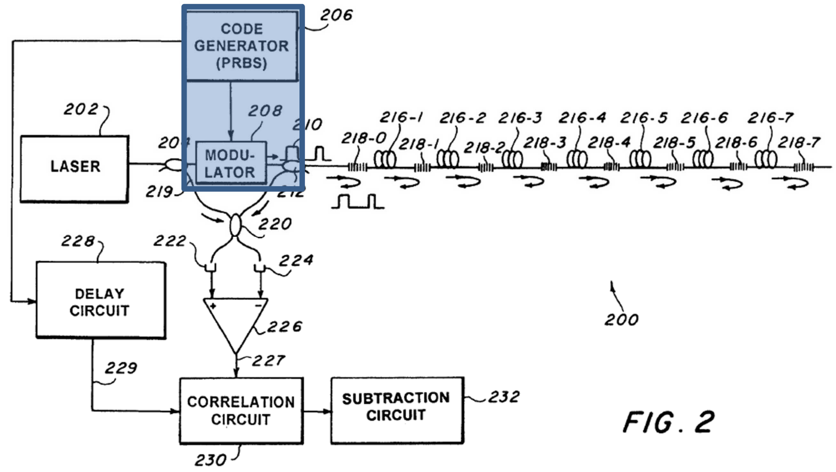
98. Claim 21 would have been obvious over Kersey in view of Yoshino or Beckmann.

21[p]. See VI.A.11	To the extent the preamble may be limiting, to a person of ordinary skill it is disclosed by Kersey. To a person of ordinary skill Kersey discloses a system wherein, at respective sensing stations of a plurality of sensing stations (Bragg gratings 214) along a span of optical fiber (fiber 214), the system senses input signals of a type having a property of inducing light path changes (“undergo a change in refractive index in response to a physical condition”) at regions of the span (fiber segments 216) influenced by such input signals. Ex. 1005, 1:13-18, 4:36-44.

21[a]. See VI.A.11	To a person of ordinary skill Kersey discloses means for illuminating an optical fiber span with a CW optical signal (laser 202). Ex. 1005, Abstract, 2:54-55, 3:29-31.

21[b]. See VI.A.11	To a person of ordinary skill Kersey discloses means for retrieving back-propagating portions of the illumination back-propagating from a continuum of locations along the span (coupler 212). Ex. 1005, 3:54-57.

	 FIG. 2

21[c]. See VI.A.11	To a person of ordinary skill Kersey discloses means for modulating (pulse modulator 208) said CW optical signal with a reiterative autocorrelatable form of modulation (PRBS generator 206). Ex. 1005 at 1:58-62, 3:35-37.  FIG. 2

21[d]. See VI.A.11	One of ordinary skill would have been motivated to

	combine Kersey with the lightwave heterodyner of either Yoshino or Beckmann to achieve a means for picking off a radio frequency (r.f.) counterpart of the retrieved signal, wherein the r.f. counterpart is in phase locked synchronism with the CW optical signal with a reasonable expectation of success based at least on Kersey's explicit suggestion to incorporate that structure. Ex. 1005, 5:7-11. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a heterodyner, such as the ones suggested in Yoshino or Backmann would have provided predictable results to address the suggestion in Kersey of producing an accurate electronic signal containing information on the backscatter. *Id*. To a person of ordinary skill Yoshino discloses a lightwave heterodyner (phase meter of Fig. 2(a)), having a first input (line BS) for receiving a primary signal, and a second input (line M) for receiving a local oscillator signal, operative to produce the beat frequency of their respective frequencies ("typical beat signals (300 kHz) of the sensing and reference fibers."). Ex. 1007 at 504. To a person of ordinary skill Beckmann discloses a lightwave heterodyner (optical detector 5) having a first input (for backscattered light from measuring waveguide 4) for receiving a primary signal and a second input (for local oscillator 6) for receiving a local oscillator signal, operative to produce the beat frequency of their respective frequencies ("intermediate-frequency portions"). Ex. 1006, 3:57-58. Kersey discloses (phasemeter of Yoshino). *See also* Beckmann (optical detector 5).Ex. 1005 at 5:7-11.

