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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/686,161	06/16/2015	Robert M Payton	300099	5544

134845 7590 06/20/2017

NUWCDIVNPT / ADELOS
1176 HOWELL STREET, Code 00L
Bldg. 102T
NEWPORT, RI 02841

EXAMINER	
RALIS, STEPHEN J	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
06/20/2017	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

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APPLICATION NO./ CONTROL NO.	FILING DATE	FIRST NAMED INVENTOR / PATENT IN REEXAMINATION	ATTORNEY DOCKET NO.
14/686,161	16 June, 2015	PAYTON, ROBERT M	300099

NUWCDIVNPT / ADELOS
1176 HOWELL STREET, Code 00L
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EXAMINER	
Stephen J. Ralis	
ART UNIT	PAPER
3992	20170608

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Commissioner for Patents

See attached.

/Stephen J. Ralis/
Primary Examiner, Art Unit 3992

PTO-90C (Rev.04-03)

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1176 HOWELL STREET, CODE 00L BLDG. 102T
NEWPORT, RI 02841

In re Application of: :
PAYTON, Robert Michael :
Appl. No.: 14/686,161 : **SUSPENSION OF**
Docket No.: 300099 : **EXAMINATION UNDER**
Filed: June 16, 2015 : **37 CFR § 1.103(e)**
For: NATURAL SPAN REFLECTOMETRY WITH HELICAL FIBER

A litigation search performed by the Office on 14 October 2016 found concurrent litigation involving U.S. Patent No. 7,030,971 ("'971 Patent"), the subject of the above-referenced reissue proceeding. (See attached October 2016 Litigation Search). A response filed 13 April 2017 by Applicant ("April 2017 Response") to a non-Final Office action mailed 18 October 2016 indicates that the '971 Patent is involved in concurrent litigation. (See April 2017 Response at 20).

MPEP 1442.02 provides, in relevant part:

> To avoid duplicating effort, **action in reissue applications in which there is an indication of concurrent litigation will be suspended *sua sponte* unless and until it is evident to the examiner**, or the applicant indicates, that any one of the following applies:
> (A) a stay of the litigation is in effect;
> (B) the litigation has been terminated;
> (C) there are no significant overlapping issues between the application and the litigation; or
> (D) it is applicant's desire that the application be examined at that time.
> **Where none of (A) through (D) above apply, action in the reissue application in which there is an indication of concurrent litigation will be suspended by the examiner**.

In view of the concurrent litigation and pursuant to MPEP 1442.02, prosecution in the above-referenced reissue proceeding is SUSPENDED FOR A PERIOD OF SIX (6) MONTHS from the date of this letter. Upon expiration of the period of suspension, applicant should make an inquiry as to the status of the application. Any inquiry concerning this decision should be directed to Timothy Speer whose telephone number is (571) 272-8385.

/Timothy Speer/
SPRS, Art Unit 3992
Central Reexamination Unit

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SEARCH REPORT

STIC Database Tracking Number: 526365

To: STEPHEN RALIS
Location: RND-8D31
Art Unit: N/A
Friday, October 14, 2016

Case Serial Number: 14686194

From: DIANE JACKSON
Location: EIC2800
JEF-4B68
Phone: (571)272-3260

diane.jackson@uspto.gov

Search Notes

Hi,

RE: Serial Number 14686194 and US Patent 7030971

Attached are litigation search results in Lexis Nexis, Courtlink and ProQuest.

Litigation was found.

If you have any questions, please feel free to contact me.

Thanks,

Diane

Application Number Information

Application Number: **14/686194** Assignments	AIA (First Inventor to File): **NO**	TYPE ENT: **U**
Filing or 371(c) Date: **06/16/2015** eDan	Examiner Number: **81637 / RALIS, STEPHEN**	IFW Madras
Effective Date: **04/14/2015**	Group Art Unit: 3992	
Application Received: **04/14/2015**	Class/Subclass: **356/035.500**	
Patent Number:	Interference Number:	
Issue Date: **00/00/0000**	Unmatched Petition: **NO**	
Date of Abandonment: **00/00/0000**	L&R Code: Secrecy Code:**1**	
Attorney Docket Number: **300096**	Third Level Review: **NO**	Secrecy Order: **NO**
Status: **30 /DOCKETED NEW CASE - READY FOR EXAMINATION**		Status Date: **06/25/2015**
Confirmation Number: **6113**	Oral Hearing: **NO**	Lost Case: **NO**
Title of Invention: **NATURAL SPAN REFLECTOMETRY FOR OIL LINE MONITORING**		

Continuity/Reexam Information for 14/686194

Parent Data

14686194, filed 06/16/2015 is a continuation of 14190478, filed 02/26/2014

14190478 is a reissue of 11056630, filed 02/07/2005 ,now U.S. Patent #7030971

11056630 Claims Priority from Provisional Application 60599437, filed 08/06/2004

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Search > Patent Search > Litigation involving patent 7030971

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Patent Search Results

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Results: 1 cases and their patents, totaling 1 items.

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Items 1 to 1 of 1

	Patent	Class	Subclass	Description	Court	Docket Number	Filed	Date Retrieved
☐	7,030,971	356	35.5	Adelos, Inc. V. Halliburton Company Et Al	US-DIS-MTD	9:16cv119	9/12/2016	10/11/2016

Items 1 to 1 of 1

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US District Court Civil Docket

U.S. District - Montana
(Missoula)

9:16cv119

Adelos, Inc. v. Halliburton Company et al

This case was retrieved from the court on Friday, October 14, 2016

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Date Filed:	**09/12/2016**		
Assigned To:	**Judge Dana L. Christensen**	Class Code:	**OPEN**
Referred To:		Closed:	
Nature of suit:	**Patent (830)**	Statute:	**35:145**
Cause:	**Patent Infringement**	Jury Demand:	**None**
Lead Docket:	**None**	Demand Amount:	**$0**
Other Docket:	**None**	NOS Description:	**Patent**
Jurisdiction:	**Federal Question**		

Litigants	Attorneys
Adelos, Inc. Plaintiff	Gregory F. Wesner LEAD ATTORNEY;ATTORNEY TO BE NOTICED LANE POWELL PC 1420 Fifth Avenue Suite 4200 Seattle , WA 98111 USA 206-223-7000 Fax: 206-223-7107 Email:Wesnerg@lanepowell.Com Jeffrey W. Reis LEAD ATTORNEY;PRO HAC VICE;ATTORNEY TO BE NOTICED LANE POWELL PC 1420 Fifth Avenue Suite 4200 Seattle , WA 98111 USA 206-223-7000 Fax: 206-223-7107 Email:Reisj@lanepowell.Com John C. Herman LEAD ATTORNEY;PRO HAC VICE;ATTORNEY TO BE NOTICED ROBBINS GELLER RUDMAN & DOWD LLP - ATLANTA 3424 Peachtree Road, Ne Suite 1650 Atlanta , GA 30326 USA 404-504-6555 Fax: 404-504-6501 Email:Jherman@rgrdlaw.Com Peter M. Jones LEAD ATTORNEY;PRO HAC VICE;ATTORNEY TO BE NOTICED ROBBINS GELLER RUDMAN & DOWD LLP - ATLANTA 3424 Peachtree Road, Ne Suite 1650 Atlanta , GA 30326 USA 404-504-6513 Fax: 404-504-6501 Email:Pjones@rgrdlaw.Com Randy J. Cox LEAD ATTORNEY;ATTORNEY TO BE NOTICED BOONE KARLBERG, P.C.

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Halliburton Energy Services, Inc. Defendant	Bradley J. Luck LEAD ATTORNEY;ATTORNEY TO BE NOTICED GARLINGTON LOHN & ROBINSON, PLLP 350 Ryman Street Po Box 7909 Missoula , MT 59807-7909 USA 406-523-2500 Fax: 406-523-2595 Email:Bjluck@garlington.Com Emma L. Mediak LEAD ATTORNEY;ATTORNEY TO BE NOTICED GARLINGTON LOHN & ROBINSON, PLLP 350 Ryman Street Po Box 7909 Missoula , MT 59807-7909 USA 406-523-2500 Fax: 406-523-2595 Email:Elmediak@garlington.Com Kathleen L. DeSoto LEAD ATTORNEY;ATTORNEY TO BE NOTICED GARLINGTON LOHN & ROBINSON, PLLP 350 Ryman Street Po Box 7909 Missoula , MT 59807-7909 USA 406-523-2500 Fax: 406-523-2595 Email:Kldesoto@garlington.Com
Optiphase, Inc. Defendant	
Sensortran, Inc. Defendant	
Pinnacle Technologies, Inc. Defendant	

Documents

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	Availability	No.	Date	Proceeding Text [Filter]	Source
	Free	1	09/12/2016	COMPLAINT for Patent Infringement and Conversion against Halliburton Company, Halliburton Energy Services, Inc., Optiphase, Inc., Pinnacle Technologies, Inc., and Sensortran, Inc. filed by Adelos, Inc. (Attachments: # 1 Exhibit A-971 Patent, # 2 Exhibit B-863 Patent, # 3 Exhibit C-884 Patent, # 4 Exhibit D-PCT-US13-054588, # 5 Exhibit E-Written Opinion, # 6 Exhibit F-U.S. App. No. 14-903,503, # 7 Exhibit G-Preliminary Claim Chart, # 8 Civil Cover Sheet) (NOS,) (Entered: 09/12/2016)	
	Runner		09/12/2016	Filing fee of $400 paid; receipt number 0977-1835279. (NOS,) (Entered: 09/12/2016)	

	Free	2	09/12/2016	Summons Issued as to Halliburton Company, Halliburton Energy Services, Inc., Optiphase, Inc., Pinnacle Technologies, Inc., SensorTran, Inc. Originals mailed to Plaintiff's counsel. (NOS,) (Entered: 09/12/2016)	
	Free	3	09/16/2016	MOTION Gregory F. Wesner and Jeffrey W. Reise to Appear Pro Hac Vice (Filing fee $ 250 receipt number 0977-1838309.) Randy J. Cox appearing for Plaintiff Adelos, Inc. (Attachments: # 1 Affidavit Gregory F. Wesner, # 2 Affidavit Jeffrey W. Reis, # 3 Text of Proposed Order) (Cox, Randy) (Entered: 09/16/2016)	
	Online	4	09/19/2016	MOTION John C. Herman and Peter M. Jones to Appear Pro Hac Vice (Filing fee $ 250 receipt number 0977-1838860.) Randy J. Cox appearing for Plaintiff Adelos, Inc. (Attachments: # 1 Affidavit John C. Herman, # 2 Affidavit Peter M. Jones, # 3 Text of Proposed Order) (Cox, Randy) (Entered: 09/19/2016)	
	Online	5	09/19/2016	AFFIDAVIT of Service for Complaint and Summons served on Halliburton Company on September 16, 2016, filed by Adelos, Inc.. (Cox, Randy) (Entered: 09/19/2016)	
	Online	6	09/19/2016	AFFIDAVIT of Service for Complaint and Summons served on Halliburton Energy Services on September 16, 2016, filed by Adelos, Inc.. (Cox, Randy) (Entered: 09/19/2016)	
	Online	7	09/19/2016	AFFIDAVIT of Service for Complaint and Summons served on Optiphase, Inc., filed by Adelos, Inc.. (Cox, Randy) (Entered: 09/19/2016)	
	Online	8	09/19/2016	AFFIDAVIT of Service for Complaint and Summons served on Pinnacle Technologies, Inc. on September 16, 2016, filed by Adelos, Inc.. (Cox, Randy) (Entered: 09/19/2016)	
	Online	9	09/19/2016	AFFIDAVIT of Service for Complaint and Summons served on SensorTran, Inc. on September 16, 2016, filed by Adelos, Inc.. (Cox, Randy) (Entered: 09/19/2016)	
	Free	10	09/20/2016	ORDER granting 3 Motion to Appear Pro Hac Vice for Attorneys Gregory F. Wesner and Jeffrey Reis for Adelos, Inc. Signed by Judge Dana L. Christensen on 9/20/2016. (ASG,) (Entered: 09/20/2016)	
	Free	11	09/20/2016	ORDER granting 4 Motion to Appear Pro Hac Vice for Attorneys John C. Herman and Peter M. Jones for Adelos, Inc. Signed by Judge Dana L. Christensen on 9/20/2016. Order served via CM/ECF on co-counsel. (ASG,) Modified on 9/21/2016 to correct attorney names. (ASG,). (Entered: 09/20/2016)	
	Free	12	09/21/2016	AO 120 Patent and Trademark form transmitted to the U.S. Patent and Trademark Office.. (Cox, Randy) (Entered: 09/21/2016)	
	Runner		09/22/2016	Filing fee received: $500.00 pd, receipt number MTX9-10009 for PHV Attorneys Reis and Jones. (ASG,) (Entered: 09/22/2016)	
	Free	13	09/26/2016	NOTICE of Acknowledgment of Pro Hac Vice Order by Adelos, Inc. (Wesner, Gregory) (Entered: 09/26/2016)	
	Free	14	09/26/2016	NOTICE of Acknowledgment of Pro Hac Vice Order by Adelos, Inc. (Reis, Jeffrey) (Entered: 09/26/2016)	
	Free	15	10/04/2016	NOTICE of Acknowledgment of Pro Hac Vice Order by Adelos, Inc. (Herman, John) (Entered: 10/04/2016)	
	Free	16	10/04/2016	NOTICE of Acknowledgment of Pro Hac Vice Order by Adelos, Inc. (Jones, Peter) (Entered: 10/04/2016)	
	Online	17	10/06/2016	NOTICE of Appearance by Bradley J. Luck on behalf of Halliburton Company, Halliburton Energy Services, Inc. (Luck, Bradley) (Entered: 10/06/2016)	
	Online	18	10/06/2016	Corporate Disclosure Statement by Halliburton Company, Halliburton Energy Services, Inc. identifying Corporate Parent Halliburton Company for Halliburton Energy Services, Inc... (Luck, Bradley) (Entered: 10/06/2016)	
	Online	19	10/06/2016	Unopposed MOTION for Extension of Time to File Answer re 1 Complaint, or Other Responsive Pleading Bradley J. Luck appearing for Defendants Halliburton Company, Halliburton Energy Services, Inc. (Attachments: # 1 Text of Proposed Order) (Luck, Bradley) (Entered: 10/06/2016)	
	Online	20	10/06/2016	ORDER granting 19 Motion for Extension of Time to Answer re 1 Complaint. Halliburton Company answer due 12/6/2016; Halliburton Energy Services, Inc. answer due 12/6/2016. Signed by Chief Judge Dana L. Christensen on 10/6/2016. (DLE) (Entered: 10/06/2016)	
	Online	21	10/11/2016	MOTION to Appear Pro Hac Vice (Steven J. Pollinger) (Filing fee $ 250 receipt number 0977-1850496.) Bradley J. Luck appearing for Defendants Halliburton Company, Halliburton Energy Services, Inc. (Attachments: # 1 Affidavit, # 2 Text of Proposed Order) (Luck, Bradley) (Entered: 10/11/2016)	
	Online	22	10/11/2016	MOTION to Appear Pro Hac Vice (Aimee Perilloux Fagan) (Filing fee $ 250 receipt number 0977-1850511.) Bradley J. Luck appearing for Defendants Halliburton Company, Halliburton Energy Services, Inc. (Attachments: # 1 Affidavit, # 2 Text of Proposed Order) (Luck, Bradley) (Entered: 10/11/2016)	
	Online	23	10/11/2016	MOTION to Appear Pro Hac Vice (Eric C. Green) (Filing fee $ 250 receipt number 0977-1850517.) Bradley J. Luck appearing for Defendants Halliburton Company, Halliburton Energy Services, Inc. (Attachments: # 1 Affidavit, # 2 Text of Proposed Order) (Luck, Bradley) (Entered: 10/11/2016)	
	Online	24	10/12/2016	Corporate Disclosure Statement by Adelos, Inc. identifying Corporate Parent S&K Technologies, Inc. for Adelos, Inc... (Cox, Randy) (Entered: 10/12/2016)	

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Citation/Abstract

Natural fiber span reflectometer providing a virtual signal sensing array capability

Payton, Robert Michael (Inventor). US HEALTH (Assignee). **US 7030971** B1. (Published 18 Apr 2006).

Complete family

Complete family ID: 115022231

EPO simple family ID: 35839931

Includes: 10 patents; 5 countries

	Publication number	Kind	Publication date	Application number	Kind	Application date	Type
	WO 2006017702	A2	20060216	WO 2005US27821	A	20050805	B
	US 20060066839	A1	20060330	US 200556630	A	20050207	
	WO 2006017702	A3	20060406	WO 2005US27821	A	20050805	
	US 7030971	B1	20060418	US 200556630	A	20050207	
	EP 1779090	A2	20070502	EP 2005782661	A	20050805	
	EP 1779090	A4	20110309	EP 2005782661	A	20050805	
	EP 1779090	B1	20150722	EP 2005782661	A	20050805	
	DK 1779090	T3	20150907	DK 2005782661	T	20050805	
	ES 2549306	T3	20151026	ES 2005782661	T	20050805	
	EP 2950069	A1	20151202	EP 15177492	A	20050805	

INPADOC / Family and Legal Status

Citation/Abstract

Natural fiber span reflectometer providing a virtual signal sensing array capability

Payton, Robert Michael (Inventor). US HEALTH (Assignee). **US 7030971** B1. (Published 18 Apr 2006).

Legal status - complete family

Patent number	Gazette date	Code	Description	Notes/additional information
DK 1779090 T3	07 Sep 2015		Date of publication of document granted on or before said date	
ES 2549306 T3	26 Oct 2015		Date of publication of document granted on or before said date	
US 7030971 B1	01 Sep 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 May 14 Created: 2015 Sep 02
US 7030971 B1	18 Aug 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 17 Created: 2015 Aug 19
US 7030971 B1	04 Aug 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 17 Created: 2015 Aug 05
US 7030971 B1	28 Jul 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 16 Created: 2015 Jul 29

US 7030971 B1	14 Jul 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 17 Created: 2015 Jul 15
US 7030971 B1	14 Jul 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 16 Created: 2015 Jul 15
US 7030971 B1	14 Jul 2015	US RF	REISSUE APPLICATION FILED	Effective: 2015 Jun 15 Created: 2015 Jul 15
US 7030971 B1	13 May 2014	US RF	REISSUE APPLICATION FILED	Effective: 2014 Feb 26 Created: 2014 May 14
US 7030971 B1	09 Sep 2013	US FPAY +	FEE PAYMENT	Paid in year: 8 Created: 2013 Sep 18
US 7030971 B1	07 Jul 2009	US FPAY +	FEE PAYMENT	Paid in year: 4 Last revised: 2011 Apr 28
US 7030971 B1	18 Apr 2006		Date of publication of document granted on or before said date	
US 7030971 B1	07 Apr 2005	US AS	ASSIGNMENT	Effective: 2005 Feb 03 Assignee: NAVY, UNITED STATES OF AMERICA, THE, AS REPRESENTE ASSIGNMENT OF ASSIGNORS INTEREST;ASSIGNOR:PAYTON, ROBERT M.;REEL/FRAME:016024/0426 Last revised: 2009 Mar 08
EP 1779090 A2	31 Aug 2016	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2016 Jun 22 Ref country: PL Paid in year: 12 Created: 2016 Sep 06
EP 1779090 A2	31 Aug 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: SI LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Sep 06
EP 1779090 A2	19 Jul 2016	EP REG/FR PLFP	REFERENCE TO A NATIONAL CODE: FEE PAYMENT	Ref country: FR Paid in year: 12

				Created: 2016 Aug 03
EP 1779090 A2	29 Jun 2016	EP 26N +	NO OPPOSITION FILED	Effective: 2016 Apr 25 Created: 2016 Jun 29
EP 1779090 A2	31 May 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: RO LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Jun 04
EP 1779090 A2	29 Apr 2016	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 24 Ref country: IT Paid in year: 11 Created: 2016 May 03
EP 1779090 A2	29 Apr 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: SK LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 May 03
EP 1779090 A2	29 Apr 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: MC LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 May 03
EP 1779090 A2	29 Apr 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: CZ LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 May 03
			LAPSED IN A CONTRACTING STATE	Effective: 2015 Jul 22 Ref country: EE

EP 1779090 A2	29 Apr 2016	EP PG25 -	ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 May 03
EP 1779090 A2	25 Apr 2016	EP REG/DE R097	REFERENCE TO A NATIONAL CODE: NO OPPOSITION FILED AGAINST GRANTED PATENT, OR EPO OPPOSITION PROCEEDINGS CONCLUDED WITHOUT DECISION	Related publication: DE 602005047047 Ref country: DE Created: 2016 Jul 02
EP 1779090 A2	29 Feb 2016	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Sep 07 Ref country: PL Paid in year: 11 Created: 2016 Mar 01
EP 1779090 A2	29 Feb 2016	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Oct 02 Ref country: IS Paid in year: 11 Created: 2016 Mar 01
EP 1779090 A2	29 Feb 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: AT LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Mar 01
EP 1779090 A2	29 Feb 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Nov 23 Ref country: PT LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Mar 01
EP 1779090		EP	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA	Effective: 2015 Jul 22 Ref country: LV LAPSE BECAUSE OF FAILURE

A2	29 Jan 2016	PG25 -	POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Feb 04
EP 1779090 A2	29 Jan 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Jul 22 Ref country: LT LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Feb 04
EP 1779090 A2	29 Jan 2016	EP PG25 -	LAPSED IN A CONTRACTING STATE ANNOUNCED VIA POSTGRANT INFORM. FROM NAT. OFFICE TO EPO	Effective: 2015 Oct 23 Ref country: GR LAPSE BECAUSE OF FAILURE TO SUBMIT A TRANSLATION OF THE DESCRIPTION OR TO PAY THE FEE WITHIN THE PRESCRIBED TIME-LIMIT Created: 2016 Feb 04
EP 1779090 A2	31 Dec 2015	EP REG/PL T3	REFERENCE TO A NATIONAL CODE: TRANSLATION OF EP PATENT	Ref country: PL Created: 2016 Feb 27
EP 1779090 A2	28 Dec 2015	EP REG/LT MG4D	REFERENCE TO A NATIONAL CODE: INVALIDATED EUROPEAN PATENT	Ref country: LT Created: 2016 Jan 08
EP 1779090 A2	23 Dec 2015	EP REG/NL FP	REFERENCE TO A NATIONAL CODE: TRANSLATION FOR EP FILED (ENTRY OF EP INTO COUNTRY)	Ref country: NL Created: 2016 Sep 07
EP 1779090 A2	15 Dec 2015	EP REG/AT MK05	REFERENCE TO A NATIONAL CODE: REVOCATION OF THE TRANSLATION OF THE EP PATENT	Related publication: AT 738175 T Effective: 2015 Jul 22 Ref country: AT Created: 2015 Dec 17
EP 1779090 A2	30 Nov 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL	Payment: 2015 Aug 21 Ref country: SE Paid in year: 11

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EP 1779090 A2	30 Nov 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 25 Ref country: FR Paid in year: 11 Created: 2015 Dec 01
EP 1779090 A2	30 Nov 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 24 Ref country: BE Paid in year: 11 Created: 2015 Dec 01
EP 1779090 A2	13 Nov 2015	EP REG/CH NV	REFERENCE TO A NATIONAL CODE: NEW AGENT	Ref country: CH Attorney: FIAMMENGHI-FIAMMENGHI, CH Created: 2015 Dec 03
EP 1779090 A2	30 Oct 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 26 Ref country: DK Paid in year: 11 Created: 2015 Nov 03
EP 1779090 A2	30 Oct 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 26 Ref country: FI Paid in year: 11 Created: 2015 Nov 03
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				Payment: 2015 Sep 21

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EP 1779090 A2	30 Sep 2015	EP PGFP +	POSTGRANT: ANNUAL FEES PAID TO NATIONAL OFFICE	Payment: 2015 Aug 27 Ref country: NL Paid in year: 11 Created: 2015 Oct 06
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EP 1779090 A2	22 Jul 2015	EP AK +	DESIGNATED CONTRACTING STATES:	Designated states: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR Created: 2015 Jul 22
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WO 2006017702 A3	02 May 2007	WO WWP +	WIPO INFORMATION: PUBLISHED IN NATIONAL OFFICE	Related publication: EP 2005782661 Last revised: 2008 Aug 21
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WO 2006017702 A3	07 Feb 2007	WO NENP	NON-ENTRY INTO THE NATIONAL PHASE IN:	Ref country: DE Last revised: 2007 May 24

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WO 2006017702 A3	16 Feb 2006	WO AL +	DESIGNATED COUNTRIES FOR REGIONAL PATENTS	Designated states: GM KE LS MW MZ NA SD SL SZ TZ UG ZM ZW AM AZ BY KG KZ MD RU TJ TM AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LT LU LV MC NL PL PT RO SE SI SK TR BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG Last revised: 2006 Mar 02
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EP 2950069 A1	06 Jul 2016	EP RBV +	DESIGNATED CONTRACTING STATES (CORRECTION):	Designated states: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR Created: 2016 Jul 06
EP 2950069 A1	06 Jul 2016	EP 17P +	REQUEST FOR EXAMINATION FILED	Effective: 2016 May 30 Created: 2016 Jul 06
EP 2950069 A1	30 Dec 2015	EP RIN1	INVENTOR (CORRECTION)	Inventor: PAYTON, ROBERT M. Created: 2016 Jan 09
EP 2950069 A1	02 Dec 2015		Date of publication of examined document not granted on or before said date	
EP 2950069 A1	02 Dec 2015	EP AC	DIVISIONAL APPLICATION (ART. 76) OF:	Related publication: EP 1779090 P Created: 2015 Dec 02
EP 2950069 A1	02 Dec 2015	EP AK +	DESIGNATED CONTRACTING STATES:	Designated states: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR Created: 2015 Dec 02

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056630 (11) 7030971 April 18, 2006

UNITED STATES PATENT AND TRADEMARK OFFICE GRANTED PATENT

7030971

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Link to Claims Section

April 18, 2006

Natural fiber span reflectometer providing a virtual signal sensing array capability

REEXAM-LITIGATE:

NOTICE OF LITIGATION

Adelos, Inc. v. Halliburton Company et al, Filed September 12, 2016, D.C. Montana, Doc. No. 9:16cv119

REISSUE:
February 26, 2014 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N. 14/190,478 , (O.G. May 13, 2014)
May 14, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N. 14/686,170 , (O.G. September 1, 2015)
June 15, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N. 14/686,188 , (O.G. July 14, 2015)
June 16, 2015 - Reissue Application filed, ; Re. S.N. 14/686,194 , (O.G. July 14, 2015)
June 16, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N.: 14/686,205 , (O.G. July 28, 2015)
June 17, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N. 14/741,822 , (O.G. July 14, 2015)
June 17, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N.: 14/741,768 , (O.G. August 18, 2015)
June 17, 2015 - Reissue Application filed, Ex. Gp.: 2877; Re. S.N.: 14/741,857 , (O.G. August 4, 2015)

INVENTOR: Payton, Robert Michael - Portsmouth, Rhode Island, United States of America (US), United States of America ()

APPL-NO: 056630 (11)

FILED-DATE: February 7, 2005

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PRIORITY: February 7, 2005 - 11056630, United States of America (US)

ASSIGNEE-PRE-ISSUE:
April 7, 2005 - ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS)., NAVY, UNITED STATES OF AMERICA, THE, AS REPRESENTED BY THE DEPARTMENT OF, 1176 HOWELL STREET, (ATTN: CODE 00OC), NAVAL UNDERSEA WARFARE CENTER, OFFICE OF COUNSEL, NEWPORT, RHODE ISLAND, UNITED STATES OF AMERICA (US), 02841-1708, Reel and Frame Number: 016024/0426

ASSIGNEE-AT-ISSUE:
The United States of America represented by the Secretary of the Navy, Washington, District of Columbia, United States of America (US), U.S. Federal government (06)

LEGAL-REP: Kasischke, James M. ; Nasser, Jean-Paul A. ; Stanley, Michael P.

PUB-TYPE: April 18, 2006 - Patent without a pre-grant publication (B1)

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July 28, 2015 - REISSUE APPLICATION FILED
August 4, 2015 - REISSUE APPLICATION FILED
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September 9, 2013 - Payment of Maintenance Fee, 8th Year, Large Entity.

FILING-LANG: English (EN) (ENG)

PUB-LANG: English (EN) (ENG)

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US-MAIN-CL: 356#35.5

US-ADDL-CL: 356#478, 356#484

CL: 356

SEARCH-FLD: 356#35.5, 356#73.1, 356#477, 356#478, 356#484, 367#140, 367#141

IPC-MAIN-CL: [8] G01L 001#24 (20060101) Advanced Inventive 20060418 (A F I B H US)

IPC-ADDL-CL: [8] G01B 009#02 (20060101) Advanced Inventive 20060418 (A L I B H US)

PRIM-EXMR: Toatley, Jr., Gregory J.

ASST-EXMR: Lyons, Michael A.

REF-CITED:

5194847, March 16, 1993, Taylor et al., United States of America (US)
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6285806, September 4, 2001, Kersey et al., United States of America (US)

NON-PATENT LITERATURE:
R. Hughes and J. Jarzynski, "Static Pressure Sensitivity Amplification in Interferometric Fiber-Optic Hydrophones", Applied Optics, Jan. 1, 1980, vol. 19., No. 1, USA.0018914716

CORE TERMS: optical, phase, phi, fiber, path, omega, electrical, cos, span, sensor, lightwave, correlation, wave, sin, psi, composite, frequency, receiver, correlator, virtual, laser, electronic, oscillator, r.f, tau, sequence, equation, interrogation, mathematical, demodulator

ENGLISH-ABST:

A CW lightwave modulated by a continuously reiterated binary pseudorandom code sequence is launched into an end of a span of ordinary optical fiber cable. Portions of the launched lightwave back propagate to the launch end

from a continuum of locations along the span because of innate fiber properties including Rayleigh scattering. This is picked off the launch end and heterodyned to produce a r.f. beat signal. The r.f. beat signal is processed by a plurality (which can be thousands) of correlator type binary pseudonoise code sequence demodulators respectively operated in different delay time relationships to the timing base of the reiterated modulation sequences. The outputs of the demodulators provide r.f. time-domain reflectometry outputs representative of signals (e.g., acoustic pressure waves) incident to virtual sensors along the fiber at positions corresponding to the various time delay relationships.

NO-OF-CLAIMS: 22

EXMPL-CLAIM: 1

NO-OF-FIGURES: 13

NO-DRWNG-PP: 13

GOVT-INTEREST:

STATEMENT OF GOVERNMENT INTEREST

[0002]The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

PARENT-PAT-INFO:

[0001]Applicant claims the benefit of a provisional application, No. 60/599,437 which was filed on 6 Aug. 2004, and which is entitled "Continuous Rayleigh Effect Sensor Backscattering Heterodyne Optical Sensor System" by Robert M. Payton.

SUMMARY:

CROSS-REFERENCE TO RELATED APPLICATIONS

[0003]"Natural Fiber Span Reflectometer Providing a Spread Spectrum Virtual Sensing Array Capability" (Navy Case No 96650) filed on even date herewith in the name of Robert M. Payton, hereby incorporated herein by reference in its entirety.

[0004]"Natural Fiber Span Reflectometer Providing A Virtual Phase Signal Sensing Array Capability" (Navy Case No. 96518) filed on even date herewith in the name of Robert M. Payton, hereby incorporated herein by reference in its entirety.

[0005]"Natural Fiber Span Reflectometer Providing a Virtual Differential Signal Sensing Array Capability" (Navy Case No. 96519) filed on even date herewith in the name of Robert M. Payton, hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0006](1) Field of the Invention

[0007]The present invention relates generally to the field of time-domain reflectometers. More specifically, it relates to such reflectometers which are a part of a photonic system application in which the object of the reflectometry is a span of fiber which has an interrogation signal launch end and a remote end. The invention enables the provision of a linear array of virtual sensors along the span. One particular type of application toward which the invention is directed are acoustic security alarm systems in which the span serves as a perimeter intrusion monitoring line.

[0008](2) Description of the Prior Art

[0009]The U.S. Department of the Navy has been engaged in the development of towed acoustic arrays which are reflectometric systems in which the object of the reflectometry is a fiber span having an interrogation signal launch end and a remote end. One such development involves forming a towed array of acoustic sensors along the span by the costly process of irradiating Bragg reflective gratings into the fiber cable. These reflective gratings form the array of sensors of the reflectometry scheme of these systems. These towed arrays have a length of the order of at least 1.0 km, and the need to irradiate the fiber has resulted in the fiber spans costing hundreds of thousands of dollars each.

[0010]The Department of the Navy development activities have been further tasked to apply their creative efforts to homeland defense problems. As part of this effort there is under consideration the use of a reflectometer in which a fiber span is the object of the reflectometry. In this scheme, the fiber span provided with acoustic sensors would be used as an intrusion detector to monitor the perimeter of an area desired to be secure. The span lengths for this type of application include lengths of the order of 5 km, (links of a U.S. border protection network, oil line protection, chemical plant protection, etc.). In such perimeter monitoring applications thousands of acoustic sensors would be required along the fiber span.

[0011]The cost of manufacturing such perimeter monitoring spans employing reflective Bragg grating sensors has been an obstacle to their use in perimeter intrusion monitoring applications. Thus, there is considerable interest in the development of a reflectometer system in which a fiber span is the object of the reflectometry optic array that does not require the high cost of Bragg reflective acoustic sensors.

[0012]Previous effort in solving related problems are described by the following patents:

[0013]U.S. Pat. No. 5,194,847 issued Mar. 16, 1993 to H. Taylor and C. Lee discloses an apparatus for sensing intrusion into a predefined perimeter which comprises means for producing a coherent pulsed light, which is injected into an optical sensing fiber having a first predetermined length and positioned along the predefined perimeter. A backscattered light in response to receiving the coherent light pulses is produced and coupled into an optical receiving fiber. The backscattered light is detected by a photodetector and a signal indicative of the backscattered light is produced. An intrusion is detectable from the produced signal as indicated by a change in the backscattered light. To increase the sensitivity of the apparatus, a reference fiber and interferometer may also be employed.

[0014]U.S. Pat. No. 6,285,806 issued on Sep. 4, 2001 to A. Kersey et al., discloses an apparatus and method for measuring strain in an optical fiber using the spectral shift of Rayleigh scattered light. The interference pattern produced by an air gap reflector and backscatter radiation is measured. Using Fourier Transforms, the spectrum of any section of fiber can be extracted. Cross correlation with an unstrained measurement produces a correlation peak. The location of the correlation peak indicates the strain level in the selected portion of optical fiber.

[0015]The above patents do not show how to obtain signals representing acoustic pressure signals incident upon a fiber span (to detect perimeter intrusion) at a very large number of sensing stations without involving high manufacturing costs. Consequently, those skilled in the arts will appreciate the present invention which addresses these and other problems.

SUMMARY OF THE INVENTION

[0016]The objects of the present invention include the provision of:

- -

  (1) A time-domain reflectometer wherein an optical fiber span is the object of the reflectometry, and which provides output signals representative of acoustic pressure waves incident the span solely by virtue of the natural, or innate, properties of commercial grade optical fiber cables.
- -

  (2) The reflectometer described in object number (1), above, capable of providing acoustic wave signal sensing lengths of 5.0 km or more.

- ~

  (3) The reflectometer described in object number (2), above, which facilitates the provision of a very large plurality (e.g. 5,000 or more) virtual acoustic sensors along the span.
- ~

  (4) The reflectometer described in object number (1), above having a mode of operation which inherently attenuates undesired noises due to span line discontinuities, such as reflections caused by fiber cable couplings.
- ~

  (5) The reflectometer described in objects numbered (1) through
- ~

  (4), above, having special utility as a perimeter intrusion monitoring line for an acoustic security alarm system.
- ~

  (6) The reflectometer described in object numbered (1), above, which is capable of providing output signals in the form of a phase signal which varies linearly with the acoustic pressure wave.
- ~

  (7) The reflectometer described in object numbered (3), above, which is capable of providing output signals in the form of phase differential signals across pairs of the virtual sensors.
- ~

  (8) The reflectometer described in the object number (7), above, providing a capability of programmably selecting a pair, or pairs, of virtual acoustic sensors across which the phase signals are picked off, from among the plurality of virtual signals along the span.

[0026]These and other objects, features, and advantages of the present invention will become apparent from the drawings, the descriptions given herein, and the appended claims. However, it will be understood that the above listed objects and advantages of the invention are intended only as an aid in understanding aspects of the invention, and not intended to limit the invention in any way, and do not form a comprehensive list of objects, features, and advantages.

[0027]Accordingly, a time-domain reflectometer is provided for sensing and providing output signals representative of acoustic wave signals incident on the fiber span which is the object of the reflectometry, wherein the innate properties of low cost, commercially available fiber optic cables are employed to create a plurality (upwardly extending to very large numbers, e.g., 5000 and more) virtual sensors.

[0028]The present invention is implemented as follows: Time and spatial domain multiplexing and de-multiplexing of optical signals is accomplished by an electronic-delay or time of-transversal-delay coupled with modulated-retransmission of a master or reference carrier wave. Each individual optical signal occupies a unique time-delay slot or bin. A master or carrier wave is modulated with each individual optical signal and delayed by the appropriate time interval specific to a particular signal. All such signals are combined and simultaneously transmitted as a composite optical signal to a receiver where these are collected and photodetected. By correlating the photodetected composite optical signal with the master or reference carrier wave, each individual optical signal is sorted or demultiplexed into separate electronic signal channels. The continuous wave nature of the master or reference carrier wave provides more power than a pulsed optical wave and heterodyne optical reception of the invention allows a very low optical detection threshold or noise floor. The invention provides significant improvement over other systems because the optical noise floor is lowered considerably over more conventional means.

[0029]The invention applies to several applications. The invention allows audio bandwidth (tens of kilohertz bandwidth) providing time-domain reflectometry measurements of fiber optical cables or other optical mediums such as glass, air, water, etc. Other time-domain reflectometry methods do not sample the optical medium fast enough to detect tens of kilohertz bandwidth variations in the medium. The invention also relates to fiber optic sensors and optical sensors generally. A fiber optic sensor array is typically time-domain multiplexed by the time-of-transversal of an interrogation lightwave to each sensor and back to a common optical collection and detection point. The invention relates generally to both amplitude and phase type optical senor arrays. The invention is an enabling technology for a Department of Navy development known as the Rayleigh Optical Scattering and Encoding (ROSE) sensor system. The spatial separation of segmentation of a ROSE acoustic array into spatial channels is enabled by the invention.

[0030]The invention relates to acoustic security alarm systems, Naval towed arrays for sensing underwater acoustic signals, fiber optic bugging devices, and many other potential ROSE applications. The invention also relates to non-fiber optical sensors such as: laser velocimeters; lasers imagers; laser radar; laser rangers; and remote laser acoustic, strain, motion or temperature measurement devices.

DRWDESC:

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawing, wherein like reference numerals refer to like parts and wherein:

[0032]FIG. 1 is a graphical depiction of certain underlying physical mechanisms of polarization;

[0033]FIG. 2 is a block diagram helpful in understanding the concept of launch of an interrogation signal along an optical fiber span providing a virtual array of pressure wave sensors by retrieval of backscatter from Rayleigh Optical Scatter (ROS) effects;

[0034]FIG. 3 is a block diagram of a natural fiber span time-domain reflectometer system in accordance with the present invention;

[0035]FIG. 4 is an electrical schematic of a balanced heterodyne optic detector circuit;

[0036]FIG. 5 is an electrical schematic of an alternative embodiment of a photodetector type heterodyner;

[0037]FIG. 6 is a block diagram of a programmable correlator subsystem, which enables spatial sampling of optical signals on the fiber optic span of the system of FIG. 3, in order to provide a virtual array of acoustic wave sensors therealong;

[0038]FIG. 7 is a block diagram depiction of a set of phase demodulator circuit assemblies which receives the outputs of the programmable correlator subsystem of FIG. 6;

[0039]FIG. 8 is a block diagram of one of the phase demodulator circuit assemblies of the set of FIG. 7;

[0040]FIG. 9 is a block diagram disclosing details of an I & Q demodulator component in a phase demodulator circuit assembly of FIG. 8;

[0041]FIG. 10 is a block diagram disclosing details of a digital embodiment of the phase detector component phase demodulator circuit assembly of FIG. 8;

[0042]FIG. 11 is a block diagram disclosing details of an analog embodiment of the phase detector component phase demodulator circuit assembly of FIG. 8;

[0043]FIG. 12 is 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

[0044]FIG. 13 is a diagrammatic depiction of embodiment of invention of FIG. 3 in which portions of the optical fiber span are wound around a hollow mandrel.

DETDESC:

DESCRIPTION OF THE PREFERRED EMBODIMENT

(1) Description of Underlying Theories

[0045]a. Heterodyne Optical Detection

[0046]Optical receivers are built around photodetectors which detect optical power rather than instantaneous electric field. Typically the photodetector output current is proportional to the incident optical power. This relationship severely limits the dynamic range of an incoherent optical receiver because for every decibel of optical power lost in a receiver system two decibels of receiver output current is lost. The square law characteristics of photodetectors limits typical incoherent optical receivers (often called video detection receivers) to dynamic ranges of less than 80 dB and optical detection noise floors to greater than −80 dBm per Hertz bandwidth. As illustration, suppose an electric field $E_{(s)}(t)$ [volt/meter] immersed in a material of impedance η [Ohms] impinges upon a photodetector of responsivity [ampere/watt] loaded by resistor $R_{(1\ )}$and amplified by amplification A, then the optical power $P_{(s\ )}$by amplification A, is:

[0047]Ps⁡(t)=⟨E⇀s⁡(t)·E⇀s⁡(t)⟩η(1)
Get Mathematical Equation
The photodetector output current [amperes] is: $i(t)=P_{(S)}(t)$ (2) The photoreceiver output [volts] is thus: $v(t)=AR_{(L)}i(t)=AR_{(L)}P_{(S)}(t)$ (3)

[0048]The output fades only if the optical signal power goes to zero because the vector dot product of an optical signal against itself has no polarization or phase effects. This lack of fading due to polarization or phase comes at a cost: phase information is lost and signal to noise ratios are severely impacted.

[0049]A coherent optical receiver takes advantage of the square law characteristics of photodetectors. A coherent optical receiver combines two optical beams, a signal and a local oscillator, together to form an interference. The interference between these optical waves produces a "beat" which allows the measurement of the phase difference between the signal and the local oscillator. This interference produces an amplitude, polarization, and phase sensitive receiver output. In order to consider these effects a discussion of the polarization state of plane waves is in order. A plane wave contains two orthogonal vector components which are also orthogonal to the direction of propagation of the wave. For purposes of discussion we will consider the plane wave to be oriented so that the vector components of the electromagnetic field lie in an X-Y plane and that the wave propagates in the Z direction. However, this choice of axes is completely arbitrary. In practice, the wave can be oriented in any propagation direction. In order to simplify discussions, a simple change of coordinates will make this discussion completely general.

[0050]The polarization of an electromagnetic (or optical) plane wave, p, is described by a minimum of five parameters. There are two basic ways of specifying these parameters. The first way leads to a description which is oriented towards that which is directly obtained from physical measurements.

[0051]E⇀p⁡(Epx,Epy,Φpx,Φpy,ωp,t)=[Epx⁡(t)⁢cos⁡(ωp⁢t+Φpx)Epy⁡(t)⁢cos⁡(ωp⁢t+Φpy)](4)
Get Mathematical Equation
The second manner of describing the polarization state of a wave, p, is oriented more towards the underlying physical mechanisms of polarization. See FIG. 1. The description is made in terms of spatial and temporal parameters:

[0052]E→p⁡(Ep,?p,ψp,φp,ωp,t)=Ep⁡(t)⁡[cos⁡(?p)sin⁡(?p)-sin⁡(?p)cos⁡(?p)]⁢[cos⁡(ψp)00sin⁡(ψp)]⁢[cos⁡(ωp⁢t+φp)sin⁡(ωp⁢t+φp)](5)
Get Mathematical Equation
Alternatively, dropping the full variable list in the parentheses and expanding:

[0053]E→p⁡(t)=Ep⁡(t)⁡[cos⁡(?p)sin⁡(?p)-sin⁡(?p)cos⁡(?p)]⁢[cos⁡(ψp)00sin⁡(ψp)]⁢[cos⁡(φp)-sin⁡(φp)sin⁡(φp)cos⁡(φp)]⁢[cos⁡

(ωp⁢t)sin⁡(ωp⁢t)](6)
Get Mathematical Equation

[0054]If $E_{(p)}$ is constant, the electrical power of this wave can be shown to be constant and equal to:

[0055]Pp⁡(t)=⟨E→p⁡(t)·E→p⁡(t)⟩η=Ep22⁢η(7)
Get Mathematical Equation
When two waves, S (signal) and L (local oscillator), interfere at the input of a photoreceiver, the output is:

[0056]vout⁡(t)=ARL⁢i⁡(t)=ARL⁢⁢⟨E→s⁡(t)·E→s⁡(t)+E→L⁡(t)·E→L⁡(t)+2⁢E→L⁡(t)·E→s⁡(t)⟩η⁢⁢vout⁡(t)=vL⁡(t)+vs⁡(t)+vLS⁡(t)=ARL⁢⁢(PL⁡(t)+Ps⁡(t)+PLS⁡(t))(8)
Get Mathematical Equation
If the optical power of the local oscillator and signal lightwaves remain constant, a constant photocurrent develops for the self-interference terms ($P_{(S)}$ and $P_{(L)}$). However, if either the local oscillator or the signal lightwaves have any temporal variation in polarization or phase, the cross interference term ($P_{(LS)}$) will be time dependent even if the power of each lightwave remains constant. Solving for the cross interference term, we obtain:

[0057]vLS⁡(t)=ARL⁢η⁢EL⁡(t)⁢Es⁡(t)⁡[cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)+sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δω⁢⁢t+Δφ)]⁢⁢vLS⁡(t)=2⁢ARL⁢⁢PL⁡(t)⁢Ps⁡(t)⁡[cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)+sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δω⁢⁢t+Δ?)](9)
Get Mathematical Equation
Where the following definitions are made: Δ?=?$_{(S)}$−?$_{(L)}$Δψ=ψ$_{(S)}$−ψ$_{(L)}$2[overscore (ψ)]=ψ$_{(S)}$+ψ$_{(L)}$Δω=ω$_{(S)}$−ω$_{(L)}$Δϕ=ϕ$_{(S)}$−ϕ$_{(L)}$ (10)

[0058]The optical cross-interference portion of the receiver output will fade due to polarization even if the local oscillator and the signal lightwaves both do not have zero optical powers. This condition will occur if: *O*=cos(Δs)cos(Δψ)cos(Δω*t*+Δϕ)=sin(Δs)sin(2[overscore (ψ)])sin(Δω*t*+ΔΦ) (11) Also, equivalently when the condition will occur:

[0059][00]=[cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δω⁢⁢t+Δφ)](12)
Get Mathematical Equation

[0060]When heterodyne optical detection is employed (Δω is non-zero, the local oscillator has a different frequency from the signal), the conditions for a fade are shown in Table 1. When homodyne detection is employed (Δω is zero), both phase and polarization fading occur. The conditions for a homodyne fade are shown in Table 2. Heterodyne detection is therefore seen to be superior to homodyne because the probability of a fade is fully one half as likely.

[0061]

Search terms may have been found within the contents of this table. Please see the table in the original document.

[0062]

Search terms may have been found within the contents of this table. Please see the table in the original document.

[0063]Given the conditions for and the functional relation of a fade, the question now arises as to how a fade can be prevented. Since the signal is being measured, no a priori knowledge is assumed and therefore $E_{(S)}$, $s_{(S)}$, Ψ$_{(S)}$, Φ$_{(S\ )}$are all probably unknown quantities. If fading is prevented, then no loss of information occurs and determination of these four parameters is possible. In order to decode the optical receiver output into these parameters, at least four independent measurements must be made to uniquely determine these four independent variables. However, if the interfering optical beam (or beams) of the local oscillator are unknown, then additional independent measurements must be made (four additional measurements for each unknown beam) to determine the $E_{(L)}$, $s_{(L)}$, Ψ$_{(L)}$, or Φ$_{(L\ )}$for each optical beam of the local oscillator. The cross-reference output of the photoreceiver, $v_{(LS)}(t)$, offers the only means by which to measure these parameters. If the parameters cannot be determined from this output, then an optical fade cannot be ruled out.

[0064]We shall now examine the information which can be gleaned from this output. Define the following functions.

[0065]vl⁡(EL,ES,Δ?,Δψ)=ARL⁢2⁢η⁢EL⁡(t)⁢ES⁡(t)⁢cos⁡(Δ?)⁢cos⁡(Δψ)=ARL⁢⁢PL⁡(t)⁢PS⁡(t)⁢cos⁡(Δ?)⁢cos⁡(Δψ)⁢⁢vQ⁡(EL,ES,Δ?,2⁢ψ_)=ARL⁢2⁢η⁢EL⁡(t)⁢ES⁡(t)⁢sin⁡(Δ?)⁢sin⁡(2⁢ψ_)=ARL⁢⁢PL⁡(t)⁢PS⁡(t)⁢sin⁡(Δ?)⁢sin⁡(2⁢ψ_)(13)
Get Mathematical Equation

[0066]In the homodyne case (Δω is zero), we obtain the following output:

[0067]vLS⁡(t)=2⁢ARL⁢⁢PL⁡(t)⁢PS⁡(t)⁢(cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δφ)+sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δφ))⁢⁢vLS⁡(t)=2⁢vl⁡(EL,ES,Δ?,Δψ)⁢cos⁡(Δφ)+2⁢vQ⁡(EL,ES,Δ?,2⁢ψ_)⁢sin⁡(Δφ)(14)
Get Mathematical Equation
The homodyne output only allows the measurement of one quantity. The output provides only one independent measurement (one equation) whereas a minimum of four are required. In the heterodyne case (Δω is non-zero), the output is:

[0068]vLS⁡(t)=2⁢ARL⁢⁢PL⁡(t)⁢PS⁡(t)⁢(cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)+sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δω⁢⁢t+Δφ))⁢⁢vLS⁡(t)=ARL⁢η⁢EL⁡(t)⁢ES⁡(t)⁢(cos⁡(Δ?)⁢cos⁡(Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)+sin⁡(Δ?)⁢sin⁡(2⁢ψ_)⁢sin⁡(Δω⁢⁢t+Δφ))⁢⁢vLS⁡(t)=2⁢vl⁡(EL,ES,Δ?,Δψ)⁢cos⁡(Δω⁢⁢t+Δφ)+2⁢vQ⁡(EL,ES,Δ?,2⁢ψ_)⁢sin⁡(Δωt+Δφ)(15)
Get Mathematical Equation

[0069]Since sine and cosine waves are orthogonal, the heterodyne receiver provides two independent measurements by mixing down to baseband the Δω radian frequency components. Thus, two outputs are obtained:

[0070]Vl⁡(t)=⟨vLS⁡(t)⁢cos⁡(Δω⁢⁢t)⟩=vl⁡(EL⁡(t),ES⁡(t),Δ?⁡(t),Δψ⁡(t))⁢cos⁡(Δφ⁡(t))⁢⁢VQ⁡(t)=⟨vLS⁡(t)⁢sin⁡(Δω⁢⁢t)⟩=vQ⁡(EL⁡(t),ES⁡(t),Δ?⁡(t),2⁢ψ_⁡(t))⁢sin⁡(Δφ⁡(t))(16)
Get Mathematical Equation

[0071]b. Correlation or Time-Delay Multiplexing

[0072]In many optical sensor applications, the lightwave signal heterodyne-detected by the photodetector system is a composite optical signal formed from the superposition of many individual optical signals. When the receiver lightwave is generated by backscatter, the composite optical signal is the superposition of individual light signals generated by a continuum of reflections of an interrogation light source. The temporal and spatial characteristics of each reflector or reflective region creates a modulation of the interrogation light source. The time-delay, amplitude, polarization and phase states control the backscattered-modulation of these individual optical signals arriving at the photodetector with a unique time-delay interval can be separated into channels which sort the optical signals into time-delay slots or bins. Depending upon how the signals are generated, these channels can represent spatial regions in space or time-delay slots of a time-domain reflectometer mechanism.

[0073]Let an interrogation lightwave source be generated by modulating the amplitude, phase or polarization of a coherent lightwave with a time-structured correlation code, c(t). The correlation code, c(t) can be a series of pulses, chirps, binary sequences or any other type of code which provides the required correlation characteristics. If the lightwave source is: $E_{(SS)}(t)=E_{(SS\ )}$cos(ω$_{(S)}t$) (17) Then an amplitude modulated interrogation source is: $E_{(I)}(t)=\mu_{(A)}c(t)E_{(SS\ )}$cos(ω$_{(S)}t$) (18) Alternatively, a phase modulated interrogation source is: $E_{(I)}(t)=E_{(SS\ )}$cos(ω$_{(S)}t+\mu_{(p)}c(t)$). (19) If c(t) is chosen to be temporally structured properly, then:

[0074]Ri⁡(τ)=⟨Ei⁡(t)⁢Ei⁡(t+τ)⟩≈[ESS22;τ≈00;otherwise(20)
Get Mathematical Equation
c(t) must be chosen so that an a priori decoding/demultiplexing function, d(t), exists such that:

[0075]b⁡(t,τ)=⟨d⁡(t)⁢Ei⁡(t+τ)⟩≈[ξ⁢⁢ESS⁢cos⁡(Δω⁢⁢t+φ);τ≈00;otherwise(21)
Get Mathematical Equation

[0076]For instance, suppose the interrogation wave is: $E_{(I)}(t)=\mu_{(A)}c(t)E_{(ss\ )}$cos(ω$_{(S)}t$) (22) and:

[0077]Rc⁡(τ)=⟨c⁡(t)⁢c⁡(t-τ)⟩≈[1;τ≈00;τ≠0(23)
Get Mathematical Equation
then a valid decoding and temporal and spatial domains demultiplexing function is:

[0078]d⁡(t)=μd⁢C⁡(t)⁢EL⁢cos⁡((Δω+ωS)⁢t+φ)⁢⁢b⁡(t,τ)=⟨d⁡(t-τ)⁢Ei⁡(t)⟩=[μd⁢μA⁢ESS⁢EL2⁢cos⁡(Δω⁡(t-τ)+φ-ωS⁢τ);τ≈00;otherwise(24)
Get Mathematical Equation

[0079]Therefore, delaying the correlation decoding/demultiplexing function d(t) allows demultiplexing of delay multiplexed signals identifiable by speed of propagation and distance of flyback travel. Suppose an optical wave is formed a summation of delayed signals modulated onto the interrogation wave $E_{(I)}(t)$, then the received wave, $E_{(b)}(t)$, is:

[0080]Eb⁡(t)=∑n=1N⁢⁢An⁡(t-τn)⁢μA⁢c⁡(t-τn)⁢ESS⁢cos⁡(ωS⁡(t-τn)+Φn⁡(t-τn))(25)
Get Mathematical Equation

[0081]Then multiplying by the decoding/demultiplexing function, d(t−τ$_{(m)}$), we obtain:

[0082]d⁡(t)=μd⁢c⁡(t)⁢EL⁢cos⁡((Δω+ωS)⁢t+φ)⁢⁢b⁡(t,τm)=⟨d⁡(t-τm)⁢Eb⁡(t)⟩⁢⁢b⁡(t,τm)≈μd⁢μA⁢ESS⁢EL2⁢Am⁡(t-τm)⁢cos⁡(Δω⁡(t-τm)+φ-ωS⁢τm+Φm⁡(t-τm)).(26)
Get Mathematical Equation
Because τ$_{(n\ )}$is unique, the amplitude signal $A_{(m)}$(t−τ$_{(m)}$) and the phase signal Φ$_{(m)}$(t−τ$_{(m)}$) are both extracted from $E_{(b)}(t)$ by multiplying by the decoding/demultiplexing function, d(t−$_{(m)}$). The technique is applicable to a wide variety of other optical signal multiplexing applications. Specifically, the technique can be used to spatially separate optical signals arriving from a

temporally varying time-domain reflectometer optical backscatter process from an array of fiber optic acoustic sensors. (2) Description and Operation of the Rayleigh Optical Scattering and Encoding (ROSE) System

[0083]a. ROSE Optical Phase Sensor Interrogation Enables Sensor Subsystem

[0084]In order to more fully describe the capabilities and new features of the invention, the application of the invention to a subsystem **1**, FIG. 2, of ROSE which launches an interrogation signal onto fiber span **9** and retrieves lightwave back propagation from a continuum of locations along the span. Back propagation mechanisms may include Rayleigh Optical Scattering (ROS) and other effects generated within the optical fiber. Rayleigh Optical Scattering (ROS) in an optical fiber backscatters light incident upon the fiber. The incident light transverses down the optical fiber to the scattering point/region. At the scattering region the incident light is backscattered back up the optical fiber. As the light transverses the round trip optical path (i.e., distance of flyback travel) any disturbance of the fiber which increase or decrease the optical path length will cause the phase of the incident and backscattered light to be modulated. Suppose a pressure is applied to the optical fiber. The pressure elongates the path length of the light transversing the region.

[0085]Refer to FIG. 2. for the following discussion. In the FIGS. like parts correspond to like numbers. Let p(t,z) be pressure applied to the outside of the optical fiber at time, t, and at point or length, z, along the fiber axis. Then if an interrogation optical wave, $E_{(i)}(t)$, generated by laser **3**, passed through optical coupler **4** and modulated by optical modulator **5** is applied to optical coupler **7**, this results in the following output interrogation wave, $E_{(i)}(t)$, being transmitted down the fiber **9**: $E_{(i)}(t)=\mu_{(A)}c(t)E_{(ss\ )}$cos(ω$_{(S)}t$). (27)

[0086]The backscattered wave, $E_{(b)}(t)$, arriving back at an optical coupler **7** from ROSE fiber optic array **9** passes into optical path **11**. The backscattered light which arrives at optical path **11** is the summation of all light backscattered from a continuum of locations along the length of the ROSE fiber optic span **9**. As will later herein be described in detail, fiber **9** has a longitudinal strain component enhancing coating **12**. If r(z) is the reflection density at point or length z along the fiber and CL is the optical wave speed, then the backscattered light after a pressure p(t,z) is applied to fiber is represented mathematically as:

[0087]Eb⁡(t)=?0∞⁢r⁡(z^⁡(t,z))⁢μA⁢c⁡(t-2⁢z^⁡(t,z)cL)⁢⁢ESS⁢cos(ωS⁡(t-2⁢z^⁡(t,z)cL)⁢)⁢ⅆz(28)
Get Mathematical Equation
where:

[0088]z^⁡(t,z)=z+μL⁢?0z⁢p⁡(t,x)⁢⁢ⅆx.(29)
Get Mathematical Equation

[0089]If the distributed reflection, r(z) is essentially independent of the applied pressure, p(t,z) then the backscatter is:

[0090]Eb⁡(t)=?0∞⁢r⁡(z)⁢μA⁢c⁡(t-2⁢z^⁡(t,z)cL)⁢⁢ESS⁢cos(ωS⁡(t-2⁢z^⁡(t,z)cL)⁢)⁢ⅆz.(30)
Get Mathematical Equation

[0091]Since optical path length change caused by the applied pressure, p(t,z) is usually extremely small (on the order of $10^{(\−6\ )}$to $10^{(1\ )}$times an optical wavelength), the backscattered light from each z distance down the fiber arrives at the optical path **11** with a transversal delay, τ(t,z), equal to:

[0092]τ⁡(t,z)≈2⁢zcL.(31)
Get Mathematical Equation

[0093]Therefore, to receive the signal $S_{(1\ )}$backscattered from the fiber region at length-down-the-fiber $z=L_{(1)}$, the correlational multiplexing characteristic of the transmitted interrogation light can be utilized. Multiplication of the total backscattered optical signal by the correlation decoding/demultiplexing function, d(t−τ(t,$z_{(1)}$)), produces an output which contains the signal, $S_{(1)}$, backscattered from a distance $L_{(1\ )}$down the fiber and rejects signals originating from other fiber regions, such as $S_{(2)}$, $S_{(n\ )}$and etc. Representing this process mathematically, the resulting channel output, B(t, $L_{(1)}$) is obtained as follows:

[0094]b⁡(t,τ1)=⟨d⁡(t-τ1)⁢Eb⁡(t)⟩=⟨d⁡(t-2⁢L1cL)⁢Eb⁡(t)⟩=B⁡(t,Li)⁢⁢d⁡(t-2⁢L1cL)=µd⁢c⁡(t-2⁢L1cL)⁢EL⁢cos⁡((Δω+ωs)⁢(t-2⁢L1cL)+φ)⁢⁢Eb⁡(t)=?0∞⁢r⁡(z)⁢µA⁢c⁢(t-2⁢zcL)⁢ESS⁢cos⁢⁢(ωs⁡(t-2⁢z^⁢(t,z)cL))⁢ⅆz⁢⁢Φ⁡(z,L1)=φ-2⁢(Δ⁢⁢ω+ωs)⁢LicL+Δ⁢⁢ω⁢⁢2⁢zcL (32)
Get Mathematical Equation

[0095]B⁡(t,L1)=⁢µd⁢µA⁢EL⁢ESS⁢?0∞⁢r⁡(z)⁢Rc⁡(2⁢(z-L1)cL)⁢cos(Δ⁢⁢ω⁢⁢t+Φ⁢(z,L1)+⁢2⁢µL⁢ωScL⁢?0z⁢p⁡(t,x)⁢⁢ⅆx)⁢⁢ⅆzΔ⁢⁢Φ⁢(t,z)=⁢Φ⁡(z,L1)+2⁢µL⁢ωScL·?0Z⁢p⁡(t,x)⁢⁢ⅆxB⁢(t,L1)=⁢VE⁢?0∞⁢r⁡(z)⁢Rc⁡(2⁢(z-L1)cL)⁢⁢cos⁡(Δ⁢⁢ω⁢⁢t+Δ⁢⁢Φ⁡(t,z))⁢ⅆzB⁡(t,L1)≈⁢VE⁢rL1⁢cos⁡(Δ⁢⁢ω⁢⁢t+ΦL1+2⁢µL⁢ωScL·?0L1⁢p⁡(t⁢,x)⁢ⅆx)(33)
Get Mathematical Equation
Because of the correlation properties of the interrogation light, the autocorrelation function $R_{(c)}$(τ) is very small at all spatial locations except those in the vicinity of z=$L_{(1)}$. Therefore, all signals originating anywhere else are rejected. Furthermore, the phase of the channel output at location $L_{(1\ )}$will be the summation or integration of all pressure changes along the bi-directional transversal path. This unusual phenomenon has been demonstrated with experimental hardware.