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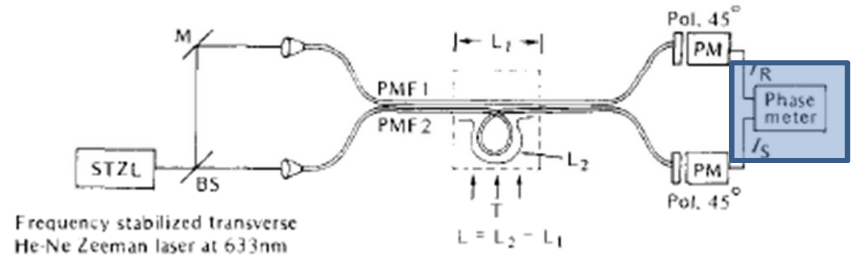

Ex. 1006 at 1:43-52.

Ex. 1006 at 3:57-58.

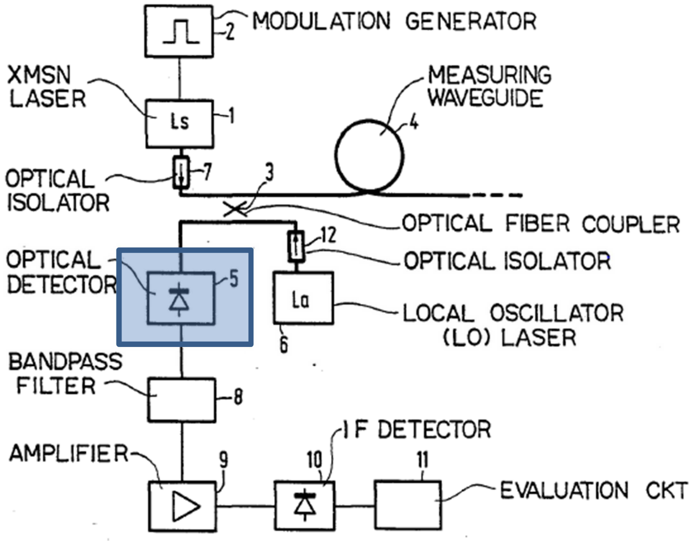

FIG. 1
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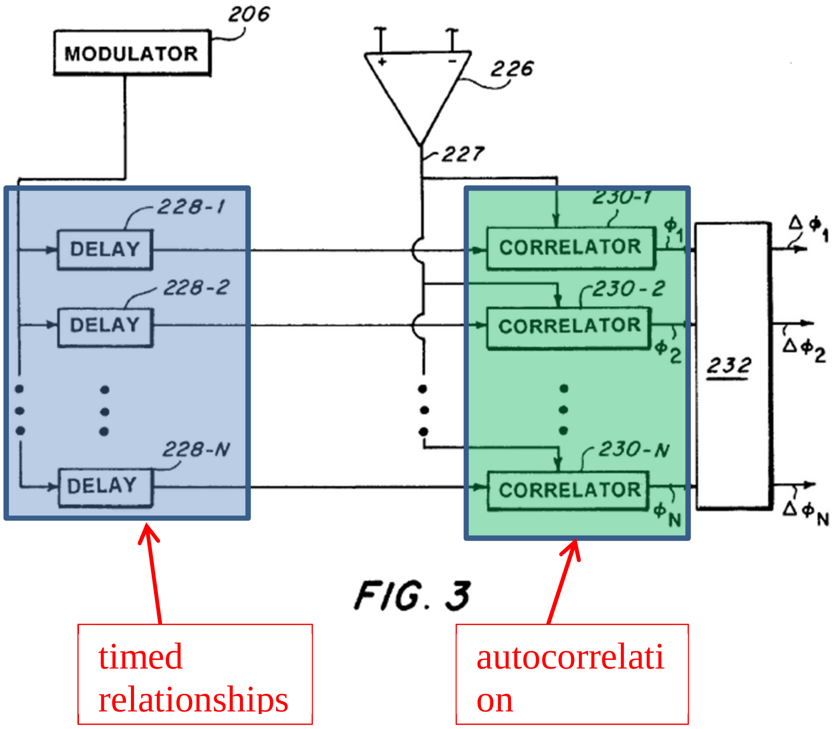
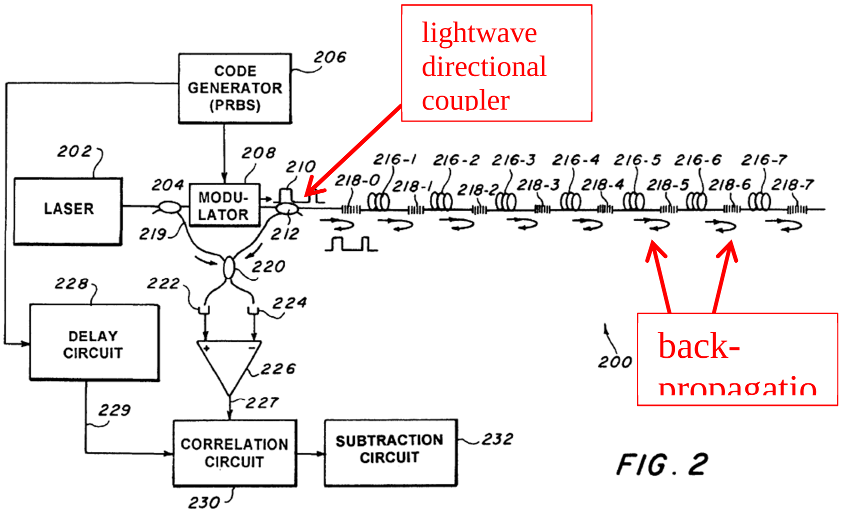
21[e]. See VI.A.11	To a person of ordinary skill Kersey discloses means for performing a corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal wherein said performing of the respective autocorrelation detections of the plurality of autocorrelation detection by said means for performing autocorrelation-detections are done in a corresponding

	plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal. Ex. 1005 at 4:44-50, 4:64-5:6, and 6:23-33.  FIG. 3 timed relationships autocorrelation

99. Claim 22 would have been obvious over Kersey in view of Yoshino or Beckmann.

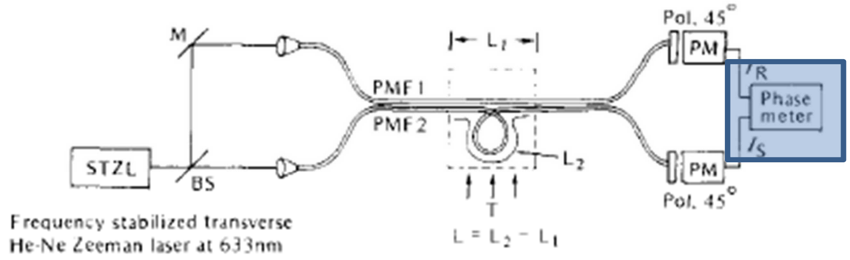
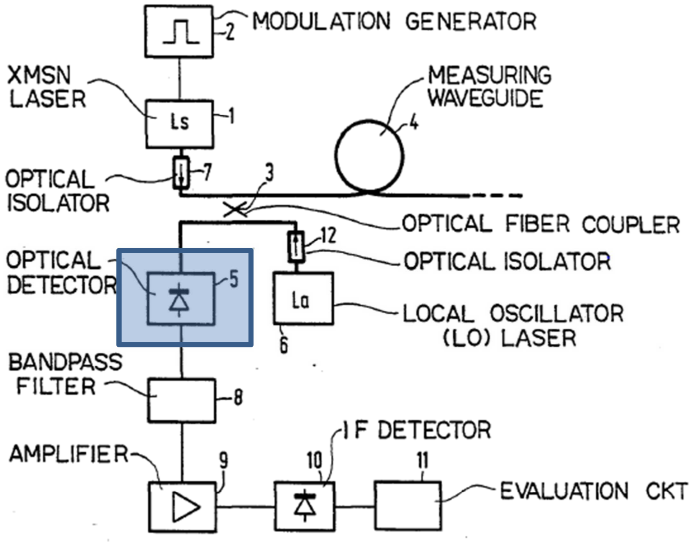
22[p]. See VI.A.12	To the extent the preamble may be limiting, to a person of ordinary skill it is disclosed by Kersey. To a person of ordinary skill Kersey discloses a signal sensing apparatus (Fig. 2) for sensing input signals at an array of a plurality of sensing stations (Bragg gratings 214) along an optical fiber span (fiber 214), wherein at respective sensing station of the array the apparatus senses input signals of a type having the property of inducing light path changes (undergo a change in