[0096]Once the correlation process isolates the optical signal originating from a spatial region, the signal must be phase demodulated to extract the pressure information. The signal is I (in phase) and Q (quadrature phase) demodulated is:

[0097]B1⁡(t,L1)=⁢⟨B⁡(t,L1)⁢cos⁡(Δ⁢⁢ω⁢⁢t)⟩B1⁡(t,L1)≈⁢VE⁢rL1⁢cos(ΦL1+2⁢µL⁢ωScL·⁢?0L1⁢p⁡(t⁢,x)⁢ⅆx⁢)=⁢V1⁢cos⁡(Φ1)BQ⁡(t,L1)=⁢⟨B⁡(t,L1)⁢sin⁡(Δ⁢⁢ω⁢⁢t)⟩BQ⁡(t,L1)≈⁢-VE⁢rL1⁢sin⁡(ΦL1+2⁢µL⁢ωScL·?0L1⁢p⁡(t⁢,x)⁢ⅆx) =⁢-V1⁢sin⁡(Φ1).(34)
Get Mathematical Equation

[0098]Then I & Q, or cosine phase and sine phase outputs are converted into either phase rate or phase outputs with simple analog or digital hardware. The phase, so demodulated, allows the inference of information about the acoustic pressure down the fiber to the measurement point.

[0099]Once the I & Q outputs are generated, the temporal phase state of B(t, $L_{(1)}$) can be determined by one of several types of phase demodulation processes. The phase state of the region of $L_{(1\ )}$spatial delay is therefore:

[0100]Φ1=ΦL1+2⁢µL⁢ωScL·?0L1⁢P⁡(t,x)⁢⁢ⅆx.(35)
Get Mathematical Equation

[0101]Likewise, the plurality (which may be a large number, e.g., 5000) of optical signals arising with spatial delays, such as the propagation time for flyback travel to $L_{(2\ )}$or $L_{(n)}$, can be correlated out of the backscattered signal $E_{(b)}$(t). These are:

[0102]B⁡(t,L2)≈VE⁢rL2⁢cos⁡(Δ⁢⁢ω⁢⁢t+ΦL2+2⁢µL⁢ωScL·?0L2⁢p⁡(t⁢,x)⁢ⅆx)⁢⁢B⁡(t,Ln)≈VE⁢rLn⁢cos⁡(Δ⁢⁢ω⁢⁢t+ΦLn+2⁢µL⁢ωScL·?0Ln⁢p⁡(t⁢,x)⁢ⅆx)(36)
Get Mathematical Equation
With corresponding phase signals of:

[0103]Φ2=ΦL2+2⁢μL⁢ωScL·?0L2⁢p⁡(t⁢,x)⁢ⅆx⁢⁢Φn=ΦLn+2⁢μL⁢ωScL·?0Ln⁢p⁡(t⁢,x)⁢ⅆx.(37)
Get Mathematical Equation

[0104]The phase signals, obtained by phase demodulation of each $B(t,L_{(m)})$, represent a pressure field p(t,z) which is integrated along the length, z, of the fiber. Therefore, rather than directly measure p(t,z) the sensor provides all of the accumulated pressure effects down the fiber to the measurement point, $L_{(m)}$(where m is integer corresponding to the measurement point). In sensor arrays, it is usually desired to detect the pressure over a specific measurement region. If two optical signals $S_{(j\ )}$and $S_{(k\ )}$are received from measurement lengths $L_{(j\ )}$and $L_{(k)}$, the corresponding demodulated phases Φ$_{(j\ )}$and Φ$_{(k\ )}$are:

[0105]Φj=ΦLj+2⁢μL⁢ωScL·?0Lj⁢p⁡(t⁢,x)⁢ⅆx⁢⁢Φk=ΦLk+2⁢μL⁢ωScL·?0Lk⁢p⁡(t⁢,x)⁢ⅆx.(38)
Get Mathematical Equation

[0106]A sensor between the lengths down the fiber of $L_{(j\ )}$and $L_{(k\ )}(L_{(k)}>L_{(j)})$ is formed by subtracting the two phases:

[0107]Φk-Φj=⁢Δ⁢⁢Φkj=⁢(ΦLk+2⁢μL⁢ωScL·?0Lk⁢p⁡(t⁢,x)⁢ⅆx)-⁢(ΦLj+2⁢μL⁢ωScL·?0Lj⁢p⁡(t⁢,x)⁢ⅆx)⁢⁢Δ⁢⁢Φkj=⁢ΦLk-ΦLj+⁢2⁢μL⁢ωScL·(?0Lk⁢p⁡(t⁢,x)⁢ⅆx-⁢?0Lk⁢p⁡(t⁢,x)⁢ⅆx)⁢⁢Δ⁢⁢Φkj=ΦLk-ΦLj+⁢2⁢μL⁢ωScL·?LjLk⁢p⁡(t⁢,x)⁢ⅆx⁢⁢Δ⁢⁢Φkj=Δ⁢⁢ΦLk⁢Lj+2⁢μL⁢ωScL·?LjLk⁢p⁡(t⁢,x)⁢ⅆx.(39)
Get Mathematical Equation

[0108]The resulting sensor is of length ΔL=$L_{(k)}$−$L_{(j\ )}$with a center position of $(L_{(k)}+L_{(j)})/2$. The differencing of phase signals Φ$_{(j\ )}$and Φ$_{(k\ )}$into a new phase signal ΔΦ$_{(kj)}$, allows a virtual sensor of arbitrary position and length to be formed. The resulting spatially differential sensor also adds the advantage of minimizing other effects such as lead-in fiber strum or vibration which create unwanted phase signals.

[0109]The above phenomena illustrates that when the interrogation light is properly encoded, a ROSE (Rayleigh Optical Scattering and Encoding) sensor system is enabled. The subject invention therefore enables the ROSE concept. The subject invention enables spatial discrimination of the optical backscatter effects in a ROSE sensor. The spatial differencing technique rejects unwanted common mode signals inadvertently introduced in fiber leads down to the sensor region. The invention also applies in a similar manner to more conventional fiber optic acoustic sensor arrays (i.e., those having Bragg reflective grating sensors) or to non-fiber optic remote optical sensors which detect phase.

[0110]b. Pointwise Signal Delay Multiplexing

[0111]The invention also applies to point-wise non-distributed sensors or artificially generated multiplexing by electronics means. The interrogation lightwave can be intercepted and retransmitted back to the receiver with an artificial, electronically generated delay, as a means of delay/correlation multiplexing many channels.

(3) Description of a Fiber System Implementation

[0112]The invention can be realized with bulk optical, fiber optical or integrated optical components. For simplicity, a fiber optic implementation will be presented. However, the fiber optic embodiment is being presented without intent of limitation. The teachings of the invention can be used to implement a reflectometer system in accordance with the present invention using these and other instrumentalities providing a light path that has the innate property of producing back propagation of portions of an interrogation signal at a continuum of locations along the length of the propagation path therethrough.

[0113]a. Optical Transmitter and Time-Delay Multiplexing Process.

[0114]FIG. 3 is an illustrative block diagram implemention of the Rayleigh optical scattering and encoding (ROSE) sensor system **2**. Like parts correspond to like numbers. A lightwave from transmitter laser, **3**, is propagated through optical coupler or beamsplitter, **4**. The smaller portion of the transmitter laser power split off by optical coupler, **4**, is passed by optical path, **39**, to the phase locking means optical receiver **35**. The larger portion of the transmitter laser light power is split by optical coupler, **4**, and propagated to optical modulator, **5**. The optical modulator, **5**, modulates the laser light passing from optical coupler, **4**, with correlation code, c(t), as electronically generated in master correlation code generator, **53**, and amplified by amplifier, **49**. The correlation code, c(t), is modulated onto the laser light in optical modulator, **5**. This modulated light comprises the optical interrogation lightwave, $E_{(i)}(t)$. The optical modulator, **5**, may modulate the amplitude, polarization or phase of the laser light subject to the teachings of the invention. The interrogation lightwave is propagated from optical modulator, **5**, to optical coupler, beamsplitter or circulator, **7**. The interrogation lightwave passes through the optical coupler, **7**, into optical fiber or other light propagation medium, **9**. Hereinafter, "down", indicates a transversal on the optical path, **9**, away from coupler, **7**; "up" indicates a transversal on the optical path **9** toward the optical coupler, beamsplitter or circulator, **7**. The interrogation lightwave which transverses down the optical fiber or medium **9** is modulated and is backscattered or returned by other means with equivalent optical path lengths (equivalent to a time delay), $L_{(1)}$, $L_{(2)}$, . . . $L_{(n)}$ corresponding to sensors or multiplexed channels $S_{(1)}$, $S_{(2)}$, . . . $S_{(n)}$. The returned interrogation lightwave is a composite optical signal modulated by signals due to the $S_{(1)}$ through $S_{(n)}$ modulating and time-domain multiplexing actions.

[0115]More particularly, 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.

[0116]One component of this composite signal is comprised of the naturally occurring continuum of optical back reflections (including Rayleigh optical scattering ((ROS)) effects) of the optical spread spectrum carrier signal that is formed by modulating the primary carrier signal by the spectrum spreading signals. Another component is comprised of the artificially occurring optical back reflections, either-point wise reflections or distributed reflections, of the optical spread spectrum carrier signal that is formed due to propagation discontinuities as the result of presence of a fiber cable coupler in span **9**. Still another component comprised of the continuum of modulations at locations along the span of the reflected signals due to longitudinal components of optical path length change, causing a delay in the reflected signal, experienced by the fiber optical span along its length.

[0117]Such optical path length change or delay may be caused by a variety of possible sources including acoustic pressure waves incident to the fiber, electromagnetic fields coupled to the fiber, mechanical strain or pressure on the fiber, thermal strain or pressure induced in the fiber, or other means of causing change in the optical path length. Use of the acoustic pressure waves mode of changing path length in perimeter intrusion monitoring systems is the principle embodiment illustrated herein. In this use, optical fiber span **9** is employed to provide an array of virtual geophones buried at a range of depths beneath the surface of the ground of about between six (6) inches and one (1) foot, to sense motion of an object on the surface of the ground. The acoustic pressure wave sensing mode is also useful to sense seismic signals, as for example as linear arrays inserted into casing structures of an existing oil wells. Predetermined artificial pressure wave producing shocks are imparted into the ground, and the responses from the sensor are used to locate secondary oil deposits. The acoustic pressure wave sensing mode is further useful for employing span **9** as an array of virtual hydrophones, with the media which couples the signals to the hydrophones at least in part being the body of water in which the array is immersed. Such hydrophone arrays find use as naval undersea warfare towed arrays, or towed geophysical exploration arrays. In the latter the arrays respond to artificially produced shocks of predetermined character and location induced in the body of water, and the response of the array to bottom return signals are used to locate ocean bottom geophysical feature indicating likely presence of an oil deposit. Yet further, a sensing position on a fiber span **9** could be used to receive as an input microphonic signals suitably imparted to the region of the sensing position. The electromagnetic field sensing mode of fiber span **9** could be used for monitoring electronic signals along a telecommunication cable's span to localize malfunctions. Responses of fiber span **9** to mechanical, pressure or thermal strains can be used in systems for monitoring such strains.

[0118]The composite lightwave propagates up the optical fiber or medium **9**, passes through optical coupler, beamsplitter or circulator, **7**, to optical pathway, **11**. Optical pathway, **11**, passes the backscattered, time-delay multiplexed, composite lightwave, $E_{(b)}(t)$, to the optical receiver, **15**.

[0119]Preferably, fiber **9** is of the relatively low cost, conventional single-mode or multimode, fiber cable types.

[0120]Further it is preferable that fiber **9** have extruded thereon a coating **12** of a material which enhances the longitudinal strain which the fiber undergoes from a given radially, or generally laterally, applied pressure wave strain. Materials which provide such enhancement include extrudable thermoplastic polymers (TPU's) or extrudable thermoplastic elastomers (TPE's) which exhibit a combination of a low Young's modules (E) and a low Poisson's ratio (s). The Poisson's ration is preferably below 0.5, which is the Poisson's ratio of natural rubber. Examples of such materials include: (i) low density polyethylene, having characteristic E=1.31 dynes/cm$^{(2)}$×10$^{(−10)}$and s=0.445; and (ii) polystyrene, E=3.78 dynes/cm$^{(2)}$and s=0.35 (values as reported in the paper, R. Hughes and J. Javzynski, "Static Pressure Sensitivity Amplification in Interferometric Fiber-Optic Hydrophones," Applied Optical/Vol. 19/No. 1/1 Jan. 1980).

[0121]An alternate embodiment of fiber **9**, albeit involving significantly greater cost per unit length of the fiber, is to provide fiber in the more expensive form of a polarization preserving or single polarization, optical fiber. The polarization preserving fiber of this type holds the backscattering light in a narrow range of polarization states so that a substantially single RF signal **21** enters a single set **23** of correlators, reducing the complexity of the system. However, in cases involving long surveillance lines this alternative embodiment becomes expensive in cost of fiber.

[0122]The correlation code generator **53** creates a signal, c(t), that has a broad bandwidth. The broadband nature of the correlation code is required to obtain the desired properties in the signals autocorrelation function. The calculation and definition of the autocorrelation function of any general signal is well known and defined in signal processing literature. The correlation code signal, c(t), is so structured that its autocorrelation function is highly peaked at zero delay, and is very small away from zero delay. This criterion is well known to those of skill in the art and is the essence of why the correlation code has a broad bandwidth. Any signal that has the desired autocorrelation function properties can be used as the correlation code in the invention. There are many reasons for choosing one correlation code over another: ease of creation; autocorrelation properties; cost of creation hardware; cost of correlation hardware; and effectiveness in producing spread spectrum signal effects. According to the teaching of the invention, the correlation code for the invention can be a binary sequence with a desired transorthogonal autocorrelation property (sometimes called a pseudonoise sequence), a pseudorandom number (PRN) sequence with the such desired autocorrelation property, chirps, or other types of signals which provide correlations code having predicable non-repetitive behavior. The foregoing list of types of sequence signals which may be employed to modulate the carrier lightwave signal includes both "binary pseudonoise sequences" and "pseudorandom number (PRN) sequences." For purposes of construction of this specification and the appended claims, these terms are employed as they are defined under the listings "Pseudonoise (PN) sequence (communication satellite)" and "Pseudorandom number sequence" at pages 747 and 748 of the "IEEE Standard Dictionary of Electrical and Electronic Terms" (Fourth Edition), which listings are hereby incorporated herein by reference. Further for purposes of construction of this specification and the appended claims, it is deemed that "binary pseudonoise sequence" is generic and "pseudorandom number sequence" is a species thereof. Still further for purposes of construction of this specification and its appended claims, both terms are deemed to include analog signal forms of sequences as well as digital signal forms.

[0123]It is to be appreciated that in addition to its correlation encoding function, master correlating code generator **53** is a source of a spectrum-spreading signal comprised of a spectrum-spreading signal which produces an autocorrelation that is well behaved. It has one dominate maxima at zero correlation delay, and its spectrum is large enough to provide sampling of the said optical fiber spatially along the length of the fiber **9** with a resolution commensurate with a sub-length ΔZ of fiber span **9**. These characteristics enable segmentation of an optical fiber **9** of span length L into n segments in accordance with a relationship L<ΔZ·n. (40) In this relationship ΔZ is a segment length of the fiber span whose length is one-half the distance traveled by light propagating through one zero delay temporal time span of the autocorrelation maxima, ΔT, such that $C_{(L)}$is the speed of light in the said optical fiber and ΔT is approximately equal to the reciprocal of the spread signal optical bandwidth.

[0124]An illustrative embodiment of generator **53** is a shift register type pseudorandom number code generator, having n bits, wherein a code is generated that satisfies said resolution sublength and segment length relationship by choosing an appropriate combination of the number of its bits and the clock time.

[0125]The temporal length of the code sequence which is reiteratively produced by generator **53** may be either less than the time period for propagation of a lightwave to the remote end of span and propagation back of a backscattering (i.e. distance of flyback travel), or greater than this time period. It cannot be equal to this period.

[0126]The predetermined timing base employed by the source of the spectrum spreading signals, which determines the length of ΔZ segment is so chosen to provide a positive enhancement to the ratio of the power of back propagating Rayleigh scattering effect $P_{(R)}$ to the power of the forward propagated Rayleigh scattering effect $P_{(T)}$, in accordance with the following equation:

[0127]PrPt⁡[dB]=-70+10⁢log10⁡(Δ⁢⁢L)-Δ⁢⁢Z100.(41)
Get Mathematical Equation

[0128]b. Laser Phase Locking Means.

[0129]Refer to FIG. 3. Local oscillator laser, **45**, generates a local oscillator lightwave. The local oscillator lightwave propagates from local oscillator laser, **45**, to optical coupler or beamsplitter, **43**. The optical coupler, **43**, splits off the smaller portion of power of the local oscillator lightwave into optical pathway, **41**. Optical path, **41**, propagates the smaller portion of the local oscillator lightwave to the phase locking means optical receiver, **35**. The larger portion of the power of the local oscillator lightwave is split off by optical coupler **43**, and passed to optical path **13**. Optical pathway, **13**, propagates the larger portion of the local oscillator lightwave to optical receiver, **15**. The phase locking means optical receiver, **35**, receives and interferes the transmitter laser lightwave from optical pathway, **39**, and the local oscillator lightwave from optical pathway **41**. The receiver **35** interferes the reference lightwaves from lasers **3** and **45** producing an electrical output which is a radio frequency wave on electrical pathway, **33**. The electrical output, **33**, provides an electronic beat frequency which directly indicates the difference in optical frequency and phase between lasers **1** and **45**. Phase locking circuitry **31**, employing a conventional phase lock loop mechanism, controls the difference in frequency between laser **1** and **45** and phase locks the two lasers to a fixed frequency and phase relationship as indicated by the dashed line between circuitry **31** and local oscillator laser **45**. The radian frequency difference is Δω as discussed early in the text. The purpose of the laser phase locking means is to insure that the local oscillator lightwave traveling on optical path, **13**, into optical receiver, **15**, has the proper phase and frequency relationship to the composite lightwave on optical pathway, **11**. It is to be appreciated that the phase locking mechanism also acts cooperatively with phase demodulator system **66** to be described later herein. Conventionally, a common master clock oscillator **311**, FIG. 7 provides the timing base for both phase locking circuitry **31** and an I & Q demodulator **300**, FIG. 7.

[0130]Refer to FIG. 3. The composite lightwave on optical path **11**, is an input into optical receiver **15**. The local oscillator lightwave on optical path, **13**, is also an input into optical receiver, **15**. The local oscillator and composite lightwaves are interfered on photodetectors producing an electronic signal which electronically represents the heterodyned optical interference power between the two lightwaves. The resulting composite radio frequency signal at output, **17**, represents electronically the composite lightwave signal on optical path, **11**. The composite electronic receiver signal is passed from optical receiver output, **17**, through amplifier, **19**, via electronic path, **21**, to the correlator system, **23**. The local oscillator lightwave on optical path, **13**, is interfered with the composite lightwave on optical path **11**. The interference power is photodetected in optical receiver, **15**, by optically interfering the composite back propagating lightwave on the local oscillator signal. As one of the components of this interfering action, there is produced a difference beat signal which is a composite radio frequency representation of the composite light wave on optical path, **11**.

[0131]This interfering of the local oscillator output lightwave **13** and the composite back-propagating CW lightwave **11** provides the translation of signal **11** from the optical domain to a CW radio frequency (r.f.) composite difference beat signal **17**. This reduces the frequency of signal **15** into an electronically processable signal frequency range. It is to be appreciated that an important aspect of the present invention that the r.f. composite difference signal produce by this translation action includes having counterpart components of the aforesaid components of the composite back-propagating lightwave signal, with the phase states of these counterpart r.f. domain signals the same as the phase states of the corresponding components of the back-propagating lightwave.

[0132]In accordance with the present invention, lasers **3** and **45** are to have sufficiently stringent high performance capability with respect to exactness of frequency to enable interference effects therebetween and heterodyne detection of acoustic perturbation signals incident to fiber **9** to produce beat frequencies within the radio frequency (r.f.) range. Also in accordance with the present invention, lasers **3** and **45** have stringent performance criteria with respect to the phase stability, or coherence, of their beams. They are to be substantially coherent over at least a propagation path distance substantially equal to twice the length, L, of sensing fiber **9**. For example, a commercially available non-planar, ring laser (e.g. Lightwave Electronics Corp. Model 125) would be suitable for an intruder sensing perimeter intrusion monitoring fiber **9** having a length of 8.0

km (approximately 5 miles). The laser beam of this commercially available laser, which is in the near infrared range, has a frequency of 227 terahertz, or 1319 nanometer wavelength, and has a frequency stability accurately within one part in a billion over 1 millisecond period, or 5 Kilohertz in a 1 millisecond period.

[0133]It is to be appreciated that the provision of such frequency and phase stability of lasers **3** and **45** enables implementing the phase locking to produce a sufficiently small non-zero radian phase locking circuitry **31**. This in turn enables lasers **3** and **45**, under regulation by phase locking circuitry **31**, to provide a pair of beams which are phase locked and with a "non-zero Δω" sufficiently small to enable a heterodyne-mode optical receiver to provide the desired beat frequency outputs in the r.f. range. It is understood that laser **45**, optical receiver **35**, circuitry **31** and beamsplitter **43** could be replaced with an apparatus applying the non-zero ΔW to the beam from optical pathway **39** to give the same result. The returned interrogation optical composite wave is defined in the preceding subsection **3**(*a*) "Optical Transmitter and Time-delay Multiplexing Process" of this DESCRIPTION OF THE PREFERRED EMBODIMENT.

[0134]In the preceding section (1) "Description of Underlying Theories" of this DESCRIPTION OF THE PREFERRED EMBODIMENT there is a definition of "non-zero Δω" and a mathematical demonstration of its importance in the heterodyne mode of interfering. It makes it possible to use relatively simple processes to avoid fading. By way of contrast, fading with the "zero Δω" homodyne mode of interfering would entail much more difficult and less effective fade avoidance processes.

[0135]c. Correlation Time-Delay Demultiplexing.

[0136]Refer to FIG. 3. The composite radio frequency signal on electrical path, **21**, is input into the correlator system, **23**. The correlator system delays the master correlation code generator output, **51**, an appropriate amount and correlates the delayed correlation code with the composite radio frequency signal. This produces electrical outputs $O_{(1)}$,$O_{(2)}$. . . $O_{(n)}$corresponding to signals $S_{(1)}$,$S_{(2)}$. . . . $S_{(n)}$, in turn corresponding to spatial delays $L_{(1)}$, $L_{(2)}$. . . $L_{(n)}$. The spatial delays $L_{(1)}$,$L_{(2)}$. . . . $L_{(n)}$are arbitrary and programmable. The electrical output $O_{(1)}$corresponds to $B(t,L_{(1)})$ referred to in the preceding subsection **2**(*a*).

[0137]The correlation process is well understood in the literature. The signal that represents the backscattered optical wave in array, **9**, that is passed from the optical receiver **15**, to the correlator system **23**, contains all of the information for all sensors or channels $S_{(1)}$,$S_{(2)}$. . . . $S_{(n)}$at once on the electronic signal path **21** entering the correlator **23**. Because the backscattered composite signal is modulated with the correlation code by modulator **5**, the backscattered light is time structured with the time structure of the correlation code. Because the correlation code is selected to have special autocorrelation code properties, the time structure of the correlation codes allows an electronic representation of the backscattered light at positions $L_{(1)}$,$L_{(2)}$. . . . $L_{(n)}$to be obtained via the correlation process in the correlator **23**. In a preferred embodiment of the invention the master code generator **53** is a shift register type pseudorandom number (PRN) code generator and each correlator of the set **23** would be a correlation type demodulator herein later described in greater depth. Code generator **53** may alternatively be embodied as a binary sequence having transorthogonal autocorrelation properties (binary pseudonoise sequence) and each correlator would then be a correlation-type demodulator for demodulating a binary pseudonoise sequence, whose implementation would be understood by those of skill in the art. The correlator uses the reference correlation code from correlation code generator, **53**, which is passed via electronic path **51** to the correlator, **23**, as a "golden ruler" enabling sorting out by temporal and spatial domain demultiplexing electronic representations of the backscattering optical signals at sensors or channels $S_{(1)}$,$S_{(2)}$. . . $S_{(n)}$. Various delayed versions of the correlation code are multiplied by the composite signal with all of the sensor or channel signals present simultaneously, from electronic path **21** so that the electronic representations of the sensors or channels $S_{(1)}$,$S_{(2)}$. . . $S_{(n)}$are output from the correlator, **23** on signals $O_{(1)}$,$O_{(2)}$. . . $O_{(n)}$with respect to the index.

[0138]Correlator system **23** is an electronic spread spectrum signal de-spreader and temporal and spatial domain de-multiplexer of the r.f. signal counterpart to the optical composite signal. Its input is coupled to the amplified output **21** of the heterodyner and photodetector, and it is operative in cooperation with said source of spectrum spreading signals to perform a coherent signal correlation process upon the r.f. counterparts of the aforesaid "one" and the aforesaid "still another" components of the composite back-propagating CW lightwave. This causes the de-spreading of the r.f. counterpart of the optical reflected spread spectrum signal and causes the temporal and spatial demultiplexing of the r.f. counterpart of the "still another" component of the composite r.f. signal. This processing provides signals which temporally and spatially sort the said "still another" component into n virtual sensor signal channels, or stated another way n of each of the ΔZ length measurement regions, measuring the induced optical path change at each of the n ΔZ-length segments of the optical fiber span **9**.

[0139]It will be appreciated that this sorting process is accomplished by the autocorrelation properties of the spectrum-spreading signal and by the time of flight of the optical spectrum-spreading signal down to each nth reflection segment and back to the heterodyne optical receiver **15**. A delayed replica of the spectrum-spreading signal is correlated against the r.f. signal counterpart of the optical composite back-propagating signal, thereby segmenting the optical fiber into n independent segments, or virtual sensors, via the time of flight of the optical composite back-propagating signal and the autocorrelation function of the transmitted spectrum-spreading signal.

[0140]It is to be appreciated that system **2** is operating in the spread spectrum transmission and reception mode. Namely, by providing optical interrogation light wave, $E_{(1)}(t)$, with modulation by the correlation code, c(t), the continuous wave carrier signal is temporally structured into a spread spectrum interrogation lightwave which continuously reiterates autocorrelatable code sequences. Then after correlation system provides an appropriate time of delay the correlator system **26** correlates the backscattered light wave $E_{(b)}(t)$ with the same output, c(t), of code generator **53**, de-spreading the spread spectrum signal.

[0141]In accordance with well known communication electronics theory this has the effect of increasing signal output of the ROSE sensor system while the noise bandwidth remains the same. In temporally and spatially sorting the r.f. counterpart of the aforesaid "still another" component of the composite back-propagation lightwave, the aforesaid "another" component of undesired noises, such as reflections from couplers in fiber span **9**, are materially attenuated.

[0142]More particularity, in accordance with this well known theory, the signal-to-noise ratio (SNR) is enhanced by considerable attenuation of noise mechanisms in frequency ranges outside of center frequency lobe of the autocorrelation function and outside the pair of first side lobes to one and the other side of the center frequency lobe.

[0143]An illustrative embodiment of electronic spread spectrum signal de-spreader and spatial de-multiplexer for cooperation with the previously described shift register type PRN code generator may comprise a series of n like-shift register code generators respectively receiving the spectrum spreading signal through a corresponding series of n feed channels which cause delays which incrementally increase by an amount of time bearing a predetermined relationship to the fiber span length, and $C_{(L)}$, the speed of light through the fiber. The composite r.f. signal is fed to a corresponding series of n multipliers connected to receive as the other multiplier the codes generated by the respective de-spreader and demultiplexer to thereby provide the de-spread and de-multiplexed signal.

[0144]d. Heterodyne Phase Demodulation.