	refractive index in response to a physical condition”) within regions influenced by such input signals. Ex. 1005, 4:36-44.

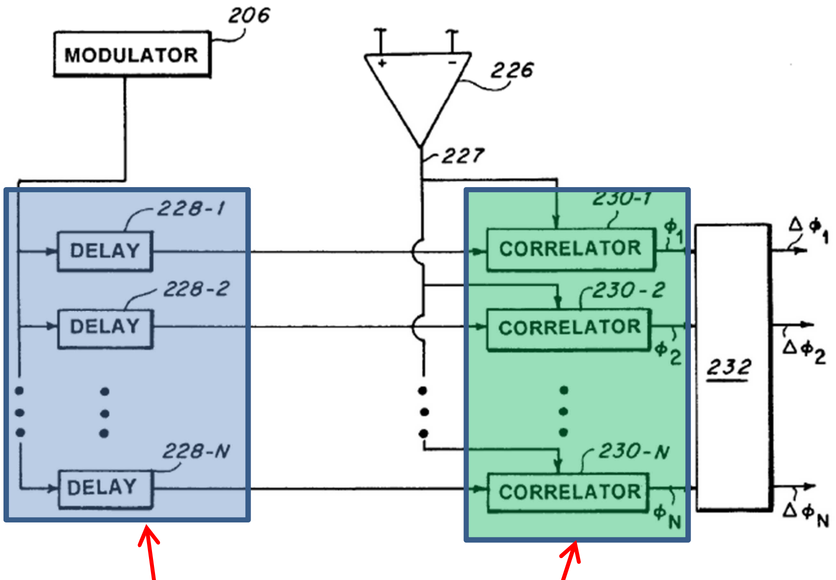
22[a]. See VI.A.12	To a person of ordinary skill Kersey discloses an optical wave network comprising a transmitter laser (laser 202) and a lightwave directional coupler (coupler 212), said network being operative to illuminate an optical fiber span (“an optical source to launch an optical signal into the fiber”) with a CW optical signal and to retrieve portions of the illumination back-propagating from a continuum of locations along the fiber span (“sum of reflected light fluxes”). Ex. 1005, Abstract, 2:54-55; 3:29-31, 3:54-57.  lightwave directional coupler back-propagatio FIG. 2

22[b]. See VI.A.12	To a person of ordinary skill Kersey discloses a modulator (modulator 106) operative to modulate the CW optical signal in accordance with a reiterative autocorrelatable form of modulation code). Ex. 1005, 1:46-51, 58-62, 3:35-38.