[0145]Refer to FIG. 3. After the composite radio frequency signal on electrical path **21** is correlation time-delay demultiplexed by the correlator system, **23**, the plurality (which upwardly may include a very large number, for instance 5,000) of outputs $O_{(1)}$, $O_{(2)}$. . . $O_{(n)}$, on the plurality of electrical paths **61**, **63** and **65** respectively are phase demodulated by a plurality of individual phase demodulations in the phase demodulator system, **66**. The outputs of the phase demodulator system, **66**, are the corresponding plurality of electrical paths **71**, **73**, and **75**. The phase demodulator outputs **71**, **73**, and **75** correspond to the correlator outputs ($O_{(1)}$, $O_{(2)}$. . . $O_{(n)}$) **61**, **63** and **65** respectively, and to the corresponding plurality of corresponding signals $S_{(1)}$, $S_{(2)}$. . . $S_{(n)}$ respectively corresponding to spatial delays $L_{(1)}$, $L_{(2)}$. . . $L_{(n)}$ respectively. The outputs **71**, **73**, and **75** electronically indicate (with tens of kilohertz potential bandwidth) the phase states of optical signals $S_{(1)}$, $S_{(2)}$. . . $S_{(n)}$. In particular, output **71** is proportional to the temporal phase Φ$_{(1)}$ of B(t, $L_{(1)}$) hereinbefore discussed in subsections 1(b) "Correlation or Time-delay Multiplexing" and 3(c) "Correlation Time-Delay Demultiplexing" of this DESCRIPTION OF THE PREFERRED EMBODIMENT. The phase demodulator outputs **73** and **75** indicate the temporal phase states Φ$_{(2)}$ and Φ$_{(n)}$ of B(t,$L_{(2)}$) and B (t,$L_{(n)}$) respectively.

[0146]e. Fading Free Polarization Processing

[0147]Preferably system **2** further includes polarization signal characteristic processing functions (not shown), which are used together with the previously described feature that the heterodyning function provides in reducing fading, of the backscattering signal, $E_{(b)}(t)$. These polarization processing functions are disclosed in the commonly assigned U.S. Pat. No. 6,043,921 entitled "Fading-Free Optical Phase Rate Receiver," hereby incorporated herein in its entirely. The optical heterodyning feature which provides benefit in reducing fading includes: (i) cooperation of phase locked lasers **3** and **45** in the formation of the optical interrogation light wave, $E_{(1)}(t)$, applied to optical fiber **9**, or other linearly extended light propagation medium producing Rayleigh effects backscattering, and (ii) the manipulation of this by optical receiver **15** to provide the composite electronic receive signal as optical receiver output **17**. This takes advantage of the feature of more favorable Heterodyne fading conditions in a way, in which polarization and phase state signal fading is materially reduced in the detected backscattered light wave $E_{(b)}(t)$. The electronic decoding module 700 of U.S. Pat. No. 6,043,921 is substantially an equivalent to the correlator system herein. However, the system disclosed in U.S. Pat. No. 6,043,921 for implementing polarization fading reduction (if not substantially eliminating fading) is a generalized stand alone system for processing any optical phase signal having temporally varying polarization, phase, and phase frequency. It must be adapted for application to system **2** by appropriate integration into system **2** included the two following alternative approaches.

[0148]One approach for such adaptation passes the fade-free optical phase rate (FFOPR) photoreceiver RF signal to the correlator **23**, performs the correlation on the RF signal and completes the Phase Demodulation by In phase and Quadrature phase (hereinafter I & Q) demodulating the correlated RF signal into outputs. This method creates low bandwidth I & Q components and therefore requires low bandwidth analog-to-digital converters (implying a requirement for a large number of analog RF correlation electronic components). This RF correlator approach requires two correlator circuits for every virtual sensor element, or spatial channel, along fiber **9**. One correlator is needed for the vertical polarization RF signal path and one correlator is needed for the horizontal polarization RF signal path.

[0149]Another approach applies the I & Q demodulator of FIG. 7 of the U.S. Pat. No. 6,043,921 prior to correlation. This approach therefore correlates a wideband set of four I & Q signals. One I, Q, set is for horizontal polarization and the other I, Q, set is for the vertical polarization. In this case the I & Q signals are the I & Q signals for the whole virtual array rather than for one virtual sensor element of the array. Four correlators are required for each sensor element. One correlator is applied to each of the four wide bandwidth I & Q signals for each virtual sensor element. This second approach requires very wideband analog-to-digital converters, but allows digital correlators to be used instead of analog RF correlators. The RF correlator or first approach requires far more analog to digital converters and RF electronics. The digital correlator approach enables the correlators to be implemented by the digital approaches of massively integrated logic circuits and/or programmed processors, requiring far more digital logic, but substantially reducing the r.f. electronics and number analog-to-digital converter units in the system.

[0150]f. Phase Differencing

[0151]Refer to FIG. 3. The plurality (which upwardly may include a very large number, for instance 5,000) of signals indicating the phase states Φ$_{(1)}$, Φ$_{(2)}$. . . Φ$_{(n)}$on electrical paths **71**, **73** and **75**, respectively, are input into the phase differencer, 99. The phase differencer forms a corresponding plurality of outputs **91**, **93** and **95** which are arbitrarily and programmably assigned as the subtractions of any two pairs of phase signals Φ$_{(j)}$and Φ$_{(k)}$(where j and k are selected from 1, 2 . . . n).

[0152]Each of the programmably selectable pairs of differenced phase signals form a signal ΔΦ$_{(kj)}$which is spatially bounded within the region of the fiber between lengths $L_{(j)}$and $L_{(k)}$. The phase differencer therefore produces differential phase outputs corresponding to a set of programmable length and position virtual sensors.

[0153]Stated another way, each programmable selection of pairs of phase signals forms a virtual spatial differential sensor which senses the difference between the phases of the Δω output of the photodector sub-system (which is the subject of the next subsections) in receiver **15**. Each Δω is an r.f. difference beat signal representative of the aforesaid "still another" component of the composite back-propagating CW lightwave signal which passes from the launch end of fiber span **9** to directional coupler **7**. These signals from each pair therefore represent signals of virtual spatial differential sensors along fiber span **9**. As a result of the choice of pairs being selectively programmable these virtual sensor can be employed to implement adaptive apertures in processing signal incident the fiber span. This feature would be useful, for example, in enabling security system operators to classify objects causing acoustic pressure wave signals incident up a fiber span **9** used as a perimeter intrusion monitoring line.

[0154]g. Optical Detector Sub-System.

[0155]The optical receivers **15** and **35**, FIGS. 3, **4** and **5**, are comprised of photodetector sub-systems. Any of the many well known photodetecting techniques and devices may be employed. Possible implementation of the photodetection sub-systems will now be discussed.

[0156]Refer to FIG. 4. Like parts correspond to like numbers. Optical signals enter the photodetector sub-system via optical paths **101** and **103** which are extensions of the paths **11** and **13** in the case of receiver **15**, and (not shown) of paths **39** and **44** in the case of subsystem **35**. The optical signals are equally split by optical coupler or beamsplitter, **105**. The optical signal on path **107** is composite signal comprised of half the optical power of path **101** and half of the optical power arriving on pate **103**. The optical signal on path **107** is illuminated on optical detector **111**. The photo-current of optical detector **111** flows into electrical conductor **115**. Likewise, the optical signal on path **109** is comprised of half the optical power on path **101** and half of the optical power on path **103**. The optical signal on path **109** is illuminated on optical detector **113**. The photo-current of optical detector **113** flows out of electrical conductor **115**. Therefore the photo-currents of optical detectors **111** and **113** are subtracted at electrical conductor or node **115**.

[0157]Photo-detectors **111** and **113** are precisely matched in responsivity. The differential photocurrent on electrical conductor **115** is input into pre-amplifier **117**, amplifier and is passed to electrical output **119**. The differential nature of the photo-detection rejects either of the self-optical interference power of the signals on paths **101** and **103** and receives only the cross-interference power between the two optical signals on paths **101** and **103**. This particular optical detector architecture is called a balanced heterodyne optical detection scheme. The scheme is 3 dB more sensitive than all other heterodyne optical detection methods and offers the distinct advantage of rejecting local oscillator noise.

[0158]Refer to FIG. 5. FIG. 5 illustrates an alternative photo-detection scheme to FIG. 4. lightwaves enter the receiver at paths **101** and **103**. The optical coupler or beamsplitter **105** combines the lightwaves on paths **101** and **103** into a composite lightwave on path **107**. The composite lightwave on path **107** illuminates optical detector **111**. The photo-current of optical detector caused by the self-interference and cross interference of lightwaves originating from optical paths **101** and **103** passes through conductor **115***a*, is amplified by pre-amplifier **117** and is passed to electrical output **119**.

[0159]The optical detector sub-system of FIGS. 4 and 5 correspond to optical receivers **15** or **35** of FIG. 3. Paths **101** and **103** correspond to **11** and **13** and output **119** corresponds outputs **17** in optical receiver **15**. Paths **101** and **103** correspond to **39** and **41** and output **119** corresponds to output **33** in optical receiver **35**. Either of the photo-detection schemes of FIG. 4 or **5** can be used for the optical receivers **15** or **35**. However, the photodetection scheme of FIG. 4 is preferred.

[0160]h. Programmable Correlator System

[0161]Refer to FIG. 6. The composite radio frequency signal, or r.f. composite reference beat signal, which electronically represents the received time-delay multiplexed optical signal, or composite back-propagation CW lightwave, $E_{(b)}(t)$, is input into the correlator system, **23**, at electrical input **21**. The composite radio frequency signal is n-way split with power splitter **203** into a plurality (which upwardly may include a very large number, for instance 5,000) of electronic pathways including **211**, **213** and **215**. The master correlation code, c(t), is input into the correlator system, **23**, at electrical input **54**. The correlation code is distributed to such a plurality of programmable delay circuits including **221**, **223** and **225**. Each programmable delay circuit delays the master correlation code by the delay required to decode/demultiplex each time-delay multiplexed channel. The plurality of programmable delay circuits including **221**, **223** and **225** output a plurality of delayed correlation codes including those on electrical pathways **231**, **233**, and **225** respectively. The corresponding plurality of delayed correlation codes including those on electrical pathways **231**, **233** and **235** are multiplied by a corresponding plurality of multipliers (or balanced mixers) including **241**, **243** and **245**, respectively, by the radio frequency signal on the plurality of electronic pathways including **211**, **213** and **215** which are amplified by a corresponding plurality of amplifiers including **261**, **263** and **265**, respectively, to produce the corresponding plurality of outputs including $O_{(1)}$, $O_{(2)}$, and $O_{(n\ )}$(on lines **61**, **63** and **65**) respectively. Each of the outputs therefore produces the corresponding demultiplexed signal which is time-gated by the corresponding time-delay of the correlation code. The correlator system **23** of FIG. 6 is an example implementation of the correlation system, **23**, of FIG. 3.

[0162]The output $O_{(1\ )}$corresponds to signal $B(t,L_{(1)})$ which is hereinbefore discussed in subsections 2(a) "ROSE Optical Phase Sensor Interrogation Enables Sensor System" and 3(c) "Correlation Time-Delay Demultiplexing" of this DESCRIPTION OF THE PREFERRED EMBODIMENT. The output $O_{(1)}, O_{(2)} \ldots O_{(n)}$ on lines **61**, **63** and **65**, respectively, correspond to signals $S_{(1)}, S_{(2)} \ldots S_{(n)}$ which in turn are based upon the spatial delay associated with distance $L_{(1)}, L_{(2)}, \ldots, L_{(n)}$ indicated in FIG. 3. These spatial delays are based on the time of propagation for flyback travel along these distances, which are arbitrary and programmable. The time delay multiplexing of the optical signals comprising the composite back-propagating optical signal on path **11**, FIG. 3, arise from a plurality (which upwardly may include a very large number, for instance 5,000) of spatial locations causing a like plurality of time-delays. The correlator system spatially separates the components of the r.f. composite difference beat signal into channels which each uniquely represent an optical signal at a single spatial location.

[0163]The correlator system allows the spatial sampling of the optical signals so that a virtual array can be formed along the fiber span **9** on FIG. 3.

[0164]i. Phase Demodulation System

[0165]The embodiment of phase demodulator system, **66**, of FIG. 3, has two uses in system **2**. It either: (i) receives the outputs of the just described r.f. correlator subsection **23**, or (ii) is part of the integration of the polarization fading reduction system of U.S. Pat. No. 6,043,921 (as discussed in the preceding subsection 2(*e*) "Fading-Free Polarization Processing" of this DESCRIPTION OF THE PREFERRED EMBODIMENT. Refer to FIG. 7. The phase demodulation system, **66**, is comprised of a plurality (which upwardly may include a very large number, for instance 5,000) of phase demodulators, **81**, **83** and **85**. The inputs to the plurality of phase demodulators, **61**, **63** and **65** (the correlator outputs $O_{(1)}, O_{(2)} \ldots O_{(n)}$ discussed previously) are phase demodulated with phase demodulators **81**, **83** and **85** respectively. The outputs of these demodulators are passed on electrical pathways **71**, **73** and **75** respectively.

[0166]Refer to FIG. 8. An example block diagram of any one of the just discussed phase demodulators **81**, **83** and **85** is shown as part **300**. The input electrical path **301** corresponds to any one of electrical path **61**, **63**, **65**, etc. of the plurality of phase demodulators. The output electrical path **319** corresponds to any one of electrical path **71**, **73**, **75**, etc. of the plurality of phase demodulators. A correlation system output such as $O_{(1)}$, $O_{(2)}$ or $O_{(n)}$ is passed via electrical path **301** into a bandpass filter **303**. The bandpass filter **303** passes only a band of radian frequencies in the vicinity of Δω so that only $B(t,L_{(m)})$ passes through the filter (where m is an integer corresponding to the particular channel). The band passed signal passes from **303** via electrical path **305** to amplitude control **307**. Amplitude control **307** is either an analog automatic gain control circuit, an electronic clipper circuit, or a combination thereof. The amplitude control **307** removes amplitude variations due to polarization fading or other types of signal fading. Because the signal, $B(t,L_{(m)})$ is a result of a heterodyne interference, the phase remains the same after clipping. It is to be appreciated that other phase demodulation schemes for fiber optic signals use a phase carrier technique which does not allow the clipping operation. Clipping is a preferred amplitude control mechanism. The amplitude control **307** passes an amplitude stabilized signal via electrical path **309** to I & Q demodulator **311**. The I & Q demodulator removes the carrier, that is it shifts the center radian frequency of the amplitude stabilized $B(t,L_{(m)})$ from Δω down to zero. The I & Q demodulator outputs a voltage proportional to cos(Φ$_{(m)}$) on electrical path **313** and a voltage proportional to sin(Φ$_{(m)}$) on electrical path **315**. The cos(Φ$_{(m)}$) and sin(Φ$_{(m)}$) proportional voltages on electrical paths **313** and **315** respectively are converted in an output signal proportional to Φ$_{(m)}$ on electrical path **319** by the phase detector **317**.

[0167]Reviewing the previous discussion, the plurality of phase demodulators **81**, **83** and **85** of FIG. 7 each function like the block diagram of **300** on FIG. 8. The plurality (which upwardly may include a very large number, for instance 5000) of phase demodulators **300** convert to a like plurality of signals $B(t,L_{(1)})$, $B(t,L_{(2)}) \ldots B(t,L_{(n)})$ into a like plurality of signals proportional to Φ$_{(1)}$, Φ$_{(2)}$ . . . Φ$_{(n)}$ which correspond to optical signals $S_{(1)}, S_{(2)} \ldots S_{(n)}$.

[0168]j. I & Q Demodulator.

[0169]An example implementation of the I & Q demodulator **311** of FIG. 8 will now be presented. Refer to FIG. 9. An amplitude stabilized $B(t,L_{(m)})$ signal (originating from the amplitude control **307** of FIG. 8) is passed on electrical path **309** to a power splitter **403**. Half of the signal power exiting from power splitter **403** is passed to analog mixer, balanced mixer, Gilbert cell or analog multiplier **413** via electrical path **411**. The other half of signal power exiting form power splitter **403** is passed to analog mixer, balanced mixer, Gilbert cell or analog multiplier **423** via electrical path **421**.

[0170]The reference oscillator **451** generates an electronic wave proportional to cos(Δωt). As noted earlier herein, this reference oscillator is also the oscillator employed in the conventional phase lock mechanism establishing the fixed phase relationship between the frequencies of primary laser **3** and local oscillator laser **45** whose differences in frequency, ΔW, are of a very low order. In accordance with known principles of heterodyning lightwaves having fixed phase relationships, heterodyning these signals can produce a difference beat signal small enough to be in the r.f. signal range, but with the frequency difference sufficiently high to provide the heterodyning with a band pass allowing transforming a given binary code rate into corresponding code components of the beat signal, such as the code rate of the PRN code sequence produced by PRN code generator **53**. This reference oscillator wave is passed from the reference oscillator **451** via the electrical path **453** to amplifier **455**. The wave is amplified by amplifier **455** and passed to hybrid coupler **459** via electrical path **447**. The hybrid coupler splits the amplified reference oscillator electronic wave into two components one proportional to cos(Δωt) on electrical path **417** (providing the "I", or In-phase reference); and one proportional to sin(Δωt) on electrical path **427** (providing the "Q", or Quadrature-phase reference).

[0171]The In-phase reference on electrical path **417** is multiplied (or frequency mixed) with the signal on electrical path **411** by multiplier **413** to produce the output on electrical path **415**. The signal on electrical path **415** is amplified by amplifier **431** and passed to electronic lowpass filter **435** via electrical path **433**. The lowpass filter **435** removes high frequency components of the multiplication or frequency mixing process and results in an output at electrical path **313** which is proportional to cos(Φ$_{(m)}$).

[0172]The Quadrature-phase reference on electrical path **427** is multiplied (or frequency mixed) with the signal on electrical path **421** by multiplier **423** to produce the output on electrical path **425**. The signal on electrical path **425** is amplified by amplifier **441** and passed to electronic lowpass filter **445** via electrical path **443**. The lowpass filter **445** removes high frequency components of the multiplication or frequency mixing process and results in an output at electrical path **315** which is proportional to sin(Φ$_{(m)}$).

[0173]k. Phase Detector

[0174]Example implementations of the phase detection **317** of FIG. 8 will now be presented. Refer to FIG. 10. An example digital phase detector implementation, **317**, is shown in the block diagram. The signal proportional to cos(Φ$_{(m)}$) on electrical path **313** is converted to a digital code or number by analog-to-digital converter (hereafter, A/D) **513**. The digital number proportional to cos (Φ$_{(m)}$) is input into the digital signal processor **501** via electrical path **515**. The signal proportional to sin (Φ$_{(m)}$) on electrical path **315** is converted to a digital code or number by A/D **523**. The digital number proportional to sin(Φ$_{(m)}$) is input into the digital signal processor, **501**, via electrical path **525**. The digital signal processor converts the numbers proportional to sin (Φ$_{(m)}$) and cos (Φ$_{(m)}$) into a number proportional to Φ$_{(m)}$ as follows.

[0175]Suppose the constant of proportionality for the sin(Φ$_{(m)}$) and cos (Φ$_{(m)}$) is V$_{(m)}$. Then the digital signal processor can optimally select estimates of Φ$_{(m)}$ and V$_{(m)}$ to minimize the calculated error function: ϵ([circumflex over (Φ)]$_{(m)}$,*[circumflex over (V)]*$_{(m)}$)=((*V*$_{(m)}$cos(Φ$_{(m)}$)−*[circumflex over (V)]*$_{(m)}$cos([circumflex over (Φ)]$_{(m)}$))$^{(2)}$+(*V*$_{(m)}$sin(Φ$_{(m)}$)−*[circumflex over (V)]*$_{(m)}$sin(Φ$_{(m)}$))$^{(2)}$) (42)

[0176]The digital signal processor can also calculate Φ$_{(m)}$ directly by taking the inverse tangent function or the inverse cotangent function:

[0177]Φm=a⁢⁢tan⁡(Vm⁢sin⁡(Φm)Vm⁢cos⁡(Φm))=a⁢⁢cot⁡(Vm⁢cos⁡(Φm)Vm⁢sin⁡(Φm))(43)
Get Mathematical Equation

[0178]If desired, the digital signal processor can also implement the differentiate and cross multiply (hereafter DCM) algorithm. The DCM method is as follows. The digital representation of the signals proportional to sin (Φ$_{(m)}$) and cos(Φ$_{(m)}$) are temporally differentiated and cross multiplied by the non-differentiated signals. The result U$_{(m)}$(t) is integrated to produce the desired output, Φ$_{(m)}$. Mathematically, this algorithm is:

[0179]Um⁡(t)=⁢Vm⁢sin⁡(Φm)⁢∂∂t⁢(Vm⁢cos⁡(Φm))-⁢Vm⁢cos⁡(Φm)⁢∂∂t⁢(Vm⁢sin⁡(Φm))Um⁡(t)=⁢Vm2⁡((cos⁡(Φm))2+(sin⁡

(Φm))2)⁢∂Φm∂tUm⁡(t)=⁢Vm2⁢∂Φm∂tΦm=⁢1Vm2⁢?Um⁡(t)⁢∂t.(44)
Get Mathematical Equation
The digital signal processor **501** converts the signals arriving on electrical paths **515** and **525** into a digital output proportional to Φ$_{(m)}$on electronic path **503**. Optionally, the digital output is passed on electronic path **505** to some other data sink such as a computer memory. The digital signal proportional to Φ$_{(m)}$on electronic path **503** is converted back to an analog signal on electrical path **319** by digital-to-analog converter **507**. By way of a summarization, the example digital phase detector **317** accepts inputs **313** and **315** which originate from the I & Q demodulator, **311**, of FIG. 8, and the digital phase detector **317** outputs the phase signal Φ$_{(m)}$on electrical path **319**. Optionally, any of other well-known implementations of digital phase detectors may be employed.

[0180]Refer to FIG. 11. An example analog phase detector implementation, **317**′ is shown in the block diagram. The example analog phase detector **317**′ shown in FIG. 11 implements an analog version of the DCM algorithm discussed in the previous text. The signal proportional to cos (Φ$_{(m)}$) on electrical path **313** is input into analog temporal differentiator **613** and analog multiplier **617**. The signal proportional to sin(Φ$_{(m)}$) on electrical path **315** is input into analog temporal differentiator **623** and analog multiplier **627**. The differentiated cosine term on signal path **625** is multiplied by the sine term on electrical path **315** by analog multiplier **627** producing the signal on electrical path **629**. The differentiated sine term on electrical path **615** is multiplied by the cosine term on electrical path **313** by analog multiplier **617** producing the signal on electrical path **619**. The signals on electrical paths **619** and **629** are applied as inputs to differential summer **631**. The output of differential summer on electrical path **633**, which is the result of the differentiated sine and cosine product being subtracted from the differentiated cosine and sine product, corresponds to $U_{(m)}(t)$ of the DCM discussion. The signal on electrical path **633** is integrated by analog integrator **635** to produce the analog phase detector output proportional to Φ$_{(m)}$on electrical path and output **319**. By way of summarization, the example analog phase detector **317** accepts inputs **313** and **315** which originate from the I & Q demodulator **311** of FIG. 8, then the analog phase detector outputs the phase signal Φ$_{(m)}$on electrical path **319**. Optionally, any of other well-known implementations of analog phase detectors may be employed.

[0181]1. Programmable Phase Difference

[0182]The example programmable phase differencer implementation shown as part **99** of FIG. 12 corresponds to part **99** shown as a block in FIG. 3. Refer to FIG. 12. The plurality (which upwardly may include a very large number, for instance 5,000) of demodulated signals proportional to optical signal phases Φ$_{(1)}$, Φ$_{(2)}$, . . . Φ$_{(n)}$are input into the programmable phase signal switching and routing network **701** via electrical paths **71**, **73** and **75**, respectively. Network **701** programmably selects on a basis of timed relation to code generator **53** and routes on a basis of conventional "hold-in memory" and "transfer-from-memory", a plurality (which upwardly may include a very large number, for instance 5,000) of pairs of phase signals onto a plurality (which upwardly may include a very large number, for instance 5,000) of pairs of electronic paths **711** and **713**, **731** and **733** and **751** and **753**. The plurality of routed pairs of phase signals are applied to the corresponding of subtracters **715**, **735** and **755** as shown on FIG. 12. The plurality of phase pairs on electronic pairs of paths **711** and **713**, **731** and **733**, and **751** and **753** are subtracted by subtracters **715**, **735** and **753**, respectively, and the differential signal are outputted on a corresponding plurality of electrical paths **91**, **93** and **95** respectively. The following description focuses on the differencing channel output on electrical path **91**, it being understood that the modes of operation of other differencing channels in network **701** are the same. Programmable phase switching and routing network **701** selects one of the phase signals on one of the plurality of electrical paths **71**, **73** or **75** and routes the signal to electrical path **711**. The signal on electrical path **711** is selected to be proportional to Φ$_{(j)}$(where j is of the set 1,2 . . . n). Network **701** also selects another of the phase signals on one of the other of the plurality of electronic paths **71**, **73** or **75** and routes the signal to electrical path **713**. The signal of electrical path **713** is selected to be proportional to Φ$_{(k)}$(where k is of set 1,2 . . . n). The signal on electrical path **711** is subtracted from the signal on electrical path **713** by subtracter **715**. The output of subtracter **715** is passed on via electrical path **91** and is proportional to ΔΦ$_{(kj)}$hereinabove discussed in subsection 3(f) "Phase Differencing" of this DESCRIPTION OF THE PREFERRED EMBODIMENT. Employing this mode, network **701** programmably makes selection from optical signal phases Φ$_{(1)}$, Φ$_{(2)}$, . . . Φ$_{(n)}$to provide other differential phase outputs on electrical paths **91**, **93** and **95**. This may include a very large number of differential phase signals, for instance 5000. As an alternative to the just described type of circuitry employing subtracters **715**, **735** and **755** any of other well-known forms of producing a differential signal my be employed.

[0183]m. An Alternative Viewpoint of the Partitioning of System **2**.

[0184]As an alternative to the viewpoint inferable from the preceding sequence discussing FIG. 3, system **2** may be considered as partitioned into: (i) an optical network for illuminating an optical fiber sensing span, or other light propagation medium sensing span, and retrieving back propagating portions of the illumination; and (ii) a photoelectronic network for establishing virtual sensors at predetermined locations along the span and picking up external physical signals incident to, or impinging upon, the sensors.

[0185]In general, the optical network for the illumination of, and for the retrieval of back-propagation from, fiber span **9** comprises transmitter laser **3**, directional optical coupler **7**, and optical fiber, or other light propagation medium **9**.

[0186]The photoelectronic network for establishing virtual sensors and picking up signals therefrom generally comprises two subdivisions. One subdivision provides a cyclically reiterative autocorrelatable form of modulation of the lightwave illuminating fiber span **9**. This modulation is in the form reiterated sequences having autocorrelatable properties. The other subdivision takes the retrieved back propagation and performs a heterodyning therewith to obtain an r.f. beat signal. It then picks up the signal from the virtual sensors by autocorrelation and further processes it into more useful forms.

[0187]In general, the subdivision providing the cyclical reiterative modulation of sequences illuminating fiber span **9** comprises master correlation code generator **53** (via one of its electrical pathway outputs) and optical modulator **5**.

[0188]In general, the subdivision for performing heterodyning with and picking up of virtual sensor signals from the retrieved back propagation from fiber span **9** includes local oscillator laser **45**, and the network which phase locks transmitter laser **3** and local oscillator **45**, and a sequence of elements which perform processing upon the retrieved back propagation. The phase locking network comprises beamsplitter **4**, phase locking means optical receiver **35**, phase locking circuitry **30**, and optical coupler **43**. First in the sequence of processing elements is an optical receiver **15** which photodetects interference power "derived" by heterodyning the back propagated illumination portion retrieved from fiber span **9** with the output of a local oscillator **45**. Lasers **3** and **45** are operated with a frequency difference to produce an r.f. beat signal, ΔW. Then correlation system **23** receives as one of its inputs another electrical pathway output from master correlation code generator **53**, and provides a series of channels which in turn respectively provide predetermined time delays in relation to the timing base of cyclic reiterative code generator **53**, to perform a series of autocorrelations of the respectively delayed inputs from code generator **53** with the signal ΔW. This picks up r.f. signals respectively representative of the affects in the lightwave domain of the external physical signals incident upon the respective virtual sensor. Phase demodulator system **66** provides a linear phase signal derived from such r.f. signals representative of optical signals at the respective virtual sensors. Programmable phase differencer **99** processes pairs of these linear phase signals occurring across segments of fiber span **9** between programmably selected pairs of the virtual sensors.

[0189]Following is another overview description which more particularly calls attentions to an aspect of the invention that the system elements which performs the autocorrelation enable providing an output in the form of an r.f. counterpart of a lightwave time-domain reflectometry output of signals incident to the virtual sensors as lightwave time domain reflectometry outputs a CW lightwave modulated by a continuously reiterated binary pseudorandom code sequence is launched into an end of a span of ordinary optical fiber cable. Portions of the launched lightwave back propagate to the launch end from a continuum of locations along the span because of innate fiber properties including Rayleigh scattering. This is picked off the launch end and heterodyned to produce an r.f. beat signal. The r.f. beat signal is processed by a plurality (which can be thousands) of correlator type binary pseudonoise code sequence demodulators respectively operated in different delay time relationships to the timing base of the reiterated modulation sequences. The outputs of the demodulators provide r.f. time-domain reflectometry outputs representative of signals (e.g., acoustic pressure waves) incident to virtual sensors along the fiber at positions corresponding to the various time delay relationships.

[0190]Following is still another overview description which more particularly calls attention to an aspect of the invention that the system elements performing the autocorrelation enable detection of unique spectral components representing a phase variations of external signals incident to the virtual sensors. A CW lightwave modulated by a continuously reiterated pseudorandom code sequence is launched into an end of a span of ordinary optical fiber cable. Portions of the launched lightwave back propagate to the launch end from a continuum of locations along the span because of innate fiber properties including Rayleigh scattering. This is picked off the launch end and heterodyned producing an r.f. beat signal. The r.f. beat signal is processed by a plurality (which can be thousands) of correlator type pseudonoise code sequence demodulation and phase demodulator units, operated in different time delay relationships to the timing base of the reiterated modulation sequences. These units provide outputs representative of phase variations in respective unique spectral components in the r.f. beat signal caused by acoustic, or other forms of signals, incident to virtual sensors at fiber positions corresponding to the various time delay relationships.

[0191]Following is yet another overview description which more particularly calls attention to an aspect of the invention that a pair of the different delay time relationships of the autocorrelation system elements are effective to establish a virtual increment of the optical fiber span, and that a substracter circuit of phase differencer **99** enables representing the differential phase signal across the virtual increment. A CW lightwave modulated by a continuously reiterated pseudorandom (PN) code sequence is launched into an end of a span of ordinary optical fiber cable. Portions of the launched lightwave back propagate to the launch end from a continuum of locations along the span because of innate fiber properties including Rayleigh scattering. This is picked off the launch end and heterodyned producing an r.f. beat signal. The r.f. beat signal is processed by a plurality (which can be thousands) of correlator pseudonoise code sequence demodulation and phase demodulator units operated in different delay time relationships to the timing base of the reiterated modulation sequences. Pairs of outputs of the units are connected to respective substracter circuits, each providing a signal representative of phase differential of incident acoustic signals, or other forms of signals, across virtual increments of the span established by a pair of said delay time relationships.

[0192]n. Air-Backed Mandrel Modified Form of Invention

[0193]FIG. 13 illustrates a so-called fiber-on-an-air-backed mandrel assembly **801**, useful in applications in which a fiber optic span **9**′ is to be immersed in a liquid medium. Assembly **801** comprises a hollow cylindrical mandrel **803** having formed therein a sealed central chamber **805** containing air or other gaseous medium **807**, which is compressible relative to the liquid medium. A segment of span **9**′ of a ROSE system **2**, FIG. 3, is helically wound the cylindrical exterior surface of mandrel **803**, and suitably fixedly bonded to the surface. The cylindral wall **809** of mandrel **803** is of a material so chosen and of a thickness so chosen to form a containic membrane with a hoop stiffness that enables acoustic pressure wave signals incident upon assembly **801** to be transformed into mandrel radial dimensional variations. As a result of mandrel **801**'s geometry these radial variations result in magnified longitudinal strain variations in fiber **9**′. It is to be appreciated that the physical structure of assembly **801** inherently provides a spatial succession of two locations along the fiber span, which a phase signal switch and routing network **701** could select and route to become the virtual bounding positions of a differential phase signal virtual sensor. This is to say, positioning a mandrel wound span **9**′ as a segment of a system total span **9** of ROSE system **2** can facilitate providing a sequential pair of virtual sensor locations along a span **9**, and the provision of a corresponding pair of delay circuits in correlator circuit **23** would cause assembly **801** to operate as a differential phase signal sensor.

(4) Advantages and New Features

[0194]The invention enables the interrogation or time-delay correlational multiplexing and demultiplexing of optical phase signals.

[0195]The invention enables the interrogation of ROSE (Rayleigh Optical Scattering and Encoding) fiber optic sensors. The invention enables the spatial sorting and separation of the temporal optical phases of backscattered optical signals arising from a plurality (which upwardly may include a very large number, for instance 5,000) of virtual optical sensors along fibers or other optical mediums. The invention enables the spatial decoding of backscattered optical signals with a bandwidth of tens of kilohertz. The invention enables the sensor locations along the fiber to be programmable. The invention allows the electronic separation or segmentation of the array of fiber sensors into programmable bounded lengths and positions. Because the correlation signal, c(t), can be designed to be a continuous wave, the invention increases the average optical power considerably over conventional pulsed optical phase sensor interrogation methods. Because the correlation signal c(t) can be chosen to have spectrum spreading properties for which dispreading electronic circuitry is readily available, undesired optical fiber system noises, such as reflection discontinuity noises due to cable couplings, can be materially attenuated.

[0196]In hypothetically assessing the potential achievable by the present invention with regard to employment of a common grade of optical fiber cable buried beneath the ground surface as a perimeter intrusion monitoring fiber span, the following assumptions have been made: (i) signal to noise ratio (S/N) degradation of Rayleigh effect light propagation in such an optical fiber cable are assumed to be 0.5 db/km; (ii) it is assumed there is a requirement for bandwidth of ten times that of the geo-acoustic intruder signal needs to be detected; (iii) and digital circuitry functions are performed employing conventional "high end" clock rates. Using these assumptions, and employing conventional single-mode or multimode fiber buried 6-12 inches underground, and using conventional engineering methodology for noise effect prediction, it can be shown that ROSE system **2** has the potential of sensing intruder caused geo-acoustic, (i.e., seismic) signals along a length of fiber span line as long as 8 km or 5 miles. (This assessment is based upon S/N degradations for flyback travel of signals from the interrogation launch end of fiber span **9** to its remote end and back.) The hypothetical segment resolution capability with such a 8 km., or 5 mile line, would be 1 meter.

[0197]The invention provides a new capability of heterodyne optical phase detection without resorting to dithered phase carrier methods. The phase demodulation method introduces heterodyne I & Q demodulation to produce cosine and sine phase components, clipped signal amplitude stabilization techniques and digital signal processing based phase detection. The spatially differential phase detection method provided by the invention enables the rejection of unwanted lead-in fiber phase signals.

[0198]The details, materials step of operation and arrangement of parts herein have been described and illustrated in order to explain the nature of the invention. Many modifications in these are possible by those skilled in the art within the teachings herein of the invention. For example, while in system **2** the transformation from optical to r.f. signal takes place prior to processing by programmable correlation **23**, it is within the skill of the art to design optical receiver **15** and correlator system **23** to have the transformation take place otherwise. Also, as an 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. The diffracted optical wave exiting the acousto-optic modulator will be Doppler shifted by an impinging-driving RF wave, that is translated into a sound wave in the acousto-optic modulator, and the so-called Bragg shifted-diffracted optical wave will exit the acousti-optical modudulator with an optical frequency equivalent to the phase locked laser **45**. The acousto-optically generated lightwave, at an equivalent frequency of the phase locked laser **45**, is sent along optical pathway **13** and becomes the local oscillator input to heterodyne photoreceiver **15**. 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**. Accordingly it is to be understood that changes may be made by those skilled in the art within the principle and scope of the inventions expressed in the appended claims.

ENGLISH-CLAIMS:
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What is claimed is:

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.

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.

3. The reflectometer 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.

4. The reflectometer of claim 3, wherein:

- ~

  said optical fiber span is an acoustic security alarm perimeter monitoring line buried at a predetermined depth beneath the surface of the ground;
- ~

  said acoustic pressure wave signal being caused by the vibration of the ground surface by movement of an object thereon; and
- ~

  said set of n sensing positions along the line form a virtual array of n geophones which respectively produce substantially linear signals respectively representative of the vibrations of the surface of the ground at corresponding sensing positions.

5. The reflectometer of claim 4 wherein the range of depths of burial of the optical fiber span beneath the surface of the ground is of six inches to the order of one foot.

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.

7. The reflectometer of claim 6, wherein:

- ~

  said the length L of said optical fiber span is at least 5.0 km.

8. The reflectometer of claim 7 wherein said first light source is a planar, ring-type laser.

9. The reflectometer of claim 3 wherein said optical fiber span comprises a single-mode fiber optic cable.

10. The reflectometer of claim 3 wherein said optical fiber span comprises a fiber optic cable of the polarization preserving type.

11. The reflectometer of claim 3, wherein:

- said optical fiber span 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.

12. The reflectometer of claim 1 wherein:

- said lightwave heterodyner is of the photodetector type.

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 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.

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°.

15. 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.

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 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.

17. The reflectometer of claim 16, wherein said reference phase signal produced by said fixed frequency oscillator is used in establishing the phase locked relationship between the local oscillator lightwave signal and the carrier lightwave signal.

18. The reflectometer of claim 1, wherein:

- -

  a time period TP is required for forward propagation of said autocorrelatable spectrum spreading signal from the output 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.

19. 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 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.

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

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.

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.

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Attorney Docket No. 300099 13 April 2017

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: ROBERT MICHAEL PAYTON Group Art Unit: 3992
Serial No.: 14/686,161 Examiner: S. RALIS
Filed: June 16, 2015 Customer No. 134845
For: **NATURAL SPAN REFLECTOMETRY WITH SENSING ZONE SEGMENTS**

AMENDMENT

Mail Stop Reissue
Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant's representative files this communication with a 3-month extension of time. Applicant's representative hereby authorizes the Commissioner to charge any deficiency of fees and credit any overpayments to the Deposit Account of Record.

In response to the Office action of 18 October 2016, amend the above-identified patent application as follows:

Amendments to the Specification: begin on page 2 of this paper.

Amendment to the Abstract: is reflected on page 14.

Amendments to the Claims: are reflected in the listing of claims which begins on page 15 of this paper.

Amendments to the Drawings: None.

Remarks/Arguments: begin on page 20 of this paper.

AMENDMENT TO THE SPECIFICATION

Replace the title of the application at column 1, line 1, as follows:

[NATURAL FIBER SPAN REFLECTOMETER PROVIDING A VIRTUAL SIGNAL SENSING ARRAY CAPABILITY] NATURAL SPAN REFLECTOMETRY WITH SENSING ZONE SEGMENTS

Insert the following paragraph at column 1, line 3, following the title of the application, prior to the STATEMENT OF GOVERNMENT INTEREST:

This application is a continuation reissue of U.S. Patent Application No. 14/190,478 which is an application for reissue of [U.S. Patent Application No. 11/056,630 filed February 7, 2005, now] U.S. Patent No. 7,030,971 that claims the benefit of a provisional application, No. 60/599,437 which was filed on 6 August 2004, and which is entitled "Continuous Rayleigh Effect Sensor Backscattering Heterodyne Optical Sensor System" by Robert M. Payton.

At column 33, lines 10-37, replace the paragraph as follows:

The details, materials, [step] steps of operation and arrangement of parts herein have been described and illustrated in order to explain the nature of the invention. Many modifications in these are possible by those skilled in the art within the teachings herein of the invention. For example, while in system 2 the transformation from optical to r.f. signal takes place prior to processing by programmable correlation 23, it is within the skill of the art to design optical receiver 15 and correlator system 23 to have the transformation take place otherwise. Also, as an 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 acousticoptic modulator, sometimes called a Bragg Cell. The diffracted optical wave exiting the acousto-optic modulator will be Doppler shifted by an impinging-driving RF wave, that is translated into a sound wave in the acousto-optic modulator, and the so-called Bragg shifted-diffracted optical wave will exit the acoustioptical [modudulator] modulator with an optical frequency equivalent to the phase locked laser 45. The acousto-optically generated lightwave, at an equivalent frequency of the phase locked laser 45, is sent along optical pathway 13 and becomes the local oscillator input to heterodyne photoreceiver 15. 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. Accordingly it is to be understood that changes may be made by those skilled in the art within the principle and scope of the inventions expressed in the appended claims.

At column 18, line 64 to column 19, line 32, replace the paragraph as follows:

Refer to FIG. 3. Local oscillator laser, 45, generates a local oscillator lightwave. The local oscillator lightwave propagates from local oscillator laser, 45, to optical coupler or beamsplitter, 43. The optical coupler, 43, splits off the smaller portion of power of the local oscillator lightwave into optical pathway, 41. Optical path, 41, propagates the smaller portion of the local oscillator lightwave to the phase locking means optical receiver, 35. The larger portion of the power of the local oscillator lightwave is split off by optical coupler 43, and passed to optical path 13. Optical pathway, 13, propagates the larger portion of the local oscillator lightwave to optical receiver, 15. The phase locking means optical receiver, 35, receives and interferes the transmitter laser lightwave from optical pathway, 39, and the local oscillator lightwave from optical pathway 41. The receiver 35 interferes the reference lightwaves from lasers 3 and 45 producing an electrical output which is a radio frequency wave on electrical pathway, 33. The electrical output, 33, provides an electronic beat frequency which directly indicates the difference in optical frequency and phase between lasers [1] 3 and 45. Phase locking circuitry 31, employing a conventional phase lock loop mechanism, controls the difference in frequency between laser 1 and 45 and phase locks the two lasers to a fixed frequency and phase relationship as indicated by the dashed line between circuitry 31 and local oscillator laser 45. The radian frequency difference is Δw as discussed early in the text. The purpose of the laser phase locking means is to insure that the local oscillator lightwave traveling on optical path, 13, into optical receiver, 15, has the proper phase and frequency relationship to the composite lightwave on optical pathway, 11. It is to be appreciated that the phase locking mechanism also acts cooperatively with phase demodulator system 66 to be described later herein. Conventionally, a common master clock oscillator 311, FIG. 7 provides the timing base for both phase locking circuitry 31 and an I & Q demodulator 300, FIG. 7.

At column 29, lines 12-60, replace the paragraph as follows:

The example programmable phase differencer implementation shown as part 99 of FIG. 12 corresponds to part 99 shown as a block in FIG. 3. Refer to FIG. 12. The plurality (which upwardly may include a very large number, for instance 5,000) of demodulated signals proportional to optical signal phases Φ_1, Φ_2 … Φ_n are input into the programmable phase signal switching and routing network 701 via electrical paths 71, 73 and 75, respectively. Network 701 programmably selects on a basis of timed relation to code generator 53 and routes on a basis of conventional "hold-in memory" and "transfer-from-memory", a plurality (which upwardly may include a very large number, for instance 5,000) of pairs of phase signals onto a plurality (which upwardly may include a very large number, for instance 5,000) of pairs of electronic paths 711 and 713, 731 and 733 and 751 and 753. The plurality of routed pairs of phase signals are applied to the corresponding of subtracters 715, 735 and 755 as shown on FIG. 12. The plurality of phase pairs on electronic pairs of paths 711 and 713, 731 and 733, and 751 and 753 are subtracted by subtracters 715, [735] <u>755</u> and 753, respectively, and the differential signal are outputted on a corresponding plurality of electrical paths 91, 93 and 95 respectively. The following description focuses on the differencing channel output on electrical path 91, it being understood that the modes of operation of other differencing channels in network 701 are the same. Programmable phase switching and routing network 701 selects one of the phase signals on one of the plurality of electrical paths 71, 73 or 75 and routes the signal to electrical path 711. The signal on electrical path 711 is selected to be proportional to Φ_j (where j is of the set 1,2 . . . n). Network 701 also selects another of the phase signals on one of the other of the plurality of electronic paths 71, 73 or 75 and routes the signal to electrical path 713. The signal of electrical path 713 is selected to be proportional to Φ_k (where k is of set 1,2 . . . n). The signal on electrical path 711 is subtracted from the signal on electrical path 713 by subtracter 715. The output of subtracter 715 is passed on via electrical path 91 and is proportional to $\Delta\Phi_{kj}$, hereinabove discussed in subsection 3(f) "Phase Differencing" of this DESCRIPTION OF THE PREFERRED EMBODIMENT. Employing this mode, network 701 programmably makes selection from optical signal phases Φ_1, Φ_2 … Φ_n to provide other differential phase outputs on electrical paths 91, 93 and 95. This may include a very large number of differential phase signals, for instance 5000. As an alternative to the just described type of circuitry employing subtracters 715, 735 and 755 any of other well-known forms of producing a differential signal [my]<u>may</u> be employed.

At column 24, lines 29-47, replace the paragraph as follows:

Refer to FIG. 4. Like parts correspond to like numbers. Optical signals enter the photodetector sub-system via optical paths 101 and 103 which are extensions of the paths 11 and 13 in the case of receiver 15, and (not shown) of paths 39 and 44 in the case of subsystem 35. The optical signals are equally split by optical coupler or beamsplitter, 105. The optical signal on path 107 is composite signal comprised of half the optical power of path 101 and half of the optical power arriving on [pate] path 103. The optical signal on path 107 is illuminated on optical detector 111. The photo-current of optical detector 111 flows into electrical conductor 115. Likewise, the optical signal on path 109 is comprised of half the optical power on path 101 and half of the optical power on path 103. The optical signal on path 109 is illuminated on optical detector 113. The photo-current of optical detector 113 flows out of electrical conductor 115. Therefore the photo-currents of optical detectors 111 and 113 are subtracted at electrical conductor or node 115.

At column 24, lines 48-59, replace the paragraph as follows:

Photo-detectors 111 and 113 are precisely matched in responsivity. The differential photocurrent on electrical conductor 115 is input into pre-amplifier 117, [amplifier] and is passed to electrical output 119. The differential nature of the photo-detection rejects either of the self-optical interference power of the signals on paths 101 and 103 and receives only the cross-interference power between the two optical signals on paths 101 and 103. This particular optical detector architecture is called a balanced heterodyne optical detection scheme. The scheme is 3 dB more sensitive than all other heterodyne optical detection methods and offers the distinct advantage of rejecting local oscillator noise.

At column 25, lines 14-45, replace the paragraph as follows:

Refer to FIG. 6. The composite radio frequency signal, or r.f. composite reference beat signal, which electronically represents the received time-delay multiplexed optical signal, or composite back-propagation CW lightwave, $E_b(t)$, is input into the correlator system, 23, at electrical input 21. The composite radio frequency signal is n-way split with power splitter 203 into a plurality (which upwardly may include a very large number, for instance 5,000) of electronic pathways including 211, 213 and 215. The master correlation code, c(t), is input into the correlator system, 23, at electrical input 54. The correlation code is distributed to such a plurality of programmable delay circuits including 221, 223 and 225. Each programmable delay circuit delays the master correlation code by the delay required to decode/demultiplex each time-delay multiplexed channel. The plurality of programmable delay circuits including 221, 223 and 225 output a plurality of delayed correlation codes including those on electrical pathways 231, 233, and [225] 235 respectively. The corresponding plurality of delayed correlation codes including those on electrical pathways 231, 233 and 235 are multiplied by a corresponding plurality of multipliers (or balanced mixers) including 241, 243 and 245 associated with electrical pathways 251, 253, and 235, respectively, by the radio frequency signal on the plurality of electronic pathways including 211, 213 and 215 which are amplified by a corresponding plurality of amplifiers including [261]161, 263 and 265, respectively, to produce the corresponding plurality of outputs including O_1, O_2, and O_n (on lines 61, 63 and 65) respectively. Each of the outputs therefore produces the corresponding demultiplexed signal which is time-gated by the corresponding time-delay of the correlation code. The correlator system 23 of FIG. 6 is an example implementation of the correlation system, 23, of FIG. 3.

At column 21, line 59 through column 22, line 2, replace the paragraph as follows:

It is to be appreciated that system 2 is operating in the spread spectrum transmission and reception mode. Namely, by providing optical interrogation light wave, $E_b(t)$, with modulation by the correlation code, c(t), the continuous wave carrier signal is temporally structured into a spread spectrum interrogation lightwave which continuously reiterates autocorrelatable code sequences. Then after correlation system provides an appropriate time of delay the correlator system [26] 23 correlates the backscattered light wave $E_b(t)$ with the same output, c(t), of code generator 53, de-spreading the spread spectrum signal.

At column 20, line 48 to line 58, replace the paragraph as follows:

Refer to FIG. 3. The composite radio frequency signal on electrical path, 21, is input into the correlator system, 23. The correlator system delays the master correlation code generator output, [51,] an appropriate amount and correlates the delayed correlation code with the composite radio frequency signal. This produces electrical outputs O_1, O_2 ... O_n corresponding to signals S_1, S_2 ... S_n, in turn corresponding to spatial delays L_1, L_2 ... L_n. The spatial delays L_1, L_2 ... L_n are arbitrary and programmable. The electrical output O_1 corresponds to B(t, L_1) referred to in the preceding subsection 2(a).

At column 20, line 59 to column 21, line 27, replace the paragraph as follows:

The correlation process is well understood in the literature. The signal that represents the backscattered optical wave in array, 9, that is passed from the optical receiver 15, to the correlator system 23, contains all of the information for all sensors or channels S_1, S_2 ... S_n at once on the electronic signal path 21 entering the correlator 23. Because the backscattered composite signal is modulated with the correlation code by modulator 5, the backscattered light is time structured with the time structure of the correlation code. Because the correlation code is selected to have special autocorrelation code properties, the time structure of the correlation codes allows an electronic representation of the backscattered light at positions L_1, L_2 ... L_n to be obtained via the correlation process in the correlator 23. In a preferred embodiment of the invention the master code generator 53 is a shift register type pseudorandom number (PRN) code generator and each correlator of the set 23 would be a correlation type demodulator herein later described in greater depth. Code generator 53 may alternatively be embodied as a binary sequence having transorthogonal autocorrelation properties (binary pseudonoise sequence) and each correlator would then be a correlation-type demodulator for demodulating a binary pseudonoise sequence, whose implementation would be understood by those of skill in the art. The correlator uses the reference correlation code from correlation code generator, 53, which is passed via an electronic path [51] to the correlator, 23, as a "golden ruler" enabling sorting out by temporal and spatial domain demultiplexing electronic representations of the backscattering optical signals at sensors or channels S_1, S_2 ... S_n. Various delayed versions of the correlation code are multiplied by the composite signal with all of the sensor or channel signals present simultaneously, from electronic path 21 so that the electronic representations of the sensors or channels S_1, S_2 ... S_n are output from the correlator, 23 on signals O_1, O_2 ... O_n with respect to the index.

AMENDMENTS TO THE ABSTRACT

Please replace the abstract with the following replacement abstract:

A distributed sensing system for an optical fiber span wherein the geometric arrangement of the span provides one or more sensing zones with different sensitivities. The span is interrogated with a series of radiated optical pulses. The backscattered signals are detected from positions along the optical fiber span and the received signals are processed to provide a measurement representative of acoustic pressure waves incident on the span at the positions.

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims

1 - 22. (Canceled)

23. (New) A system comprising:

a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function;

a light source operative to provide a continuous wave (CW) optical signal;

a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span;

an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.

24. (New) The system of claim 23, wherein at least one zone segment of said span is helically disposed.

25. (New) The system of claim 23, wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times the length L..

26. (New) The system of claim 25, wherein the length L of said span is at least about 5 km.

27. (New - currently amended) The system of claim 23, wherein said light source is a laser.

28. (New) The system of claim 23, wherein said span of optical fiber comprises a single mode fiber optic cable.

29. (New) The system of claim 23, wherein said span of optical fiber is made from the polarization preserving type of optical fiber.

30. (New) The system of claim 23, wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates.

31. (New) A method for sensing comprising the steps of:

providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;

illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation;

receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a backpropagating portions of the illumination from locations along the span in response to induced light path changes;

producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.

32. (New) The method of claim 31, wherein said step of providing the span includes providing at least one sensing zone segment of the span in a helical disposition.

33. (New) The method of claim 31, wherein the span of optical fiber span has a length L, and the light source is a laser

having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L.

34. (New) The method of claim 33, wherein the length L of said span is at least about 5 km.

35. (New - Currently Amended) The method of claim 31, wherein said light source is a laser.

36. (New) The method of claim 31, wherein said span of optical fiber comprises a single mode fiber optic cable.

37. (New) The method of claim 31, wherein said span of optical fiber is made from the polarization preserving type of optical fiber.

38. (New) The method of claim 31, wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates.

REMARKS / ARGUMENTS

Claims 23-38 are currently pending in the application. No claims have been allowed. Claims 23-38 are rejected. Claims 23-38 were entered by preliminary amendment. None of these new claims are amended by this response.

The Application supports the claims as presented. The amendments submitted herein do not introduce new matter.

These rejections and objections submitted in the Office action are respectfully traversed in view of these amendments and remarks that follow.

Litigation

The patent for which the reissue has been filed is involved in litigation. As such, it is believed that prosecution of this reissue application is suspended after the filing of this response.

Application Data Sheet

An corrected ADS will be filed to properly identify the domestic benefit information of the '768 Reissue Proceedings as both a continuation of the '478 Proceedings and a reissue application of the '971 patent.

The Reissue Oath/Declaration is Not Defective

The Applicant respectfully disagrees that the stated error is insufficient. The Applicant has stated an error that identifies an error, and respectfully requests the objection be withdrawn.

Objections to the Specification

The Applicant believes that the Amendments to the Specification address the objections. As such, the Applicant respectfully requests the objections be withdrawn.

Objections to the Drawings

The Applicant respectfully submits that the drawings comply with 37 C.F.R. 1.84(p)(4). The Applicant hereby submits that the amendments to the specification address the objection and/or submits that the same reference numbers are used to designate the same parts. The Applicant respectfully request that these objections be withdrawn.

The Nov 2015 Claim Amendment Complies with 37 CFR 1.173(c)

The Applicant respectfully submits that the Nov 2015 claim amendments comply with 37 CFR 1.173(c) and respectfully request the rejection be withdrawn. The Applicant respectfully requests clarification for the statement in the Office Action on page 10 that "The Nov 2015 Remarks at 10 purports to include such an explanation of support for the changes made in the Nov 2015 Claim Amendment, but do not fully address the new claims.

Lexicographic Definitions

The Applicant submits that the specification clearly defines specific terms.

The Claims are Not Broadened

The Applicant submits that the claim amendments are not directed at enlarging the scope of the patent and respectfully requests the rejection be withdrawn.

Light Source is not New Matter

It is well known that a laser is a light source.

Claims 23-38 Comply With § 112, First and Second Paragraph

The Applicant respectfully disagrees with the Examiner's arguments and respectfully submits that a laser is a light source. The Applicant also herein amends claims as shown above. Applicant respectfully requests the rejections be withdrawn.

Double Patenting

The Applicant respectfully requests the nonstatutory double patenting rejections be held in abeyance until allowable subject matter is indicated.

Kersey Does Not Anticipate Claims 23-25, and 31-33

Claims 23-25, and 31-33 stand rejected under 35 U.S.C. § 102(b) as allegedly being anticipated by Kersley et al (US Patent No. 6, 285, 806). Applicant respectfully traverses the rejection. Among other differences, Kersey does not teach or suggest the recitation for "detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment" as recited in claim 23 or the recitation of claim 31 for "detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span."

For at least the reasons presented herein, Kersey does not disclose all of the features of the claims. Accordingly, Applicant submits that Kersey does not anticipate claims 23-25, and 31-33, and respectfully requests that the Office withdraw the § 102 rejections.

35 U.S.C. § 103(a) Rejections for Claims 26-30, and 34-38

Claims 26-30, and 34-38 ultimately depend from one of independent claims. As discussed above, claims 23 and 31 are not anticipated by Kersey, and are therefore allowable over the cited document. Therefore, claims 26-30, and 34-38 are also allowable over the cited document of record for at least their dependency from an allowable base claim, and also for the additional features that each recites.

Accordingly, Applicant respectfully requests that the Office withdraw the § 103 rejections.

Conclusion

For at least the foregoing reasons, all pending claims are in condition for allowance. Applicant respectfully requests reconsideration and prompt issuance of the application.

If any issues remain that would prevent allowance of this application, **Applicant requests that the Examiner contact the undersigned representative before issuing a subsequent Action.**

Respectfully submitted,

ROBERT MICHAEL PAYTON

13 April 2017

By/JAMES M. KASISCHKE/
JAMES M. KASISCHKE
Attorney of Record
Reg. No. 36562

Electronic Patent Application Fee Transmittal

Application Number:	14686161
Filing Date:	16-Jun-2015
Title of Invention:	NATURAL SPAN REFLECTOMETRY WITH SENSING ZONE SEGMENTS
First Named Inventor/Applicant Name:	Robert M Payton
Filer:	James Martin Kasischke
Attorney Docket Number:	300099

Filed as Large Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension - 3 months with $0 paid	1253	1	1400	1400
Miscellaneous:				
		Total in USD ($)		**1400**

Electronic Acknowledgement Receipt

EFS ID:	28913667
Application Number:	14686161
International Application Number:	
Confirmation Number:	5544
Title of Invention:	NATURAL SPAN REFLECTOMETRY WITH SENSING ZONE SEGMENTS
First Named Inventor/Applicant Name:	Robert M Payton
Customer Number:	134845
Filer:	James Martin Kasischke
Filer Authorized By:	
Attorney Docket Number:	300099
Receipt Date:	13-APR-2017
Filing Date:	16-JUN-2015
Time Stamp:	09:26:56
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$1400
RAM confirmation Number	041317INTEFSW00010304140590
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	300099ReissueAM.pdf	997871 04621f30437e91bd4020a9139b32771cce3c1f7b	no	25
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31026 04a976b9e0ddcbd451fc8b3863ba6f4e736613fb	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1028897		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/686,161	Filing Date 06/16/2015	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	04/13/2017	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 16	Minus	** 20	= 0	x $80 =	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	x $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
PATRICIA F. LEWIS

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/686,161	06/16/2015	Robert M Payton	300099	5544

134845 7590 10/18/2016

NUWCDIVNPT / ADELOS
1176 HOWELL STREET, Code 00L
Bldg. 102T
NEWPORT, RI 02841

EXAMINER	
RALIS, STEPHEN J	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
10/18/2016	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/686,161	Applicant(s) PAYTON, ROBERT M	
	Examiner Stephen J. Ralis	Art Unit 3992	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *6/16/2015*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *23-38* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *23-38* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☒ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *6/16/2015* is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

DETAILED ACTION

The instant application is being examined under the pre-AIA first to invent provisions.

In the event the determination of the status of the application as subject to AIA 35 U.S.C. 102 and 103 (or as subject to pre-AIA 35 U.S.C. 102 and 103) is incorrect, any correction of the statutory basis for the rejection will not be considered a new ground of rejection if the prior art relied upon, and the rationale supporting the rejection, would be the same under either status.

I. Priority

Applicant filed the instant continuation reissue[1] application 14/686,161 ("'161 RI Proceedings") on 16 June 2015 of a U.S. Reissue Application No. 14/190,478 ("'478 Reissue Proceedings"), filed 26 February 2014, for U.S. Application No. 11/056,630 (" '630 Proceedings"), now U.S. Patent No. 7,030,971 ("'971 patent"), issued 07 February 2005, which claims priority to U.S. Provisional Patent Application 60/599,437, filed 06 August 2004.

Thus, the Examiner concludes that the '971 patent claims a domestic priority date of 06 August 2004.

II. Claim Status

The Examiner finds that the '161 Reissue Proceedings include a preliminary amendment to the '971 patent filed 24 November 2015 ("Nov 2015 Preliminary Amendment"). The Nov 2015 Preliminary Amendment includes a "Remarks" ("Nov 2015 Remarks"), "Amendment to the Claims" ("Nov 2015 Claim Amendment"), and "Amendments to the Specification" ("Nov

[1] The Examiner finds that the Nov 2015 Spec Amendment indicates that the '161 Reissue Proceedings "is a continuation reissue of U.S. Patent Application No. 14/190,478 which is an application for reissue of U.S. Patent 7,030,971...." (Nov 2015 Spec Amendment at 2).