22[c]. See VI.A.12	One of ordinary skill would have been motivated to combine Kersey with the lightwave heterodyner of either Yoshino or Beckmann to achieve a means for picking off a radio frequency (r.f.) counterpart of the retrieved signal, wherein the r.f. counterpart is in phase locked synchronism with the CW optical signal with a reasonable expectation of success based at least on Kersey's explicit suggestion to incorporate that structure. Ex. 1005, 5:7-11. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a heterodyner, such as the ones suggested in Yoshino or Backmann would have provided predictable results to address the suggestion in Kersey of producing an accurate electronic signal containing information on the backscatter. *Id*. To a person of ordinary skill Yoshino discloses a heterodyner (phasemeter) which, in phase locked synchronism with said transmitter laser ("stabilized within about 1 kHz), receives said retrieved back-propagated portions of illumination and derives therefrom a radio frequency (r.f.) counterpart ("frequency separation from about 300 to 400 kHz"). Ex. 1007, 504, Fig. 2(a). Beckmann also discloses a heterodyner (optical detector 5). Ex. 1006, 1:43-52, 3:57-58, Fig. 1. To a person of ordinary skill Beckmann discloses a lightwave heterodyner (optical detector 5) having a first input (for backscattered light from measuring waveguide 4) for receiving a primary signal and a second input (for local oscillator 6) for receiving a local oscillator signal, operative to produce the beat frequency of their respective frequencies ("intermediate-frequency portions"). Ex. 1006, 3:57-58. Kersey discloses (phasemeter of Yoshino). *See also* Beckmann (optical detector 5).Ex. 1005 at 5:7-11.

	 Frequency stabilized transverse He-Ne Zeeman laser at 633nm  FIG. 1

22[d]. See VI.A.12	To a person of ordinary skill Kersey discloses a corresponding plurality of autocorrelation detectors (correlators 230) operative upon said r.f. counterpart of the retrieved optical signal in respective timed relationships of a corresponding plurality of different timed relationships with respect to said reiterative autocorrelatable form of modulation code (PRBS). Ex. 1005 at 4:44-50, 4:64-5:6, 6:23-33.

	 FIG. 3 timed relationships autocorrelation detectors

100. In my opinion Claim 11 would have been obvious over Kersey in view of Yoshino or Beckmann and further in view of Henning.

11. See VI.E.1	To a person of ordinary skill Kersey in view of Yoshino or Beckmann teaches the reflectometer of claim 3, but does not specify the coating for the optical fiber. A person of ordinary skill in the art implementing Kersey's system with the suggested heterodyner of Yoshino or Beckmann would be motivated to look to similar optical fiber measurement systems to decide on what type of coating to use. Henning is a similar system which teaches the advantages, such as sensitivity, of using a low Young's Modulus and low Poisson's ratio coating. Ex. 1009 at 4. Based on the Kersey and Henning systems a person of ordinary skill would have had a reasonable expectation of success in implementing the fiber coating suggested by Henning in the Everard system. Based on my experience designing fiber sensing systems in the

	2000-2003 time frame, my opinion is that to those of skill in the art the use of a fiber optic cable coating known to increase sensitivity to certain physical conditions would have provided predictable results to better achieve the design goal expressed in Kersey of detecting acoustic or other vibrations and disturbances. Ex. 1004, Abstract, 1:8-9.

101. In my opinion Claim 13 would have been obvious over Kersey in view of Yoshino or Beckmann and further in view of Wright (Ex. 1010)

13. See VI.F.1	To a person of ordinary skill Kersey in view of Yoshino or Beckmann teaches the reflectometer of claim 12, but Kersey's explicit suggestion to use heterodyne processing does not specify the configuration of the detector. Ex. 1005 at 5:7-11. Wright teaches a balanced optical detector circuit with identical photodetectors 11 and 12. Ex. 1010 at Fig. 1 and 1:42-45 ("second identical photodetector"). Wright also teaches applying the input signal to each photodetector and producing a differential current output in the same manner as Figure 4 of the '971 Patent. Compare Ex. 1010 at Fig. 1 with Ex. 1001 at Fig. 4. Wright teaches that use of the balanced detector circuit with fibre optic systems having an "optical fibre coupler" like the "optical coupler 105" used in Fig. 4 will result in advantages of "low noise" and "efficient use" of the available power. Ex. 1010 at 2:6-15. Based on Kersey's suggestion of using heterodyne processing, a person of ordinary skill would be motivated to achieve the advantages taught by Wright by using its balanced detector circuit and would have had a reasonable expectation of success. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a balanced heterodyner design would have provided predictable results of lower noise to better achieve the design goal expressed in Kersey of detecting acoustic or other vibrations and disturbances. Ex. 1004,