2015 Spec Amendment"). The Nov 2015 Spec Amendment includes a new Title, new Abstract, and modifies the Applications filing status to correct the priority of the '161 Reissue Proceedings. The Nov 2015 Claim Amendment cancels claims 1-22 and adds new claims 23-38.

The claim status is as follows:

Claims 1-22 (Original and Canceled)

Claims 23-38 (New)

Thus, the Examiner concludes that claims 23-38 are pending ("Pending Claims") in the '161 Reissue Proceedings. Claims 23-38 are examined ("Examined Claims").

III. Reissue Requirements

For reissue applications filed before September 16, 2012, all references to 35 U.S.C. 251 and 37 CFR 1.172, 1.175, and 3.73 are to the law and rules in effect on September 15, 2012. Where specifically designated, these are "pre-AIA" provisions.

For reissue applications filed on or after September 16, 2012, all references to 35 U.S.C. 251 and 37 CFR 1.172, 1.175, and 3.73 are to the current provisions.

Applicant is reminded of the continuing obligation under 37 CFR 1.178(b), to timely apprise the Office of any prior or concurrent proceeding in which the '9710 patent is or was involved. These proceedings would include interferences, reissues, reexaminations, and litigation.

Applicant is further reminded of the continuing obligation under 37 CFR 1.56, to timely apprise the Office of any information which is material to patentability of the claims under consideration in this reissue application.

These obligations rest with each individual associated with the filing and prosecution of this application for reissue. See also MPEP §§ 1404, 1442.01 and 1442.04.

IV. Application Data Sheet

The application data sheet (ADS) filed on 24 November 2015 ("Nov 2015 ADS") is objected to because the Nov 2015 ADS does not properly identify the domestic benefit information of the '161 Reissue Proceedings as both a continuation of the '478 Proceedings and a reissue application of the '971 patent (emphasis added). See the Reissue Application Filing Guide at http://www.uspto.gov/sites/default/files/forms/uspto_reissue_ads_guide_Sept2014.pdf for more information and in particular see the screen shot on page 10 given the sample facts presented on page 9. The corrected ADS should comply with 37 CFR 1.76(c)(2), which requires that any changes to an ADS be identified with markings (underline for addition, strike through for deletion).

Applicant should additionally file, as a paper separate from its next response, a Request for Corrected Filing Receipt. This is the best way to ensure that these changes are acted upon and corrected by the appropriate official.

V. Reissue Oath/Declaration

The reissue oath/declaration filed with the '161 Reissue Proceedings is defective because it does not specifically identify an error with reference to the particular claim(s) and claim language in which the error is found. See 37 CFR 1.175 and MPEP § 1414.

The reissue oath/declaration filed on 16 June 2015 ("June 2015 Declaration") states the at least one error which the '161 Reissue Proceedings is based on the failure "to claim aspects of the indention related to sensing gone segments on a span optical fiber wherein the zone segments have specialized sensing functions." (June 2015 Declaration). The Examiner finds that the at least one error relied upon by Applicant is insufficient in that the June 2015 Declaration does not identify a single word, phrase, or expression in the specification or in an original claim, and how it renders the original patent wholly or partly inoperative or invalid. (See MPEP § 1414.II).

VI. Objections to the Specification

The Nov 2015 Spec Amendment does not comply with 37 CFR 1.173(b) and is objected to because the deleted text is not enclosed in brackets and the new matter added to the Abstract is not underlined as set forth in 37 CFR 1.173(d). (See MPEP § 1453).

The Nov 2015 Spec Amendment is further objected to because the first sentence of the specification does not contain sufficient notification stating that <u>more than one</u> reissue application has been filed and identifying each of the reissue applications by relationship, application number and filing date as set forth in 37 CFR 1.177(a). (See MPEP § 1451).

The specification is objected to as failing to provide proper antecedent basis for the claimed subject matter. See 37 CFR 1.75(d)(1) and MPEP § 608.01(o). Correction of the following is required: The Examiner finds that claims 27 and 35 recite "said/the light source is a planar, ring-type laser." The Examiner finds that the '971 patent has insufficient antecedent basis for a light source being a <u>planar</u>, ring type laser (emphasis added).

In addition, the disclosure is objected to because of at least the following informalities:

"lasers 1 and 45" in c.19, ll.17-19 should read –lasers 3 and 45–;

"**735**, respectively, and the... in c.29, l. 32 should read –**755**, respectively, and the.... –;

reference character "99" in c.23, l.60 should be bolded;

"pate **103**" in c.24, l.38 should read –path **103--**;

"pre-amplifier **117**, amplifier and is..." in c.24, l.50 should read –the pre-amplifier **117** and is... –;

"paths **101** and **103**" in c.24, l.55 should read –optical paths **101** and **103**–; and

"electrical pathways **231**, **233**, **225** respectively." in c.25, l.30 should read –electrical pathways **231**, **233**, **235** respectively.–.

While the above informalities are utilized to illustrate examples of informalities present throughout the disclosure of the '971 patent, the Examiner finds that the '971 patent is replete with such typos and incorrect element to Figure mappings. So as to avoid further specification objection issues and to provide clear and consistent language throughout the '971 patent, the Examiner suggests that Applicant evaluate the '971 patent and amend accordingly.

Appropriate correction is required.

VII. Objections to the Drawing

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(4) because reference character "9" has been used to designate "fiber span", "ROSE fiber optic array", "optic fiber or medium", "optical fiber span", "span", and "fiber"; reference character "15" has been used to designate "optical receiver", "receiver", "heterodyne optical receiver", and "signal"; reference character "23" has been used to designate "a single set of correlators", "correlator system", "correlator circuit", "correlator", "the set" and "programmable correlation"; and reference character "53" has been used to designate "a correlation code generator", "master correlating code generator", "generator", "PRN code generator" and "code generator"

Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(4) because reference characters "23" and "26" have both been used to designate the correlator system. Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they do not include the following reference sign(s) mentioned in the description: "261" in c.25, l.38 of '971 patent. Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they include the following reference character(s) not mentioned in the description: "251", "253" and "255" in Figure 6 are not disclosed in the Specification. Corrected drawing sheets in compliance with 37 CFR 1.121(d), or amendment to the specification to add the reference character(s) in the description in compliance with 37 CFR 1.121(b) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they do not include the following reference sign(s) mentioned in the description: "51". Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

While the above informalities are utilized to illustrate examples of the drawing issues present throughout the disclosure of the '971 patent, the Examiner finds that the '971 patent is replete with such typos and incorrect element to Figure mappings. So as to avoid further drawings objection issues and to provide clear and consistent language throughout the '971 patent, it is suggested that Applicant amend the '971 patent.

Appropriate correction is required.

VIII. Objections to the Claims

The Nov 2015 Claim Amendment does not comply with 37 CFR 1.173(b) and is objected to because the new matter added to the Nov 2015 Claim Amendment is not underlined as set forth in 37 CFR 1.173(d). (See MPEP § 1453).

The Nov 2015 Claim Amendment to the claims does not comply with 37 CFR 1.173(c) and are objected to because there is no explanation of the written description support for the new claims in the '971 patent. See MPEP § 1453. The Nov 2015 Remarks at 10 purports to include such an explanation of support for the changes made in the Nov 2015 Claim Amendment, but do not fully address the new claims.

IX. Claim Interpretation

After careful review of the original specification, the prosecution history, and unless expressly noted otherwise by the Examiner, the Examiner finds that he is unable to locate any lexicographic definitions (either express or implied) with reasonable clarity, deliberateness, and precision. Because the Examiner is unable to locate any lexicographic definitions with reasonable clarity, deliberateness, and precision, the Examiner concludes that Applicant is not his/her own lexicographer. See MPEP §2111.01 IV.

Additionally, the Examiner finds that because the Examined Claims do not recite "step," "means" or a claim term used as a substitution for "means" (*i.e.* a generic placeholder for "means"), the Examined Claims fail Prong (A) as set forth in MPEP §2181 I. Because the Examined Claims fail Prong (A) as set forth in MPEP §2181 I., the Examiner concludes that all Examined Claims do not invoke 35 U.S.C. §112, 6th paragraph. See also *Ex parte Miyazaki*, 89 USPQ2d 1207, 1215-16 (B.P.A.I. 2008)(precedential).

The Examiner hereby adopts the following interpretations below under the broadest reasonable interpretation standard. In other words, the Examiner has provided the following interpretations simply as express *notice* of how he is interpreting particular terms under the broadest reasonable interpretation standard.

X. Broadening of Examined Claims

The following is a quotation of 35 U.S.C. § 251(d):

> (d) REISSUE PATENT ENLARGING SCOPE OF CLAIMS.—No reissued patent shall be granted enlarging the scope of the claims of the original patent unless applied for within two years from the grant of the original patent.

The Examiner finds that independent new independent claims 23 and 31 are broadened claims because the claims enlarge the scope of the patent, *i.e.*, a claim which is greater in scope than each and every claim of the original patent. (See MPEP § 1412.03(I)).

A. System of Claims 23-30

With respect to the reissue claim 23 of the '161 Reissue Proceedings ("RI Claim 23"), the Examiner finds that RI Claim 23 is similar in scope to that of now patented claim 21 of '971 patent ("Patent Claim 21"). (See Nov 2015 Remarks at 10).

The Examiner finds that RI Claim 23 recites:

a light source operative to provide a continuous wave (CW) optical signal ("Broad Claim 23 Light Source");

> **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**

("Broad Claim 23 Optical Receiver"); and

> **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give a measurement representative of the electromagnetic field proximate to at least one zone segment.**

("Broad Claim 23 Correlator").

('768 Reissue Proceedings, Nov 2015 Claim Amendment, RI Claim 23).

The Examiner finds that Patent Claim 21 recites:

> **means for illuminating an optical fiber span with a CW optical signal**

("Narrow Claim 21 Light Source"); and

> **means for retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span**

("Narrow Claim 21 Lightwave Coupler");

> **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**

("Narrow Claim 21 Optical Receiver");

> **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**

("Narrow Claim 21 Correlator"). ('971 patent, Patent Claim 21).

In Patent Claim 21, the Examiner finds that the Narrow Claim 21 Light Source, Narrow Claim 21 Lightwave Coupler, Narrow Claim 21 Optical Receiver, and Narrow Claim 21

Correlator elements recite their claim structure requirements with “means for” language. Use of the word “means” (or “step for”) in a claim with functional language creates a rebuttable presumption that the claim element is to be treated in accordance with 35 U.S.C. 112(f) (pre-AIA 35 U.S.C. 112, sixth paragraph). The presumption that 35 U.S.C. 112(f) (pre-AIA 35 U.S.C. 112, sixth paragraph) is invoked is rebutted when the function is recited with sufficient structure, material, or acts within the claim itself to entirely perform the recited function.

Absence of the word “means” (or “step for”) in a claim creates a rebuttable presumption that the claim element **is not** to be treated in accordance with 35 U.S.C. 112(f) (pre-AIA 35 U.S.C. 112, sixth paragraph). The presumption that 35 U.S.C. 112(f) (pre-AIA 35 U.S.C. 112, sixth paragraph) is not invoked is rebutted when the claim element recites function but fails to recite sufficiently definite structure, material or acts to perform that function.

Claim elements in Patent Claim 21 that use the word “means” (or “step for”) are presumed to invoke 35 U.S.C. 112(f) except as otherwise indicated in an Office action. Similarly, claim elements that do not use the word “means” (or “step for”) are presumed not to invoke 35 U.S.C. 112(f) except as otherwise indicated in an Office action.

(1) Functional Phrase

The Examiner finds that Patent Claim 21 expressly recites:

> *means for* illuminating an optical fiber span with a CW optical signal.
> [Emphasis added].

“Functional Phrase 1” or “FP1” – From Patent Claim 21.

To invoke 35 U.S.C. § 112 6th paragraph, a claimed phrase must meet the three (3) prong analysis as set forth in MPEP § 2181 I.

i. 3-Prong Analysis: Prong (A)

In accordance with Prong (A), the MPEP states:

> (A) the claim limitation uses the term "means" or "step" or a term used as a substitute for "means" that is a generic placeholder (also called a nonce term or a non-structural term having no specific structural meaning) for performing the claimed function ....

MPEP § 2181 I. — Prong (A).

Because FP1 expressly recites a "means for," the Examiner concludes that FP1 meets Invocation Prong (A).

ii. 3-Prong Analysis: Prong (B)

In accordance with the MPEP, Prong (B) requires:

> (B) the term "means" or "step" or the generic placeholder is modified by functional language, typically, but not always linked by the transition word "for" (e.g., "means for") or another linking word or phrase, such as "configured to" or "so that" ....

MPEP § 2181 I. — Prong (B).

Based upon a review of FP1, the Examiner finds that claimed functions are:

illuminating an optical fiber span with a CW optical signal.

- "Function of Functional Phrase 1" or "FFP1."

Because FP1 recites the above recited functions, the Examiner concludes that FP1 meets Invocation Prong (B).

iii. 3-Prong Analysis: Prong (C)

In accordance with the MPEP, Prong (C) requires:

> (C) the term "means" or "step" or the generic placeholder is not modified by sufficient structure, material, or acts for performing the claimed function.

MPEP § 2181 I. — Prong (C).

Based upon a review of the entire FP1, the Examiner concludes that FP1 does not contain sufficient structure for performing the entire claimed function of FP1.[2] In fact, the Examiner finds that the Functional Phrase 1 recites very little structure (if any) for performing the claimed function.

Because the Functional Phrase 1 does contain insufficient structure for performing the entire claimed functions, the Examiner concludes that the FP1 meets Invocation Prong (C).

In conclusion, because FP1 meets the three prong analysis set forth in MPEP §2181 I., the Examiner concludes that Functional Phrase 1 invokes 35 U.S.C. §112, 6th paragraph.

iv. Corresponding structure for Functional Phrase #1

Once a claimed phrase invokes 35 U.S.C. § 112 6^{th} paragraph, the next step is to determine the corresponding structure. (MPEP § 2181 II).

The Examiner has again carefully reviewed the original disclosure to determine the corresponding structure for FP1. In reviewing the original disclosure, the Examiner finds that the '971 patent discloses

> FIG. 3 is an illustrative block diagram implemention [*sic*] of the Rayleigh optical scattering and encoding (ROSE) sensor system **2**. Like parts correspond to like numbers. **A lightwave from transmitter laser, 3**, is propagated through optical coupler or beamsplitter, 4.

[2] Although not necessary, the Examiners have reviewed the rest of claim 21 and the *entire claim* does not contain sufficient structure for performing the functions as set forth within the Functional Phrases.

(‘971 patent at c.15, ll.51-55; see Figure 3; emphasis added); and

> In accordance with the present invention, **lasers 3** and **45** are to have sufficiently stringent high performance capability with respect to exactness of frequency to enable interference effects therebetween and heterodyne detection of acoustic perturbation signals incident to fiber **9** to produce beat frequencies within the radio frequency (r.f.) range. Also in accordance with the present invention, **lasers 3** and **45** have stringent performance criteria with respect to the phase stability, or coherence, of their beams. They are to be substantially coherent over at least a propagation path distance substantially equal to twice the length, L, of sensing fiber **9**. **For example, a commercially available non-planar, ring laser (e.g. Lightwave Electronics Corp. Model 125) would be suitable for an intruder sensing perimeter intrusion monitoring fiber 9 having a length of 8.0 km** (approximately 5 miles). The laser beam of this commercially available laser, which is in the near infrared range, has a frequency of 227 terahertz, or 1319 nanometer wavelength, and has a frequency stability accurately within one part in a billion over 1 millisecond period, or 5 Kilohertz in a 1 millisecond period.

(‘971 patent at c.20, ll.1-21; emphasis added).

Thus, in light of the portions of the ‘971 patent cited above, the Examiner concludes the structure for performing the FFP1 of Patent Claim 21 (*i.e.*, the Narrow Claim 21 Light Source) as <u>a transmitter laser that is of the non-planar, ring-type</u>.

(2) Functional Phrase

The Examiner finds that Patent Claim 21 expressly recites:

> *means for* retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span. [Emphasis added.]

“Functional Phrase 2” or “FP2” – From Patent Claim 21.

To invoke 35 U.S.C. § 112 6th paragraph, a claimed phrase must meet the three (3) prong analysis as set forth in MPEP § 2181 I.

i. 3-Prong Analysis: Prong (A)

Because FP2 expressly recites a "means for," the Examiner concludes that FP2 meets Invocation Prong (A).

ii. 3-Prong Analysis: Prong (B)

Based upon a review of FP2, the Examiner finds that claimed function is:

retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span.

- "Function of Functional Phrase 2" or "FFP2."

Because FP2 recites the above recited function, the Examiner concludes that FP2 meets Invocation Prong (B).

iii. 3-Prong Analysis: Prong (C)

Based upon a review of the entire FP2, the Examiner concludes that FP2 does not contain sufficient structure for performing the entire claimed function of FP2.[3] In fact, the Examiner finds that the Functional Phrase 2 recites very little structure (if any) for performing the claimed function.

Because the Functional Phrase 2 does contain insufficient structure for performing the entire claimed functions, the Examiner concludes that the FP2 meets Invocation Prong (C).

In conclusion, because FP2 meets the three prong analysis set forth in MPEP §2181 I., the Examiner concludes that Functional Phrase 2 invokes 35 U.S.C. §112, 6th paragraph.

[3] *Id.*

iv. Corresponding structure for Functional Phrase #2

Once a claimed phrase invokes 35 U.S.C. § 112 6th paragraph, the next step is to determine the corresponding structure. (MPEP § 2181 II).

The Examiner has again carefully reviewed the original disclosure to determine the corresponding structure for FP2. In reviewing the original disclosure, the Examiner finds that the '971 patent discloses

> **The interrogation lightwave is propagated from optical modulator, 5, to optical coupler, beamsplitter or circulator, 7. The interrogation lightwave passes through the optical coupler, 7, into optical fiber or other light propagation medium, 9**. Hereinafter, "down", indicates a transversal on the optical path, 9, away from coupler, 7; **"up" indicates a transversal on the optical path 9 toward the optical coupler, beamsplitter or circulator, 7**. The interrogation lightwave which transverses down the optical fiber or medium 9 is modulated ... **The composite lightwave propagates up the optical fiber or medium 9, passes through optical coupler, beamsplitter or circulator, 7**, to optical pathway, 11. Optical pathway, 11, passes the backscattered, time-delay multiplexed, composite lightwave, $E_b(t)$, to the optical receiver, 15.

('971 patent at c.16, l. 1 – c.17, l.14; see Figure 3; emphasis added)

Thus, in light of the portions of the '971 patent cited above, the Examiner concludes the structure for performing the FFP2 of Patent Claim 21 (*i.e.*, the Narrow Claim 21 Lightwave Coupler) as <u>an optical coupler, beamsplitter or circulator</u>.

(3) Functional Phrase

The Examiner finds that Patent Claim 21 expressly recites:

> *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. [Emphasis added.]

"Functional Phrase 3" or "FP3" – From Patent Claim 21.

To invoke 35 U.S.C. § 112 6th paragraph, a claimed phrase must meet the three (3) prong analysis as set forth in MPEP § 2181 I.

i. 3-Prong Analysis: Prong (A)

Because FP3 expressly recites a "means for," the Examiner concludes that FP3 meets Invocation Prong (A).

ii. 3-Prong Analysis: Prong (B)

Based upon a review of FP3, the Examiner finds that claimed function is:

picking off a radio frequency (r.f.) counterpart of the retrieved signal.

- "Function of Functional Phrase 3" or "FFP3."

Because FP3 recites the above recited function, the Examiner concludes that FP3 meets Invocation Prong (B).

iii. 3-Prong Analysis: Prong (C)

Thus, based upon a review of the entire FP3, the Examiner concludes that FP3 does not contain sufficient structure for performing the entire claimed function of FP3.[4] In fact, the Examiner finds that the Functional Phrase 3 recites very little structure (if any) for performing the claimed function.

Because the Functional Phrase 3 does contain insufficient structure for performing the entire claimed functions, the Examiner concludes that the FP3 meets Invocation Prong (C).

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[4] *Id.*

In conclusion, because FP3 meets the three prong analysis set forth in MPEP §2181 I., the Examiner concludes that Functional Phrase 3 invokes 35 U.S.C. §112, 6th paragraph.

iv. Corresponding structure for Functional Phrase #3

Once a claimed phrase invokes 35 U.S.C. § 112 6^{th} paragraph, the next step is to determine the corresponding structure. (MPEP § 2181 II).

The Examiner has again carefully reviewed the original disclosure to determine the corresponding structure for FP3. In reviewing the original disclosure, the Examiner finds that the '971 patent discloses

> Optical pathway, 11, passes the backscattered, time-delay multiplexed, composite lightwave, $E_b(t)$, **to the optical receiver**, **15**.

('971 patent at c.17, ll.12-15; see Figures 3-5; emphasis added);

> Refer to FIG. 3. **The composite lightwave on optical path 11, is an input into optical receiver 15. The local oscillator lightwave on optical path, 13, is also an input into optical receiver, 15**. The local oscillator and composite lightwaves are interfered on photodetectors producing an electronic signal which electronically represents **the <u>heterodyned optical interference power between the two lightwaves</u>**... The local oscillator lightwave on optical path, 13, is interfered with the composite lightwave on optical path 11. **The interference power is photodetected in optical receiver, 15, by optically interfering the composite back propagating lightwave on the local oscillator signal**. As one of the components of this interfering action, there is produced a difference beat signal which is a composite radio frequency representation of the composite light wave on optical path, 11.

(*Id.* at c.19, l.33-53; see Figures 3, 4; emphasis added);

> **The interrogation lightwave is propagated from optical modulator, 5, to optical coupler, beamsplitter or circulator, 7. The interrogation lightwave passes through the optical coupler, 7, into optical fiber or other light propagation medium, 9**. Hereinafter, "down", indicates a transversal on the optical path, 9, away from coupler, 7; **"up" indicates a transversal on the optical path 9 toward the optical coupler, beamsplitter or circulator, 7**. The

> interrogation lightwave which transverses down the optical fiber or medium 9 is modulated ... **The composite lightwave propagates up the optical fiber or medium 9, passes through optical coupler, beamsplitter or circulator, 7**, to optical pathway, 11. **Optical pathway, 11, passes the backscattered, time-delay multiplexed, composite lightwave, $E_b(t)$, to the optical receiver, 15**.

(*Id.* at c.16, l. 1 – c.17, l.14; see Figure 3; emphasis added). The Examiner finds that the '971 patent provides two embodiments of the "heterodyne optical receiver", with Figure 4 being "preferred." (*Id.* at c.24, l. 25 – c.25, l.11; see Figures 4-5; emphasis added).

Thus, in light of the portions of the '971 patent cited above, the Examiner concludes the structure for performing the FFP3 of Patent Claim 21 (*i.e.*, the Narrow Claim 21 Optical Receiver) as a heterodyne optical receiver having either all of the required the characteristics of Figure 4 or 5.

(4) Functional Phrase

The Examiner finds that Patent Claim 21 expressly recites:

> *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 [Emphasis added.]

"Functional Phrase 4" or "FP4" – From Patent Claim 21.

To invoke 35 U.S.C. § 112 6th paragraph, a claimed phrase must meet the three (3) prong analysis as set forth in MPEP § 2181 I.

i. 3-Prong Analysis: Prong (A)

Because FP4 expressly recites a “means for,” the Examiner concludes that FP4 meets Invocation Prong (A).

ii. 3-Prong Analysis: <u>Prong (B)</u>

Based upon a review of FP4, the Examiner finds that claimed function is:

performing a corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal

- “Function of Functional Phrase 4” or “FFP4.”

Because FP4 recites the above recited function, the Examiner concludes that FP4 meets Invocation Prong (B).

iii. 3-Prong Analysis: <u>Prong (C)</u>

Thus, based upon a review of the entire FP4, the Examiner concludes that FP4 does not contain sufficient structure for performing the entire claimed function of FP4.[5] In fact, the Examiner finds that the Functional Phrase 4 recites very little structure (if any) for performing the claimed function.

Because the Functional Phrase 4 does contain insufficient structure for performing the entire claimed functions, the Examiner concludes that the FP4 meets Invocation Prong (C).

In conclusion, because FP4 meets the three prong analysis set forth in MPEP §2181 I., the Examiner concludes that Functional Phrase 2 invokes 35 U.S.C. §112, 6th paragraph.

iv. Corresponding structure for Functional Phrase #4

[5] *Id.*

Once a claimed phrase invokes 35 U.S.C. § 112 6th paragraph, the next step is to determine the corresponding structure. (MPEP § 2181 II).

The Examiner has again carefully reviewed the original disclosure to determine the corresponding structure for FP4. In reviewing the original disclosure, the Examiner finds that the '971 patent discloses

> [t]he resulting composite radio frequency signal at output, **17**, represents electronically the composite lightwave signal on optical path, **11**. **The composite electronic receiver signal is passed from optical receiver output, 17, through amplifier, 19, via electronic path, 21, to the correlator system, 23**.

('971 patent at c.19, ll.39-44; see Figures 3, 6; emphasis added);

> [t]he correlator system delays the master correlation code generator output, **51**, an appropriate amount and correlates the delayed correlation code with the composite radio frequency signal. This produces electrical outputs O_1, O_2. . . O_n corresponding to signals S_1, S_2 . . . S_n, in turn corresponding to spatial delays L_1, L_2 . . . L_n. The spatial delays L_1, L_2 . . . L_n are arbitrary and programmable. The electrical output O_1 corresponds to B(t, L_1) referred to in the preceding subsection 2(a).
>
> The correlation process is well understood in the literature. The signal that represents the backscattered optical wave in array, **9**, that is passed from the optical receiver **15**, **to the correlator system 23**, contains all of the information for all sensors or channels S_1, S_2 . . . S_n at once on the electronic signal path **21** entering the correlator **23**. Because the backscattered composite signal is modulated with the correlation code by modulator **5**, **the backscattered light is time structured with the time structure of the correlation code**. **Because the correlation code is selected to have special autocorrelation code properties, the time structure of the correlation codes allows an electronic representation of the backscattered light at positions L_1, L_2 . . . L_n to be obtained via the correlation process in the correlator 23**.

('971 patent at c.20, l. 50 – c.21, l.5; see Figure 3; emphasis added). The Examiner finds that the '971 patent provides an embodiment of the "correlator system", with Figure 6 being "an example implementation of the correlation system." (*Id.* at c.25, ll.12-67; see Figure 6; emphasis added).

Thus, in light of the portions of the '971 patent cited above, the Examiner concludes the structure for performing the FFP4 of Patent Claim 21 (*i.e.*, the Narrow Claim 21 Correlator) as a correlator system having all of the required characteristics of Figure 6.

In light of the invocation of 35 U.S.C. § 112 6th paragraph in Patent Claim 21, the Examiner finds that any new claim similar to Patent Claim 21 must include the claim requirements of the Functional Phrases as set forth above in order to not be interpreted as broadened. (See §§ X.A.(1)-(4) above).

The Examiner finds that RI Claim 23 does not include the light source that is a transmitter laser that is of the non-planar, ring-type. The Examiner finds that RI Claim 23 does not include the optical receiver that is a heterodyne optical receiver having either the characteristics of Figure 4 or 5. The Examiner finds that RI Claim 23 does not include a processor that is a correlator system having all of the required characteristics of Figure 6. The Examiner finds that RI Claim 23 does not include any recitation to a directional/lightwave optical coupler, beamsplitter or circulator.

Thus, the Examiner concludes that RI Claim 23 is broadened at least by deleting/omitting the patent claim language requiring:

means for illuminating an optical fiber span with a CW optical signal

("Claim 23 Light Source Omission"; *i.e.*, **a transmitter laser that is of the non-planar, ring-type**; emphasis added);

means for retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span

("Claim 23 Lightwave Coupler Omission"; *i.e.*, **a directional/lightwave optical coupler, beamsplitter or circulator**; emphasis added);

> **<u>means for performing a corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal</u> 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**

("Claim 23 First Optical Receiver Omission"; *i.e.*, **<u>a heterodyne optical receiver</u> having either the characteristics <u>of Figure 4 or 5</u>**; emphasis added);

> **<u>means for performing a corresponding plurality of autocorrelation detections upon said (r.f.) counterpart of the retrieved optical signal</u>** 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

("Claim 23 Correlator Omission"; *i.e.*, **<u>a correlator system</u> having all of the required characteristics <u>of Figure 6</u>**; emphasis added);

Thus, since these omissions provide claims which are greater in scope than each and every claim of the original patent, the Examiner concludes that at least new independent claim 23 and dependent claims thereof are broadened reissue claims, as compared to the claims of the '971 patent.

B. Method of Claims 31-38

With respect to the reissue claim 31 of the '161 Reissue Proceedings ("RI Claim 31"), the Examiner finds that RI Claim 31 recites a process claim that has not been previously presented in the '630 Proceedings. MPEP § 1412.03 states,

> [t]he addition of process claims as a new category of invention to be claimed in the patent (*i.e.*, where there were no method claims present in the original patent)

is generally considered as being a broadening of the invention. See *Ex parte Wikdahl*, 10 USPQ2d 1546 1549 (Bd. Pat. App. & Inter. 1989).

Thus, since Applicant has added claims to a new category of invention in the '161 Reissue Proceedings, the Examiner concludes that at least new independent claim 31 and dependent claims 32-38 thereof are broadened reissue claims. (See MPEP § 1412.03(III)).

XI. Rejections under 35 U.S.C. § 251

Claims 23-38 are rejected under 35 U.S.C. 251 as being broadened in a reissue application filed outside the two year statutory period. The Examiner finds that the claim limitations that broaden the scope of the reissue claims of the '161 Reissue Proceedings are identified and explained in § X above, which is incorporated by reference. A claim is broader in scope than the original claims if it contains within its scope any conceivable product or process which would not have infringed the original patent. A claim is broadened if it is broader in any one respect even though it may be narrower in other respects.

Claims 23-38 are rejected under 35 U.S.C. 251 as being improperly broadened in a reissue application made and sworn to by the assignee. The application for reissue may be made and sworn to by the assignee of the entire interest only if the application does not seek to enlarge the scope of the claims of the original patent or, for reissue applications filed on or after September 16, 2012, the application for the original patent was filed by the assignee of the entire interest under 37 CFR 1.46.

The Examiner finds that the claim limitations that broaden the scope of the reissue claims of the '161 Reissue Proceedings are identified and explained in § X above, which is incorporated by reference. A claim is broader in scope than the original claims if it contains within its scope any conceivable product or process which would not have infringed the original patent. A claim is broadened if it is broader in any one respect even though it may be narrower in other respects.

Claims 23-38 are rejected under 35 U.S.C. 251 as being based upon new matter added to the patent for which reissue is sought. The added material which is not supported by the prior patent is as follows:

The Examiner finds that there is insufficient indication in the specification that Applicant had possession of a system for detecting an acoustic signal and method for sensing that includes a light source that is not a laser. (See § XII below for further explanation)

Claims 23-38 are rejected as being based upon a defective reissue declaration under 35 U.S.C. 251 as set forth above. See 37 CFR 1.175.

The nature of the defect(s) in the declaration is set forth in the discussion above in this Office action. (See § V above, which is incorporated by reference).

XII. Rejections under 35 U.S.C. § 112

The following is a quotation of the first paragraph of pre-AIA 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

> The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:
> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 23-38 are rejected under 35 U.S.C. 112(a) or 35 U.S.C. 112 (pre-AIA), first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor or a joint inventor, or for pre-AIA the inventor(s), at the time the application was filed, had possession of the claimed invention. The Examiner finds that new independent claims 23 and 31 recite,

> a light source operative to provide a continuous wave (CW) optical signal

(Nov 2015 Claim Amendment, claim 23); and

> illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation

(Nov 2015 Claim Amendment, claim 31). The Examiner finds that the 'light source' and 'illuminating step' provide a 'continuous wave optical signal' that is either modulated or potentially both (*i.e.*, modulated or un-modulated). The Examiner finds that the 'light source' and 'illuminating step' inherently include both 'coherent' and 'incoherent' light sources. The Examiner finds that new claims 23 and 31 have insufficient claim limitations requiring the 'light source' or 'illuminating' to be performed by another light source other than a laser as the '971 patent requires (*i.e.*, an incoherent light source such as an LED, etc.). (See Claim 23 Light Source Omission discussion in § X above). To support the Examiner's position that only a 'laser' is required to be the light source, the Examiner finds that the '971 patent states,

> FIG. 3 is an illustrative block diagram implemention [*sic*] of the Rayleigh optical scattering and encoding (ROSE) sensor system **2**. Like parts correspond to like numbers. A lightwave from transmitter laser, 3, is propagated through optical coupler or beamsplitter, 4. The smaller portion of the transmitter laser power split off by optical coupler, **4**, is passed by optical path, **39**, to the phase locking means optical receiver **35**. **The larger portion of the transmitter laser light power is split by optical coupler, 4, and propagated to optical modulator, 5**. The optical modulator, **5**, modulates the laser light passing from optical coupler, **4**, with correlation code, c(t), as electronically generated in master correlation code generator, **53**, and amplified by amplifier, **49**. The correlation code, c(t), is modulated onto the laser light in optical modulator, **5**. This modulated light comprises the optical interrogation lightwave, $E_i(t)$. The optical modulator, **5**, may modulate the amplitude, polarization or phase of the laser light subject to the teachings of the invention. **The interrogation lightwave is propagated from optical modulator, 5, to optical coupler, beamsplitter or circulator, 7. The interrogation lightwave passes through the optical coupler, 7, into optical fiber or other light propagation medium, 9**.

('971 patent at c.15, l.51 – the c.16, l.5; see Figure 3; emphasis added); and

> In accordance with the present invention, **lasers 3** and **45** are to have sufficiently stringent high performance capability with respect to exactness of frequency to enable interference effects therebetween and heterodyne detection of acoustic perturbation signals incident to fiber **9** to produce beat frequencies within the radio frequency (r.f.) range. Also in accordance with the present invention, **lasers 3** and **45** have stringent performance criteria with respect to the phase stability, or coherence, of their beams. They are to be substantially coherent over at least a propagation path distance substantially equal to twice the length, L, of sensing fiber **9**. **For example, a commercially available non-planar, ring laser (e.g. Lightwave Electronics Corp. Model 125) would be suitable for an intruder sensing perimeter intrusion monitoring fiber 9 having a length of 8.0 km** (approximately 5 miles). The laser beam of this commercially available laser, which is in the near infrared range, has a frequency of 227 terahertz, or 1319 nanometer wavelength, and has a frequency stability accurately within one part in a billion over 1 millisecond period, or 5 Kilohertz in a 1 millisecond period.

('971 patent at c.20, ll.1-21; emphasis added).

As set forth above, the Examiner finds that the Claim 23 Light Source Omission includes:

a first light source for producing **a coherent carrier lightwave signal of a first predetermined wavelength**;

means for illuminating an optical fiber span with a CW optical signal;

> **A transmitter laser...** to illuminate an optical fiber span with a CW optical signal...

(Claim 23 Light Source Omission; emphasis added). The Examiner finds that 'a coherent light wave signal of a predetermined wavelength' as recited in Patent Claim 1 is inherently produced by a laser since only a laser produces 'coherent' lightwave signals. The Examiner finds that the 'means for illuminating an optical fiber span with a CW optical signal' as recited in Patent Claim 21 invokes 112 6th, paragraph, and as such, is a transmitter laser that is of the non-planar, ring-type, as the '971 patent discloses. ('971 patent at c.15, l.51 – c.16, l.5; see Figure 3; see § X.A.(1) above for analysis). The Examiner finds that Patent Claim 22 explicitly recites 'a transmitter laser'. Therefore, the Examiner finds that there is only support for a light source being a transmitter laser that provides a coherent carrier continuous wave optical signals.

Thus, as such, the Examiner concludes that there is insufficient indication in the specification that Applicant had possession of a system for detecting an acoustic signal and method for sensing that includes a light source that is not a laser.

Claims 24-30 and 32-38 are similarly rejected based on their dependency from independent claims 23 and 31.

Claims 23-38 are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

Claim 23 recites the limitation "said/the span" in lines 3, 13 and 14. There is insufficient antecedent basis for this limitation in the claim. The Examiner finds that claim 23 initially recites “a span of optical fiber” in line 2. The Examiner further finds that claims 28-30 recite the limitation “said span of optical fiber” in lines 1-2. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said span of optical fiber– where appropriate. The claims will be examined as such.

Similarly, claim 31 recites the limitation "the span" in lines 3-4, 6, 9, 12 and 22. There is insufficient antecedent basis for this limitation in the claim. The Examiner finds that claim 31 initially recites “a span of optical fiber” in line 2. The Examiner further finds that claims 36-38 recite the limitation “said span of optical fiber” in lines 1-2. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said span of optical fiber– or –said coated span of optical fiber– where appropriate. The claims will be examined as such.

Claim 23 recites the limitation "the modulated CW optical fiber" in lines 12-13. There is insufficient antecedent basis for this limitation in the claim. The Examiner further queries Applicant to whether this recitation should be –the modulated CW optical signal–, since the CW optical signal is modulated in claim 23. (Nov 2015 Claim Amendment, claim 23). Further clarification and appropriate correction is required.

Claim 23 recites the limitation "the counterpart signal" in lines 23-24. There is insufficient antecedent basis for this limitation in the claim. The Examiner finds that claim 23 initially recites “a radio frequency (r.f.) counterpart signal” in lines 20-21. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said r.f. counterpart signal– where appropriate. The claims will be examined as such.

Claim 23 recites the limitation "said receiver" in line 18. There is insufficient antecedent basis for this limitation in the claim. The Examiner finds that claim 23 initially recites “an optical receiver” in line 15. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said optical receiver– where appropriate. The claims will be examined as such.

Claim 23 recites the limitation “sensing zone segments” in lines 4-5 and 18. The Examiner queries Applicant to how instances of “sensing zone segments” are required in claim 23. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said sensing zone segments– where appropriate. The claims will be examined as such.

Claim 23 recites the limitation,

> a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.

(Nov 2015 Claim Amendment, claim 23). The Examiner finds that claim 23 requires a processor to receive information and utilize two inputs to "give at least one signal for each zone segment." The Examiner queries Applicant to how a processor, that is utilized to process data produced from the regions the span of optical fiber, can give at least one signal for each zone segment. Further clarification s required.

Claim 29 recites the limitation "the polarization preserving type of optical fiber" in lines 2-3. The Examiner finds that it is unclear and indefinite to what exactly constitutes ‘polarization preserving type’ (emphasis added). Further clarification is required.

Claim 31 recites the limitation "the illumination" in line 11. There is insufficient antecedent basis for this limitation in the claim.

Claim 31 recites the limitation "the counterpart signal" in line 17. There is insufficient antecedent basis for this limitation in the claim. The Examiner finds that claim 31 initially recites “a radio frequency (r.f.) counterpart signal” in line 16. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said r.f. counterpart signal– where appropriate. The claims will be examined as such.

Claim 31 recites the limitation “sensing zone segments” in lines 3-4 and 22. The Examiner queries Applicant to how instances of “sensing zone segments” are required in claim 23. In order to provide clear and consistent language through the claims, the Examiner suggests Applicant recite –said sensing zone segments– where appropriate. The claims will be examined as such.

Claim 33 recites the limitation "the light source" in line 2; and claim 35 recites the limitation "the light source" in 1. There is insufficient antecedent basis for this limitation in the claims.

Claim 37 recites the limitation "said span of optical fiber is made from the polarization preserving type of optical fiber" in lines 2-3. The Examiner finds that it is unclear and indefinite to what exactly constitutes ‘polarization preserving type’ (emphasis added). Further clarification is required.

In general, the claims are replete with such 35 U.S.C. 112, second paragraph issues. The above notes are exemplary with respect to all of the 35 U.S.C. 112, second paragraph rejections present in the instant case, all claims must be carefully reviewed and appropriate corrections should be made in response to this rejection.

The Examiner finds that because claims 23-38 are indefinite under 35 U.S.C. §112 second paragraph as outlined above, it is impossible to properly construe claim scope at this time. See *e.g. Honeywell International Inc. v. ITC*, 68 USPQ2d 1023, 1030 (Fed. Cir. 2003) ("Because the claims are indefinite, the claims, by definition, cannot be construed."). However, in accordance with MPEP § 2173.06 and the USPTO's policy of trying to advance prosecution by providing art rejections even though these claim are indefinite, the claims are construed and the art is applied as much as practically possible.

XIII. Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the claims at issue are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed.

Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); In re Vogel, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the reference application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159. See MPEP §§ 706.02(l)(1) - 706.02(l)(3) for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit www.uspto.gov/forms/. The filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to http://www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

A. U.S. Reissue Application No. 14/741,857

Claims 23, 25, 27-31, 33 and 35-38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23-36 ("***'857 ODP Claims***") of copending Application No. 14/741,857 ("'857 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings are merely broader in scope than that of the '857 RI Application. Therefore, the '857 RI Application system for monitoring characteristics along the length of a well casing structure meets the limitations of the instant application. For example, by comparing the pending claims 23, 25, 27-31, 33 and 35-38 and the *'857 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	System Claims of '857 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the**	**Pending Claim 30**: 30. **A system** for monitoring characteristics along the length of a well casing structure, comprising: **a span of optical fiber inserted along the length of the well casing structure wherein the span provides multiple sensing locations along its length, each sensing location being responsive to acoustic pressure waves proximate the location;** **a light source operative to illuminate said span with a continuous wave (CW) optical signal, said span being capable of providing back-propagating illumination from each sensing location;** **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation;** **an optical receiver joined to said span and**

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retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.

Pending Claim 25:

25. The system of claim 23, wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L.

Pending Claim 27:

27. The system of claim 23, wherein said light source is a planar, ring-type laser.

Pending Claim 28:

28. The system of claim 23, wherein said span of optical fiber comprises a single mode fiber optic cable.

Pending Claim 29:

29. The system of claim 23, wherein said span of optical fiber is made from the
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capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises the phase shifted back-propagating portions of the illumination from locations along said span, said receiver operative to produce an radio frequency (r.f.) counterpart signal of the retrieved optical signal;

an autocorrelation detector operative to perform

autocorrelation detections upon the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals associated with the sensing locations; and

a processor operative to utilize the signals associated with the sensing locations to monitor characteristics proximate to the well casing structure.

Pending Claim 31:

31. The system of claim 30, wherein said span of optical fiber has a length L, and said light source is a laser having the capability to generate a lightwave signal with sufficient phase stability to substantially retain coherency in propagation along said span for a distance at least equal to two times length L.

Pending Claim 33:

33. The system of claim 31, wherein said light source is a planar, ring-type laser.
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polarization preserving type of optical fiber. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 34**: 34. The system of claim 30, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 35**: 35. The system of claim 30, **wherein said span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 36**: 36. The system of claim 30, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident on said span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.

Method Claims of '161 Reissue Proceedings — Method Claims of '857 RI Application

Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated**	**Pending Claim 23**: 23. **A method for monitoring characteristics along the length of a well casing structure,** comprising: **inserting a span of optical fiber along the length of the well casing structure wherein the span provides multiple virtual sensors along its length, individual ones of the multiple virtual sensors responsive to acoustic pressure waves imparted into the**

continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.** **Pending Claim 33**: 33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 35**: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**.	**ground;** **illuminating the inserted span with a continuous wave (CW) optical signal light source;** **modulating the CW optical signal with a reiterative autocorrelatable form of modulation;** **receiving a backscattered light signal from the span that comprises back-propagating portions of illumination associated with the light source that are back propagating from locations that correspond to various time delay relationships along the optical fiber span to produce an radio frequency (r.f.) counterpart of the backscattered light signal;** **performing autocorrelation detections upon the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals from the multiple virtual sensors**; and **identifying characteristics proximate to the well casing structure utilizing the signals from the multiple virtual sensors**. **Pending Claim 24**: 24. The method of claim 23, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**.

Pending Claim 36: 36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**.	**Pending Claim 26**: 26. The method of claim 23, **wherein the light source is a planar, ring-type laser**.
Pending Claim 37: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**.	**Pending Claim 27**: 27. The method of claim 23, **wherein the span of optical fiber comprises a single mode fiber optic cable**.
Pending Claim 38: 38. The method of claim 31, **wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 28**: 35. The method of claim 23, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 29**: 29. The method of claim 23, **wherein the span of optical fiber has a coating thereon 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident on the span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.

The Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘857 ODP Claims*, just somewhat broader. (See comparison above). In addition, where 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings and the *‘857 ODP Claims* are not exactly the same, the Examiner finds that claims

23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'857 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'857 ODP Claims*** of the '857 RI Application in view of ***Kersey et al. '806*** (U.S. Patent No. 6,285,806).[6]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'857 ODP Claims*** of the '857 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[7]

This is a provisional nonstatutory double patenting rejection.

B. U.S. Reissue Application No. 14/741,892

Claims 23 and 31 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 30, 31, 33, 40 and 41 ("***'892 ODP Claims***") of copending Application No. 14,741,892 ("'892 RI Application").

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[6] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806* below for *prima facie* teachings of claim requirements and obviousness.
[7] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23 and 33 are identical or similar and/or covered by the *'892 ODP Claims*. For example, by comparing the pending claims 23 and 33 and the *'892 ODP Claims* shown below:

Claims of '161 Reissue Proceedings	Claims of '892 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding**	**Pending Claim 23**: 23. **A system** for the interrogation of an optical fiber span, comprising: **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator** operative **to modulate the CW optical signal with a reiterative autocorrelatable form of modulation and to illuminate the optical fiber span with the modulated CW optical signal**; **an optical receiver joinable to the optical fiber span and operative to receive a backscattered signal from the optical fiber span that comprises back-propagating portions of illumination from locations in the optical fiber span that correspond to various time delay relationships utilizing a heterodyne operation to produce a radio frequency (r.f.) counterpart signal of the received backscattered signal**; **a correlator** operative **to correlate the counterpart signal to a plurality of signals from the locations in the optical fiber span by utilizing the reiterative autocorrelatable form of modulation of the CW optical signal;** a demodulator operative to demodulate the plurality of signals from the locations into at

plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment. **Pending Claim 31**: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.**	least a first phase signal and a second phase signal; and a signal combiner operative to combine at least the first phase signal and the second phase signal to determine a measure of the phase difference of the signals incident at locations on the optical fiber span. **Pending Claim 30**: 30. The system according to claim 23, **wherein said modulator utilizes pulse modulation**. **Pending Claim 31**: 31. The system according to claim 30, **wherein pulse modulation is a composite of at least two pulsed signals having different frequencies**. 33. **A method for sensing signals from an optical fiber span** comprising the steps of: **providing a continuous wave (CW) optical signal**; **modulating the CW optical signal with a reiterative autocorrelatable form of modulation**; **illuminating the optical fiber span with the modulated CW optical signal wherein signals incident to the span induce light path changes at regions of the span responsive to the signals resulting in a phase shifted back-propagating signal**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal**

	comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal, wherein the counterpart signal is a beat signal**; **correlating the counterpart signal utilizing the reiterative autocorrelatable form of modulation to produce a plurality of signals from locations in the fiber optic span**; demodulating individual ones of the plurality of signals from the locations into at least a first phase signal and a second phase signal; and combining at least the first phase signal and the second phase signal to determine a measure of the phase difference of the signal incident at locations on the optical fiber span. **Pending Claim 30**: 40. The method according to claim 33, **wherein the step of modulating utilizes pulse modulation**. **Pending Claim 41**: 31. The method according to claim 40, **wherein the pulse modulation includes at least two pulsed signals having different frequencies**.

The Examiner finds that claims 23 and 31 of the '161 Reissue Proceedings have essentially the same claim requirements as the *'892 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23 and 31 of the '161 Reissue Proceedings and the *'892 ODP Claims* are not exactly the same, the Examiner finds that claims 23 and 31 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'892 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24, 25, 32 and 33 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[8]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[9]

This is a provisional nonstatutory double patenting rejection.

[8] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24, 25, 32 and 33 over *Kersey et al.'806* below for *prima facie* teachings of claim requirements and obviousness.
[9] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 26 and 34 over *Kersey et al.'806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

Claims 27 and 35 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of in view of ***Nilsson*** (U.S. Patent No. 5,177,764).[10]

This is a provisional nonstatutory double patenting rejection.

Claims 28 and 36 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of in view of ***Groves-Kirkby*** (UK Publication No. GB 2372100 A) and ***Bailey et al.*** (U.S. Patent No. 6,626,043).[11]

This is a provisional nonstatutory double patenting rejection.

Claims 29 and 37 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of in view of ***Townley-Smith et al***. (U.S. Publication No. 2005/0077455).[12]

This is a provisional nonstatutory double patenting rejection.

Claims 30 and 38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'892 ODP Claims*** of the '892 RI Application in view of in view of ***Goldner et al***. (International Publication No. WO 2004/034096).[13]

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[10] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 27 and 35 over *Kersey et al. '806* and *Nilsson* below for *prima facie* teachings of claim requirements and obviousness.
[11] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 28 and 36 over *Kersey et al. '806*, *Groves-Kirkby* and *Bailey et al.* below for *prima facie* teachings of claim requirements and obviousness.
[12] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 29 and 37 over *Kersey et al. '806* and *Townley-Smith et al.* below for *prima facie* teachings of claim requirements and obviousness.

This is a provisional nonstatutory double patenting rejection.

C. U.S. Reissue Application No. 14/741,768

Claims 23, 25, 27-29, 31, 33 and 35-37 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23-32 ("***'768 ODP Claims***") of copending Application No. 14,741,768 ("'768 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23, 25, 27-29, 31, 33 and 35-37 are identical or similar and/or covered by the *'768 ODP Claims*. For example, by comparing the pending claims 23, 25, 27-31, 33 and 35-38 and the *'768 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings System Claims of '768 RI Application

Pending Claim 23:	**Pending Claim 23**:
23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW**	23. **A system** to detect electromagnetic fields **comprising:** **a span of optical fiber having sensing zone segments wherein electromagnetic signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signals**; **a light source operative to provide a continuous wave (CW) optical signal;** **a modulator** operative **to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW**

[13] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 29 and 37 over *Kersey et al. '806* and *Goldner et al.* below for *prima facie* teachings of claim requirements and obviousness.

optical fiber to the span; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**. **Pending Claim 27**: 27. The system of claim 23, **wherein said light source is a planar, ring-type laser**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**.	**optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give a measurement representative of the electromagnetic field proximate to at least one zone segment.** **Pending Claim 24**: 24. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times the length L**. **Pending Claim 25**: 25. The system of claim 23, **wherein said light source is a planar, ring-type laser**. **Pending Claim 26**: 26. The system of claim 23, **wherein said span of optical fiber comprises a single**

Pending Claim 29: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**.	**mode fiber optic cable**. **Pending Claim 27**: 27. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**.

Method Claims of '161 Reissue Proceedings — Method Claims of '768 RI Application

Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect**	**Pending Claim 28**: 28. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein electromagnetic signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation;** **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes;** **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and** **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of**

to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span. **Pending Claim 33**: 33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 35**: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**. **Pending Claim 36**: 36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 37**: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**.	**different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span responsive to the electromagnetic signal at the sensing zone segment**. **Pending Claim 29**: 29. The method of claim 28, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 30**: 30. The method of claim 28, **wherein said light source is a planar, ring-type laser**. **Pending Claim 31**: 31. The method of claim 23, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 32**: 32. The method of claim 23, **wherein said span of optical fiber comprises a fiber optic cable of the polarization preserving type**.

The Examiner finds that claims 23, 25, 27-29, 31, 33 and 35-37 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘768 ODP Claims*, just somewhat broader.

(See comparison above). In addition, where claims 23, 25, 27-29, 31, 33 and 35-37 of the '161 Reissue Proceedings and the *'768 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 27-29, 31, 33 and 35-37 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'768 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'768 ODP Claims*** of the '768 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[14]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'768 ODP Claims*** of the '768 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[15]

This is a provisional nonstatutory double patenting rejection.

[14] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806* below for *prima facie* teachings of claim requirements and obviousness.
[15] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

Claims 30 and 38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'768 ODP Claims*** of the '768 RI Application in view of in view of ***Goldner et al***. (International Publication No. WO 2004/034096).[16]

This is a provisional nonstatutory double patenting rejection.

D. U.S. Reissue Application No. 14/686,170

Claims 23, 25, 27-31, 33 and 35-38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 26-31 and 34-38 ("***'170 ODP Claims***") of copending Application No. 14/686,170 ("'170 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings are merely broader in scope than that of the '170 RI Application. Therefore, the '170 RI Application system and method for sensing meets the limitations of the instant application. For example, by comparing the pending claims 23, 25, 27-31, 33 and 35-38 and the *'170 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	System Claims of '170 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein**	**Pending Claim 23**: 23. **A system** for detecting **an acoustic signal** comprising: **a span of optical fiber** wherein signals incident to said span have a property of inducing light path changes at regions of the span that result in a back-propagating signal;

[16] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 29 and 37 over *Kersey et al. '806* and *Goldner et al.* below for *prima facie* teachings of claim requirements and obviousness.

each zone segment has a specialized sensing function;

a light source operative to provide a continuous wave (CW) optical signal;

a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span;

an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.

Pending Claim 25:

25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**.

Pending Claim 27:

a coating disposed on said span being capable of enhancing strain variation derived from the acoustic signal incident on said span;

a light source operative to provide a continuous wave (CW) optical signal;

a modulator operative **to modulate the CW optical signal with a reiterative autocorrelatable form of modulation**, said modulator providing the modulated CW optical fiber to the span;

an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from locations along said span, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal, wherein the counterpart signal is in phase locked synchronism with the CW optical signal; and

a processor joined to receive the counterpart signal and capable utilizing the reiterative autocorrelatable form of modulation and a plurality of different timed relationships to give signals from regions of said span.

Pending Claim 26:

26. The system of claim 23, **wherein said span of optical fiber has a length L, and said light source is a laser having the capability to generate a lightwave signal with sufficient phase stability to substantially retain coherency in**

27. The system of claim 23, **wherein said light source is a planar, ring-type laser**.	**propagation along said span for a distance at least equal to two times length L**.
Pending Claim 28:	**Pending Claim 27**:
28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**.	27. The system of claim 23, **wherein said light source is a planar, ring-type laser**.
Pending Claim 29:	**Pending Claim 28**:
29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**.	28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**.
Pending Claim 30:	**Pending Claim 29**:
30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**.
	Pending Claim 30:
	30. The system of claim 23, **wherein said coating is 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**.

Method Claims of '161 Reissue Proceedings	Method Claims of '170 RI Application
Pending Claim 31:	**Pending Claim 31**:
31. **A method for sensing** comprising the steps of:	31. **A method for sensing** comprising the steps of:

providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal; **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.** **Pending Claim 33**: 33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**.	**providing a coated span of optical fiber wherein signals incident to the span induce light path changes at regions of the span responsive to the signals resulting in a back-propagating signal, said coating of the span being made of a material capable of enhancing strain variation in the span**; **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes;** **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from regions of the span**. **Pending Claim 34**: 34. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**.

Pending Claim 35: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**. **Pending Claim 36**: 36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 37**: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 38**: 38. The method of claim 31, **wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 35**: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**. **Pending Claim 36**: 36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 37**: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type.** **Pending Claim 38**: 38. The method of claim 31, **wherein the coating of the span is 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**. **span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.

The Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘170 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 25, 27-31, 33 and 35-38 of the ‘161

Reissue Proceedings and the *'170 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'170 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'170 ODP Claims*** of the '170 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[17]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'170 ODP Claims*** of the '170 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[18]

This is a provisional nonstatutory double patenting rejection.

E. U.S. Reissue Application No. 14/686,194

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[17] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806* below for *prima facie* teachings of claim requirements and obviousness.
[18] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

Claims 23, 25, 27-31, 33 and 35-38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 29-34 and 40-42 ("***'194 ODP Claims***") of copending Application No. 14/686,194 ("'194 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings are merely broader in scope than that of the '194 RI Application. Therefore, the '194 RI Application system and method for sensing meets the limitations of the instant application. For example, by comparing the pending claims 23, 25, 27-31, 33 and 35-38 and the *'194 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	System Claims of '194 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the**	**Pending Claim 34**: 34. **A system** for monitoring characteristics of an oil line comprising: **a span of optical fiber proximate to or within the oil line wherein the span provides multiple sensing locations along its length, each sensing location being responsive to acoustic pressure waves proximate the location**; **a light source operative to illuminate said span with a continuous wave (CW) optical signal, said span being capable of providing back-propagating illumination from each sensing location**; **a modulator** operative **to modulate the CW optical signal with a reiterative autocorrelatable form of modulation**; **an optical receiver joined to said span and capable of receiving a retrieved optical**

retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.

Pending Claim 25:

25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**.

Pending Claim 27:

27. The system of claim 23, **wherein said light source is a planar, ring-type laser**.

Pending Claim 28:

28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**.

Pending Claim 29:

29. The system of claim 23, **wherein said span of optical fiber is made from the**

signal returned therefrom, wherein the retrieved optical signal comprises the phase shifted back-propagating portions of the illumination from locations along said span, said receiver operative to produce an electrical counterpart signal of the retrieved optical signal;

an autocorrelation detector operative to perform autocorrelation detections upon the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals associated with the sensing locations; and

a processor operative to utilize the signals associated with the sensing locations to monitor characteristics of the oil line related to mechanical strain, pressure, and thermal strain.

Pending Claim 40:

40. The system of claim 34, **wherein said span of optical fiber has a length L, and said light source is a laser having the capability to generate a lightwave signal with sufficient phase stability to substantially retain coherency in propagation along said span for a distance at least equal to two times length L**.

Pending Claim 41:

41. The system of claim 34, **wherein said span of optical fiber comprises a fiber optic cable of the polarization preserving type**.

polarization preserving type of optical fiber. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 42**: 42. The system of claim 34, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**.

Method Claims of '161 Reissue Proceedings	Method Claims of '194 RI Application
Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**;	**Pending Claim 23**: 23. **A method for monitoring characteristics of an oil line** comprising: **inserting a span of optical fiber** proximate to or within the oil line **wherein the span provides multiple virtual sensors along its length, individual ones of the multiple virtual sensors responsive to acoustic pressure waves imparted to the span;** **illuminating the inserted span with a continuous wave (CW) optical signal light source**; **modulating the CW optical signal with a reiterative autocorrelatable form of modulation**; **receiving a backscattered light signal from the span that comprises back-propagating**

producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and

detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.

Pending Claim 33:

33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**.

Pending Claim 35:

35. The method of claim 31, **wherein the light source is a planar, ring-type laser**.

Pending Claim 36:

36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**.

Pending Claim 37:

37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic**

portions of illumination associated with the light source that are back propagating from locations that correspond to various time delay relationships along the optical fiber span to produce an electrical counterpart of the backscattered light signal;

performing autocorrelation detections upon the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals from the multiple virtual sensors; and

identifying signals from the multiple virtual sensors as being caused by at least one of mechanical strain, pressure, and thermal strain proximate to at least one of the multiple virtual sensors.

Pending Claim 27:

27. The method of claim 23, **further comprising analyzing at least one signal from the multiple virtual sensors to detect a variation in frequency for that signal**.

Pending Claim 28:

28. The method of claim 27, **wherein said step of analyzing further comprises determining the extent of the variation in frequency**.

Pending Claim 29:

29. The method of claim 23, **wherein the light source is a planar, ring-type laser**.

cable of the polarization preserving type. **Pending Claim 38**: 38. The method of claim 31, **wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 30**: 30. The method of claim 23, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 31**: 31. The method of claim 23, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 32**: 32. The method of claim 23, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 33**: 33. The method of claim 23, **wherein the span of optical fiber has a coating thereon 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**.

The Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘194 ODP Claims*, just somewhat broader.

(See comparison above). In addition, where claims 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings and the *‘194 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the ‘161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *‘194 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***‘194 ODP Claims*** of the ‘194 RI Application in view of ***Kersey et al.’806*** (U.S. Patent No. 6,285,806).[19]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***‘194 ODP Claims*** of the ‘194 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[20]

This is a provisional nonstatutory double patenting rejection.

F. U.S. Reissue Application No. 14/686,205

[19] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.’806* below for *prima facie* teachings of claim requirements and obviousness.
[20] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.’806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

Claims 23, 24, 31 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 29, 33, 38 and 39 ("***'205 ODP Claims***") of copending Application No. 14,686,205 ("'205 RI Application") in view of ***Goldner et al.*** (International Publication No. WO 2004/034096).