	Abstract, 1:8-9.

102. In my opinion Claim 15 would have been obvious over Kersey in view of Yoshino or Beckmann and further in view of Everard (Ex. 1004)

15. See VI.A.7	To a person of ordinary skill Everard discloses the use of shift registers to generate its pseudo random bit sequences. Based on Kersey's suggestion of using for the PRBS generator 206 "any known optical, or electro-optical, modulation device," a person of ordinary skill would be motivated to achieve the advantages taught by Everard, including increasing the average power transmitted and received, by using shift registers and would have had a reasonable expectation of success. Ex. 1004, Fig. 5, 2:64, 6:1-7; Ex. 1005, 5:29-30. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of shift registers would have provided predictable results of to address problems of low average power for other types of code generators.

103. In my opinion Claim 16 would have been obvious over Kersey in view of Yoshino or Beckmann and further in view of Payton '921 (Ex. 1011)

15. See VI.G	To a person of ordinary skill Kersey in view of Yoshino or Beckmann teaches the reflectometer of claim 1 as discussed above, but does not require a particular receiver structure for detecting phase variance. Kersey does suggest measuring the phase of backscatter, including specific suggestion of using a "phase detector". Ex. 1005, 2:56-58, 4:32-34. To a person of ordinary skill Payton '921 teaches a receiver for detecting an optical phase signal having

	varying polarization with signal to noise advantage. Ex. 1011, 1:11-14, 2:7-20. Payton ’921 teaches producing a reference phase signal and feeding that signal to phase demodulators, including I & Q quadrature demodulators that also receive the RF counterpart of the backscatter, including the portion indicating changes in characteristics along the fiber. *Id.*, Fig. 7, 12:23-39. The output includes two phase signals mixed to provide output signals. *Id.*, Fig. 7, 12:40-53. Phase detectors then receive the demodulator outputs to produce outputs that “provide power proportional to the external optical signal power over all phase and polarization values.” *Id.*, Fig. 7, 12:58-63. Based on either Kersey’s suggestion of using phase detectors or Payton ’921’s teaching that its detector has the advantages of consistent signal to noise ratio and unlimited electronic output voltages, a person of ordinary skill would be motivated to achieve the advantages taught by Payton ’921 by using its signal decoding module detector with Kersey’s system, including the heterodyner of Yoshino or Beckmann for the reasons described above, for spatial detection of backscatter and would have had a reasonable expectation of success. The ’971 Patent confirms the motivation and expectation. Ex. 1001, 23:34-53. Based on my experience designing fiber sensing systems in the 2000-2003 time frame, my opinion is that to those of skill in the art the use of a reference frequency driven phase demodulator to isolate signal indicating fiber characteristics would have provided predictable results to address Everard’s suggestion of using a “phase detector”. Ex. 1005, 2:56-58, 4:32-34.

IX. CONCLUSION

104. In my opinion, claims 1-3 and 6-16, and 18-22 of the ‘971 Patent are either anticipated or would have been obvious for at least the reasons stated above.

105. I reserve the right to supplement my opinions in the future to respond to any arguments raised by the owner of the '971 Patent and to take into account new information that becomes available to me.

106. I declare under penalty of perjury that all statements made herein are of my own knowledge and are true and correct.

Respectfully submitted,

Date: 9/13/2017

Dr. Faramarz Farahi