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23, 24, 31 and 32 are identical or similar and/or covered by the *'205 ODP Claims*. For example, by comparing the pending claims 23, 24, 31 and 32 and the *'205 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings System Claims of '205 RI Application

Pending Claim 23:	**Pending Claim 33**:
23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination**	33. **A system** comprising: **a span of optical fiber wherein signals incident to said span have a property of inducing light path changes at regions of the span that result in a phase shifted back-propagating signal**; **a compliant mandrel having a portion of said span of optical fiber wound thereon** wherein mandrel geometry is selected to be responsive to radial variations resulting in a magnified longitudinal strain in the portion of said span wound on the mandrel; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, wherein the modulation is one or more of a varying input pulse, a varying pulse separation or a varying duty cycle, said**

from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 24**: 24. The system of claim 23, **wherein at least one zone segment of said span is helically disposed**.	**modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises the phase shifted back-propagating portions of the illumination from locations along said span, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to:** **detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to obtain an acoustic signal from a portion of said span**, and provide an indication of a detection of a seismic vibration in an area of interest proximate said span**.** **Pending Claim 38**: 38. The system of claim 33, **wherein said modulator is capable of providing a pulse modulation to the CW optical signal**. **Pending Claim 39**: 39. The system of claim 33, **wherein said processor is operative to obtain acoustic signals from portions of said span having varying lengths**.

Method Claims of '161 Reissue Proceedings	Method Claims of '205 RI Application
Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.** **Pending Claim 32**: 24. The method of claim 31, **wherein said step of providing the span includes providing at least one sensing zone segment**	**Pending Claim 23**: 23. **A method for sensing** comprising the steps of: **providing a span of optical fiber** wherein portions of the span are helically disposed**, and signals incident to the span induce light path changes at regions of the span responsive to the signals resulting in a phase shifted back-propagating signal**; **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to identify signals from at least one region of the span representative of acoustic pressure waves incident on the region of the span**; and utilizing the signal from at least one region of the span to provide a detection of vibrations from the helically disposed region of the span.

of the span in a helical disposition.	**Pending Claim 29**: 29. The method of claim 23, **further comprising the step of applying an acoustic stimulus to the area of interest**.

The Examiner finds that claims 23, 24, 31 and 32 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘205 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 24, 31 and 32 of the ‘161 Reissue Proceedings and the *‘205 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 24, 31 and 32 of the ‘161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *‘205 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 25 and 33 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***‘205 ODP Claims*** of the ‘205 RI Application in view of ***Kersey et al.’806*** (U.S. Patent No. 6,285,806).[21]

This is a provisional nonstatutory double patenting rejection.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***‘205 ODP Claims*** of the ‘205 RI Application in view of

[21] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24, 25, 32 and 33 over *Kersey et al.’806* below for *prima facie* teachings of claim requirements and obviousness.

in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[22]

This is a provisional nonstatutory double patenting rejection.

Claims 27 and 35 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'205 ODP Claims*** of the '205 RI Application in view of in view of ***Nilsson*** (U.S. Patent No. 5,177,764).[23]

This is a provisional nonstatutory double patenting rejection.

Claims 28 and 36 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'205 ODP Claims*** of the '205 RI Application in view of in view of ***Groves-Kirkby*** (UK Publication No. GB 2372100 A) and ***Bailey et al.*** (U.S. Patent No. 6,626,043).[24]

This is a provisional nonstatutory double patenting rejection.

Claims 29 and 37 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'205 ODP Claims*** of the '205 RI Application in view of in view of ***Townley-Smith et al***. (U.S. Publication No. 2005/0077455).[25]

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[22] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 26 and 34 over *Kersey et al. '806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.
[23] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 27 and 35 over *Kersey et al. '806* and *Nilsson* below for *prima facie* teachings of claim requirements and obviousness.
[24] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 28 and 36 over *Kersey et al. '806*, *Groves-Kirkby* and *Bailey et al.* below for *prima facie* teachings of claim requirements and obviousness.
[25] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 29 and 37 over *Kersey et al. '806* and *Townley-Smith et al.* below for *prima facie* teachings of claim requirements and obviousness.

This is a provisional nonstatutory double patenting rejection.

Claims 30 and 38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'205 ODP Claims*** of the '205 RI Application in view of in view of ***Goldner et al***. (International Publication No. WO 2004/034096).[26]

This is a provisional nonstatutory double patenting rejection.

G. U.S. Reissue Application No. 14/741,822

Claims 23, 25-31 and 33-38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 25, 28-33, 35 and 38-42 ("***'822 ODP Claims***") of copending Application No. 14,741,822 ("'822 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23, 25-31 and 33-38 are identical or similar and/or covered by the *'822 ODP Claims*. For example, by comparing the pending claims 23, 25-31 and 33-38 and the *'822 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	System Claims of '822 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein**	**Pending Claim 23**: 23. **A system** for sensing input signals comprising: **a span of optical fiber** having a plurality of sensing stations positioned therealong **wherein signals incident to said span have a property of inducing light path changes at**

[26] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 29 and 37 over *Kersey et al. '806* and *Goldner et al.* below for *prima facie* teachings of claim requirements and obviousness.

each zone segment has a specialized sensing function; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**.	**regions of the span that result in a phase shifted back-propagating signal;** **a light source operative to provide a continuous wave (CW) optical signal;** **a modulator** operative **to modulate the CW optical signal with a reiterative autocorrelatable form of modulation,** wherein the modulation is one or more of a varying input pulse, a varying pulse separation or a varying duty cycle, **said modulator providing the modulated CW optical fiber to the span;** **a heterodyne optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises the phase shifted back-propagating portions of the illumination from locations along said span, said receiver operative to produce a radio frequency counterpart signal of the retrieved optical signal, wherein the counterpart signal is a beat signal; and** **a processor operative to:** **detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to identify at least a first portion of said span;** identify a first retrieved signal at a first time from the first portion of said span and determine the first retrieved signal phase; identify a second retrieved signal at a second time from the first portion of said span and determine the second retrieved signal phase;

Pending Claim 26: 26. The system of claim 25, **wherein the length L of said span is at least about 5 km**. **Pending Claim 27**: 27. The system of claim 23, **wherein said light source is a planar, ring-type laser**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 29**: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	compare the first retrieved signal phase with the second retrieved signal phase; and determine a measure of the rate of change of the first retrieved signal phase with the second retrieved signal phase. **Pending Claim 25**: 25. The system of claim 23, **wherein the signals incident to the span of optical fiber are at least one of acoustic pressure waves,** electromagnetic fields coupled to said span, mechanical strain or pressure on said span, thermal strain or pressure **induced in said span**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times the length L**. **Pending Claim 29**: 29. The system of claim 28, **wherein the length L of said span is less than about 40 km**. **Pending Claim 30**: 30. The system of claim 28, **wherein said laser is a planar, ring-type laser**.

	Pending Claim 31: 31. The system of claim 23, **wherein said span comprises at least one of a single-mode type**, multimode type, and **polarization preserving type fiber optic cable**. **Pending Claim 32**: 32. The system of claim 23, **further comprising a coating disposed on said span 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, wherein the coating enhances the longitudinal component of the signals incident to said span**.

Method Claims of '161 Reissue Proceedings — Method Claims of '822 RI Application

Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path**	**Pending Claim 33**: 33. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at regions of the span responsive to the signals resulting in a phase shifted back-propagating signal**; **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation,** wherein the modulation is at least one of a varying input pulse, a varying pulse separation and a varying duty cycle; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of**

changes; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span.**	**the illumination from locations along the span in response to induced light path changes;** **producing a radio frequency counterpart signal of the retrieved optical signal**, wherein the counterpart signal is a beat signal; **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to identify at least a first portion of the span**;
Pending Claim 33: 33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**.	identifying a first retrieved signal at a first time from the first portion of the span and determining the first retrieved signal phase; identifying a second retrieved signal at a second time from the first portion of the span and determining the second retrieved signal phase; comparing first retrieved signal phase with the second retrieved signal phase; and
Pending Claim 34: 34. The system of claim 33, **wherein the length L of said span is at least about 5 km**.	determining a measure of the rate of change of the first retrieved signal phase with the second retrieved signal phase.
Pending Claim 35: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**. **Pending Claim 36**: 36. The method of claim 31, **wherein the span of optical fiber comprises a single**	**Pending Claim 35**: 35. The system of claim 33, **wherein the signals incident to the span of optical fiber are at least one of acoustic pressure waves,** electromagnetic fields coupled to said span, mechanical strain or pressure on said span, thermal strain or pressure **induced in said span**.

mode fiber optic cable. **Pending Claim 37**: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 38**: 38. The method of claim 31, **wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	**Pending Claim 38**: 38. The method of claim 33, **wherein said span has a length L and is illuminated by a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along the span for a distance at least equal to two times the length L**. **Pending Claim 39**: 39. The system of claim 38, **wherein the length L of said span is less than about 40 km**. **Pending Claim 40**: 40. The method of claim 38, **wherein the span is illuminated by a planar, ring-type laser**. **Pending Claim 41**: 41. The method of claim 33, **wherein the span comprises at least one of a single-mode type**, multimode type, and **polarization preserving type fiber optic cable**. **Pending Claim 42**: 42. he [*sic*] method of claim 33, **wherein the step of providing a span of optical fiber comprises providing an optical fiber having 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, wherein the coating enhances the longitudinal component of the signals incident to the**

	span.

The Examiner finds that claims 23, 25-31 and 33-38 of the '161 Reissue Proceedings have essentially the same claim requirements as the *'822 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 25-31 and 33-38 of the '161 Reissue Proceedings and the *'822 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25-31 and 33-38 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'822 ODP Claims*.

This is a provisional nonstatutory double patenting rejection.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'822 ODP Claims*** of the '822 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[27]

This is a provisional nonstatutory double patenting rejection.

H. U.S. Reissue Application No. 14/686,188

Claims 23, 25, 27-31, 33 and 35-38 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 23, 29-34 and 39-42 ("***'188 ODP Claims***") of copending Application No. 14/686,188 ("'188 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings are merely

[27] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806* below for *prima facie* teachings of claim requirements and obviousness.

broader in scope than that of the '188 RI Application. Therefore, the '188 RI Application system and method for sensing meets the limitations of the instant application. For example, by comparing the pending claims 23, 25, 27-31, 33 and 35-38 and the *'188 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	System Claims of '188 RI Application
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding**	**Pending Claim 34**: 34. **A system** for monitoring integrity of a casing structure comprising: **a span of optical fiber** proximate to or within an oil line **wherein the span provides multiple sensing locations along its length, each sensing location being responsive to acoustic pressure waves proximate the location;** **a light source operative to illuminate said span with a continuous wave (CW) optical signal, said span being capable of providing back-propagating illumination from each sensing location;** **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation;** **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises the phase shifted back-propagating portions of the illumination from locations along said span, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal;** **an autocorrelation detector operative to perform autocorrelation detections upon**

plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment. **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**. **Pending Claim 27**: 27. The system of claim 23, **wherein said light source is a planar, ring-type laser**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 29**: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span has a coating made of a thermoplastic material having**	**the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals associated with the sensing locations**; and a processor operative to utilize the signals associated with the sensing locations to monitor integrity of the casing structure related to mechanically induced strain, pressure induced strain, electromagnetically induced strain, and thermally induced strain strain [*sic*]. **Pending Claim 39**: 39. The system of claim 34, **wherein said span of optical fiber has a length L, and said light source is a laser having the capability to generate a lightwave signal with sufficient phase stability to substantially retain coherency in propagation along said span for a distance at least equal to two times length L**. **Pending Claim 40**: 40. The system of claim 34, **wherein said light source is a planar, ring-type laser**. **Pending Claim 41**: 41. The system of claim 34, **wherein said span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 42**: 42. The system of claim 34, **wherein said**

the combined characteristics of a low Young's modulus and a Poisson's ratio below that of natural rubber, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates.	**span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**.

Method Claims of '161 Reissue Proceedings — Method Claims of '188 RI Application

Method Claims of '161 Reissue Proceedings	Method Claims of '188 RI Application
Pending Claim 31: 31. **A method for sensing** comprising the steps of: **providing a span of optical fiber wherein signals incident to the span induce light path changes at sensing zone segments of the span responsive to the signals resulting in a back-propagating signal;** **illuminating the span with a modulated continuous wave (CW) optical signal with a reiterative autocorrelatable form of modulation**; **receiving a retrieved optical signal from the span, wherein the retrieved optical signal comprises a back-propagating portions of the illumination from locations along the span in response to induced light path changes**; **producing a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **detecting the reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of**	**Pending Claim 23**: 23. **A method for monitoring integrity of a casing structure** comprising the steps of: **inserting a span of optical fiber** proximate to or within the casing structure **wherein the span provides multiple virtual sensors along its length, individual ones of the multiple virtual sensors responsive to acoustic pressure waves imparted to the span**; **illuminating the inserted span with a continuous wave (CW) optical signal light source**; **modulating the CW optical signal with a reiterative autocorrelatable form of modulation**; **receiving a backscattered light signal from the span that comprises back-propagating portions of illumination associated with the light source that are back propagating from locations that correspond to various time delay relationships along the optical fiber span to produce a radio frequency (r.f.) counterpart of the backscattered light signal**;

different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to provide signals from sensing zone segments of said span. **Pending Claim 33**: 33. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 35**: 35. The method of claim 31, **wherein the light source is a planar, ring-type laser**. **Pending Claim 36**: 36. The method of claim 31, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 37**: 37. The method of claim 31, **wherein the span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 38**: 38. The method of claim 31, **wherein said span of optical fiber has a coating made of a thermoplastic material having the combined characteristics of a low Young's**	**performing autocorrelation detections upon the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to produce signals from the multiple virtual sensors**; and identifying signals from the multiple virtual sensors as being caused by at least one of mechanically induced strain, pressure induced strain, electromagnetically induced strain and thermal induced strain proximate to at least one of the multiple virtual sensors. **Pending Claim 29**: 29. The method of claim 23, **wherein the light source is a planar, ring-type laser**. **Pending Claim 30**: 30. The method of claim 31, **wherein the span of optical fiber span has a length L, and the light source is a laser having the capability to generate a lightwave signal with sufficient stability to substantially retain coherency in propagation along the span for a distance at least equal to two times length L**. **Pending Claim 31**: 31. The method of claim 23, **wherein the span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 32**: 32. The method of claim 31, **wherein the**

modulus and a Poisson's ratio below that of natural rubber, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates.	**span of optical fiber comprises a fiber optic cable of the polarization preserving type**. **Pending Claim 33**: 33. The method of claim 23, **wherein said span of optical fiber 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal**.

The Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings have essentially the same claim requirements as the *'188 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings and the *'188 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 27-31, 33 and 35-38 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'188 ODP Claims*.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'188 ODP Claims*** of the '188 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[28]

This is a provisional nonstatutory double patenting rejection.

[28] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806* below for *prima facie* teachings of claim requirements and obviousness.

Claims 26 and 34 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'188 ODP Claims*** of the '188 RI Application in view of in view of ***Taylor et al.*** (U.S. Patent No. 5,194,847) and ***Farhadiroushan*** (U.S. Patent No. 5,754,293).[29]

This is a provisional nonstatutory double patenting rejection.

I. U.S. Reissue Application No. 14/190,478

Claims 23 and 25-30 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1, 3, 6-11, 19 and 20-23 ("***'478 ODP Claims***") of copending Application No. 14,190,478 ("'478 RI Application").

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23 and 25-30 are identical or similar and/or covered by the *'478 ODP Claims*. For example, by comparing the pending claims 23 and 25-30 and the *'478 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings Apparatus Claims of '478 RI Application

Pending Claim 23:	**Pending Claim 1**:
23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein**	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**

[29] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806*, *Taylor et al.* and *Farhadiroushan* below for *prima facie* teachings of claim requirements and obviousness.

each zone segment has a specialized sensing function; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**.	**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

Pending Claim 26: 26. The system of claim 25, **wherein the length L of said span is at least about 5 km**. **Pending Claim 27**: 27. The system of claim 23, **wherein said light source is a planar, ring-type laser**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 29**: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	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**. .

	Pending Claim 3: 3. The reflectometer 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**. **Pending Claim 6**: 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 2L**. **Pending Claim 7**: 7. The reflectometer of claim 7, **wherein the length L of said optical fiber span is at least 5 km**. **Pending Claim 8**: 8. The reflectometer of claim 7, **wherein said first light source is a planar, ring-type laser**. **Pending Claim 9**: 9. The reflectometer of claim 3, **wherein said span comprises a single-mode fiber optic cable**.

	Pending Claim 10: 10. The reflectometer of claim 3, **wherein said optical fiber span comprises a fiber optic cable of the polarization preserving type.** **Pending Claim 11**: 11. The reflectometer of claim 3, **wherein: said optical fiber span 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. **Pending Claim 19**: 19. 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 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. **Pending Claim 20**: 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-propagating lightwave signal, **is a continuous wave (CW) signal**. **Pending Claim 21**: 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**. **Pending Claim 22**: 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 relationships with respect to said reiterative autocorrelatable form of modulation code**. **Pending Claim 23**: 23. **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:** **a light source that illuminates an optical fiber span with a CW optical signal**; **a demodulator that receives a retrieved signal that comprises back-propagating portions of the illumination that are back propagating from a continuum of locations along the span**; **a modulator that modulates the CW optical signal with a reiterative autocorrelatable form of modulation**; **a correlator that correlates 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; **an autocorrelation detector that performs autocorrelation detections upon the r.f. counterpart of the retrieved optical signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal**.

The Examiner finds that claims 23 and 25-30 of the '161 Reissue Proceedings have essentially the same claim requirements as the *'478 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23 and 25-30 of the '161 Reissue Proceedings and the *'478 ODP Claims* are not exactly the same, the Examiner finds that claims 23 and 25-30 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'478 ODP Claims*.

This is a provisional nonstatutory double patenting rejection.

Claims 24 and 32 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'478 ODP Claims*** of the '478 RI Application in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[30]

This is a provisional nonstatutory double patenting rejection.

J. U.S. Patent No. 7,271,884

[30] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806* below for *prima facie* teachings of claim requirements and obviousness.

Claims 23, 25, 26, 28-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1, 3, 5-7, 10, 11, 20, 21 and 22 ("***'884 ODP Claims***") of U.S. Patent No. 7,271,884 ("'884 patent").

Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23, 25, 26, 28-30 are identical or similar and/or covered by the *'884 ODP Claims*. For example, by comparing the pending claims 23, 25, 26, 28-30 and the *'884 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings	Apparatus Claims of '884 patent
Pending Claim 23: 23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency**	**Patent Claim 1**: 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**

(r.f.) counterpart signal of the retrieved optical signal; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**. **Pending Claim 26**: 26. The system of claim 25, **wherein the length L of said span is at least about 5 km**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 29**: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**.	**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

Pending Claim 30: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	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; **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**; and a corresponding set of n phase demodulators for transforming each respective r.f. counterpart of said second component into a substantially linear signal representative of radian phase of the corresponding lightwave subcomponent signal. **Patent Claim 3**: 3. The reflectometer 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**. **Patent Claim 5**: 5. 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 2L. **Patent Claim 6**: 7. The reflectometer of claim 5, **wherein the length L of said optical fiber span is at least 5 km**. **Patent Claim 7**: 7. The reflectometer of claim 3, **wherein said span comprises a single-mode fiber optic cable**. **Patent Claim 10**: 10. The method of claim 3, **wherein said optical fiber span comprises a fiber optic cable of the polarization preserving type.** **Patent Claim 11**: 11. The reflectometer of claim 3, **wherein: said optical fiber span 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. **Patent Claim 20**: 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-propagating lightwave signal, **is a continuous wave (CW) signal**. **Patent Claim 21**: 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 and for retrieving back-propagating portions of the illumination back propagating from a continuum of locations along the span**; **means for modulating the CW optical signal in accordance with a reiterative autocorrelatable form of modulation code**; **means for picking off from said retrieved back-propagating portions of the**

	illumination a radio frequency (r.f.) counterpart of the retrieved back-propagated modulated CW optical signal; **means for performing a corresponding plurality of autocorrelation detections processes on said (r.f.) counterpart of the retrieved optical signal in respective predetermined timed relationships to said reiterated modulation code**; and means for performing a corresponding plurality of phase demodulation processes upon said r.f. counterpart of the retrieved back-propagated moduluated [*sic*] CW optical signal, said demodulation processes bing [*sic*] performed in phase locked synchronism with said CW optical signal. **Patent Claim 22**: 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 autocorrelable form of modulation code;**

	a heterodyner which receives said retrieved back-propagated portions of illumination and derives therefrom a radio frequency (r.f.) counterpart thereof; and **a subsystem which receives said r.f. counterpart of the retrieved back-propagated portions of said illumination and is operative to derive signals representative of the phases of input signals respectively influencing the sensing stations of said plurality of sensing stations, said subsystem including;** **a corresponding plurality of autocorrelation detectors which respectively detect components of said r.f. counterpart of the retrieved portions of the illumination representative of the optical input signals influencing the corresponding sensing stations**; and a corresponding plurality of phase demodulators which receive respective corresponding detected components of the input signals, said demodulators being operative in phase locked synchronism with said CW optical signal.

The Examiner finds that claims 23, 25, 26, 28-30 of the ‘161 Reissue Proceedings have essentially the same claim requirements as the *‘884 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 25, 26, 28-30 of the ‘161 Reissue Proceedings and the *‘884 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 26, 28-30 of the ‘161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *‘884 ODP Claims*.

Claim 24 is rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'884 ODP Claims*** of the '884 patent in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[31]

Claim 27 is rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'884 ODP Claims*** of the '884 patent in view of ***Nilsson*** (U.S. Patent No. 5,177,764).[32]

K. U.S. Patent No. 7,274,441

Claims 23, 25, 26, 28-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1, 5, 7-9, 12-14, 23 and 24 ("***'441 ODP Claims***") of U.S. Patent No. 7,274,441 ("'441 patent"). Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23, 25, 26, 28-30 are identical or similar and/or covered by the *'441 ODP Claims*. For example, by comparing the pending claims 23, 25, 26, 28-30 and the *'441 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings Apparatus Claims of '441 patent

Pending Claim 23:	**Patent Claim 1**:
23. **A system** comprising: **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that**	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**

[31] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al.'806* below for *prima facie* teachings of claim requirements and obviousness.
[32] See the pre-AIA 35 U.S.C. 103(a) rejection of claim 27 and 35 over *Kersey et al.'806* and *Nilsson* below for *prima facie* teachings of claim requirements and obviousness.

result in a back-propagating signal wherein each zone segment has a specialized sensing function; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative autocorrelatable form of modulation, said modulator providing the modulated CW optical fiber to the span**; **an optical receiver joined to said span and capable of receiving a retrieved optical signal returned therefrom, wherein the retrieved optical signal comprises back-propagating portions of the illumination from sensing zone segments, said receiver operative to produce a radio frequency (r.f.) counterpart signal of the retrieved optical signal**; and **a processor operative to detect a reiterative autocorrelatable form of modulation from the counterpart signal in a corresponding plurality of different timed relationships with respect to the reiterative autocorrelatable form of modulation of the CW optical signal to give at least one signal for each zone segment.** **Pending Claim 25**: 25. The system of claim 23, **wherein said span has a length L and said light source is a laser having the capability to generate a lightwave signal with sufficient stability to retain coherency in propagation along said span for a distance at least equal to two times length L**.	**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

Pending Claim 26: 26. The system of claim 25, **wherein the length L of said span is at least about 5 km**. **Pending Claim 28**: 28. The system of claim 23, **wherein said span of optical fiber comprises a single mode fiber optic cable**. **Pending Claim 29**: 29. The system of claim 23, **wherein said span of optical fiber is made from the polarization preserving type of optical fiber**. **Pending Claim 30**: 30. The system of claim 23, **wherein said span of optical fiber span 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, wherein the coating enhances the longitudinal component of strain variation derived from an acoustic wave signal whose wave front is incident to the optical fiber span from a direction at least in part having a lateral component in the direction along which the wave front propagates**.	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 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**; **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**;

	a corresponding set of n phase demodulators for transforming each respective r.f. counterpart of said second component into a substantially linear signal representative of radian phase of the corresponding lightwave subcomponent signal; and at least one subtracter circuit having a first and a second input for respectively receiving outputs from a selected first and a selected second of said set of n phase demodulators, to produce a differential phase signal which is representative of the difference between the radian phases of the r.f. counterparts of two subcomponents of said second component of the composite back-propagating lightwave signal, which two subcomponents are caused by external signals at sensing positions along said optical fiber span established by the time delay circuits respectively associated with said selected first and said selected second phase demodulators. **Patent Claim 5**: 5. The reflectometer 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**. **Patent Claim 7**: 7. The reflectometer of claim 5 **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 2L**.

	Patent Claim 8: 8. The reflectometer of claim 7, **wherein the length L of said optical fiber span is at least 5 km**. **Patent Claim 9**: 9. The reflectometer of claim 5, **wherein said span comprises a single-mode fiber optic cable**. **Patent Claim 12**: 12. The method of claim 5, **wherein said optical fiber span comprises a fiber optic cable of the polarization preserving type.** **Patent Claim 13**: 13. The reflectometer of claim 5, **wherein: said optical fiber span 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. **Patent Claim 14**: 14. The reflectometer of claim 5, **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-propagating lightwave signal, **is a continuous wave (CW) signal**. **Patent Claim 23**: 23. **A system** wherein, at respective span increment sensing stations of a plurality of increment sensing stations along a span of optical fiber, **the system senses the phase differential between input signals respectively incident upon the bounds of each station, for signals of a type having a property of inducing light path changes at regions of the span influenced by such signals,** said system comprising: **means for illuminating the span with a CW optical signal and 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 in accordance with a reiterative autocorrelatable form of modulation with respect to a reference timing base**; **means for picking off from said retrieved back-propagating portions of the illumination a radio frequency (r.f.) counterpart of the retrieved modulated CW optical signal**; **means for performing a second plurality of autocorrelation detections processes upon**

	said (r.f.) counterpart of the retrieved back-propagated modulated CW optical signals, said second plurality corresponding to the number of bounds of sensing stations, said second plurality of autocorrelation detection processes being performed in different timed relationships relative the reference timing base determined by propagation distances which the modulated CW optical signal travels to the respective bound; means for detecting the radian phase of each input signal at each respective timed relationship by which said autocorrelation detection means performs processing for a respective bound, said detection means performing the radian phase detection of each input signal in phase locked relationship to said CW optical signal; and means for determining the difference between radian phases of the signals at the respective timed relationships associated with each pair of bounds of each span increment sensing station. **Patent Claim 24**: 24. **Signal sensing array apparatus**, wherein **at respective span increment sensing stations of a first plurality of span increment sensing stations along a span of optical fiber the apparatus senses phase differentials between input signals respectively incident the bounds of each span increment sensing station**, **the input signals being of a type having a property of inducing light path changes at regions of the span influenced by such 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 autocorrelable form of modulation code**; **a heterodyner which receives said retrieved, back-propagated, portions of illumination and derives therefrom a radio frequency (r.f.) counterpart thereof**; and **a phases-of-input-signals detector for determining the phase of input signal at each bound of each span increment sensing station of said first plurality of span increment sensing stations, said phases-of-input-signals detector being operative in respective timed relationships of a second plurality of timed relationships corresponding to the bounds of the sensing stations, said timed relationships being with respect to said reiterative autocorrelable form of modulation code, said phases-of-input-signals detector including**: **a corresponding second plurality of autocorrelation detectors which respectively detect temporal portions of the r.f. counterparts of the retrieved, back-propagated, portions of said illumination that occur in the timed relationships corresponding to the bounds of each span increment sensing station and detect electronic representations of the optical input signals incident the respective bounds**;

	a corresponding second plurality of phase demodulators which are operative in phase locked relationships with said CW optical signal and which respectively receive said detected electronic representations of the optical input signals; and a subtracter network coupled to receive the outputs of said second plurality of phase demodulators and which is operative to determine the differences between the phase demodulator outputs of each pair of phase demodulator outputs which correspond to a pair of bounds of each span increment sensing station of the first plurality of said stations.

The Examiner finds that claims 23, 25, 26, 28-30 of the '161 Reissue Proceedings have essentially the same claim requirements as the *'441 ODP Claims*, just somewhat broader. (See comparison above). In addition, where claims 23, 25, 26, 28-30 of the '161 Reissue Proceedings and the *'441 ODP Claims* are not exactly the same, the Examiner finds that claims 23, 25, 26, 28-30 of the '161 Reissue Proceedings would be obvious variants to one of ordinary skill in the art based on engineering expediency of the *'441 ODP Claims*.

Claim 24 is rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'441 ODP Claims*** of the '441 patent in view of ***Kersey et al.'806*** (U.S. Patent No. 6,285,806).[33]

[33] See the pre-AIA 35 U.S.C. 103(a) rejection of claims 24 and 32 over *Kersey et al. '806* below for *prima facie* teachings of claim requirements and obviousness.

Claim 27 is rejected on the ground of nonstatutory double patenting as being unpatentable over the ***'441 ODP Claims*** of the '441 patent in view of ***Nilsson*** (U.S. Patent No. 5,177,764).[34]

L. U.S. Patent No. 7,268,863

Claims 23 and 25-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1, 4, 6-9, 22, 23, 26, 27, 31 and 32 ("***'863 ODP Claims***") of U.S. Patent No. 7,268,863 ("'863 patent"). Although the claims at issue are not identical, they are not patentably distinct from each other because the scopes of the pending claims 23 and 25-30 are identical or similar and/or covered by the *'863 ODP Claims*. For example, by comparing the pending claims 23 and 25-30 and the *'863 ODP Claims* shown below:

System Claims of '161 Reissue Proceedings Apparatus Claims of '863 patent

Pending Claim 23:	**Patent Claim 1**:
23. **A system** comprising**:** **a span of optical fiber having sensing zone segments wherein signals incident to said span have a property of inducing light path changes at sensing zone segments that result in a back-propagating signal wherein each zone segment has a specialized sensing function**; **a light source operative to provide a continuous wave (CW) optical signal**; **a modulator operative to modulate the CW optical signal with a reiterative**	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**

[34] See the pre-AIA 35 U.S.C. 103(a) rejection of claim 27 and 35 over *Kersey et al.'806* and *Nilsson* below for *prima facie* teachings of claim requirements and obviousness.