Paper 1
Filed: July 6, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ANALYTICS FOR LIFE, INC.,
Petitioner,

v.

8825319 CANADA LIMITED,
Patent Owner.

Case: Unassigned
Patent 9,131,864

PETITION FOR INTER PARTES REVIEW

TABLE OF CONTENTS

EXHIBIT LIST

Exhibit No.	Description
1001	U.S. Patent No. 9,131,864
1002	Declaration of David V. Anderson, Ph.D. in Support of Petition
1003	*Curriculum vitae* of David V. Anderson
1004	PCT Publication No. 2012/106729
1005	U.S. Pat. Publ. No. 2006/0211930 A1 to Scharf *et al.*
1006	U.S. Pat. No. 6,325,761 to Jay
1007	Korenberg, M.J., "A Robust Orthogonal Algorithm for System Identification and Time-Series Analysis," Biol. Cybern. 60, 267-276 (1989)
1008	Korenberg, M.J. and Adeney, K.M., "Iterative Fast Orthogonal Search for Modeling by a Sum of Exponentials or Sinusoids," Biomedical Engineering Society, pp. 316-327 (1998)
1009	Korenberg, M.J. and Paarmann, L.D., "Applications of Fast Orthogonal Search: Time-Series Analysis and Resolution of Signals in Noise," Annals of Biomedical Engineering, Vol. 17, pp. 219-231 (1989)
1010	Mao, K.Z., "Orthogonal Forward Selection and Backward Elimination Algorithms for Feature Subset Selection," IEEE Transactions on Systems Man and Cybernetics Part B: Cybernetics, vol. 34, pp. 629-634 (2004)
1011	Ahlstrom, C, "Nonlinear Phonocardiographic Signal Processing," Linkoping Studies in Science and Technology (2008)
1012	File History of U.S. Patent No. 9,131,864
1013	Excerpt of Merriam Webster's Collegiate Dictionary (11th Ed. 2016)
1014	Johnson, L.W., Riess, R.D., and Arnold, J.T., "Introduction to Linear Algebra," Fourth Edition, Addison Wesley (1998)
1015	Mallat, S. G.; Zhang, Z., "Matching Pursuits with Time-Frequency Dictionaries," IEEE Transactions on Signal Processing, pp. 3397-3414 (1993)
1016	Tibshirani, Robert, "Regression Shrinkage and Selection via the lasso," Journal of the Royal Statistical Society. Series B, Vol. 58 (1), pp. 267–88 (1996)

1017	Siddharth, J. and Boyd, S., "Sensor Selection via Convex Optimization," IEEE Transactions on Signal Processing, Vo. 57, No. 2 (2009)
1018	Brown L, "Estimation with incompletely specified loss functions (the case of several location parameters)," Journal of the American Statistical Association, Vol. 70, pp. 417-427 (1975)
1019	Bunke O, "Least Squares Estimators as Robust and Minimax Estimators," Math. Operations Forsch U. Statist, Vol. 6, pp. 687-688 (1975).

I. INTRODUCTION

Petitioner Analytics For Life, Inc. ("A4L" or "Petitioner") seeks an *Inter Partes* Review (IPR) of U.S. Patent No. 9,131,864 to Michael Korenberg ("the '864 patent", **X1001**[1]), owned by 8825319 Canada Limited ("Patent Owner") on the grounds detailed below.

II. COMPLIANCE WITH REQUIREMENTS FOR IPR PETITION

A. Grounds for Standing — 37 C.F.R. § 42.104(a)

A4L certifies that the '864 patent is available for IPR and that A4L is not estopped from requesting IPR challenging the patent's claims on the grounds identified below.

B. Fee for IPR Request — 37 C.F.R. § 42.15(a)

The required fee of $25,000 is included with this petition. The Director is authorized to charge any remaining fees specified by 37 C.F.R. § 42.15(a) to Deposit Account No. 50-5226.

C. Mandatory Notices — 37 C.F.R. § 42.8(b)

1) Real Parties in Interest

The real parties of interest of this petition are Analytics For Life, Inc. and its wholly owned subsidiary, A4L (US), Inc.

[1] Exhibits are referred to throughout with the prefix of X followed by Petitioner's exhibit number (*e.g.*, **X1001** refers to **Exhibit 1001**).

2) Related Proceedings

There are no other judicial or administrative matters that would affect, or be affected by, a decision in the proceeding.

3) Designation of Petitioner's Counsel

Lead Counsel	Back-Up Counsel
David Moreland Reg. No. 60,134 Meunier Carlin & Curfman LLC 999 Peachtree St. NE Suite 1300 Atlanta, GA 30309 678.869.7749 dmoreland@mcciplaw.com	Lawrence Aaronson Reg. No. 38,369 Meunier Carlin & Curfman LLC 999 Peachtree St. NE Suite 1300 Atlanta, GA 30309 404.645-7713 laaronson@mcciplaw.com
	T. Paul Tanpitukpongse Reg. No. 71,589 Meunier Carlin & Curfman LLC 999 Peachtree St. NE Suite 1300 Atlanta, GA 30309 678.771.7781 ptanpitukpongse@mcciplaw.com

4) Service Information

Petitioner consents to service in this proceeding by electronic mail directed to Petitioner's counsel.

D. Identification of Challenged Claims — 37 C.F.R. § 42.104(b)

Claims 1-20 ("the challenged claims") of the '864 patent (*i.e.*, independent claims 1, 9, and 19 and dependent claims 2-8, 10-18, and 20) are unpatentable under 35 U.S.C. §§ 102 and 103 in view of the following grounds.

Ground 1: Independent claim 1 and dependent claims 2-6 and 13 are anticipated and/or obvious in view of U.S. Pat. No. 6,325,761 to Jay ("**Jay**," **X1006**) and U.S. Pat. Publ. No. 2006/0211930 A1 to Scharf *et al.* ("**Scharf**," **X1005**).

Ground 2: Dependent claims 7-8, 14-15, and 17-18 are obvious in view of **Jay**; **Scharf**; and Christer Ahlström, "Nonlinear Phonocardiographic Signal Processing," LiU-Tryck, Linköping (2008) ("**Ahlström,**" **X1011**).

Ground 3: Independent claim 9 and dependent claims 10-12 and 16 are anticipated and/or rendered obvious in view Korenberg, M.J., "A Robust Orthogonal Algorithm for System Identification and Time-Series Analysis," Biol. Cybern. 60, 267-276 (1989) ("**Korenberg**," **X1007**).

Ground 4: Independent claim 19 and dependent claim 20 are obvious in view of Korenberg, M.J. and Adeney, K.M., "Iterative Fast Orthogonal Search for Modeling by a Sum of Exponentials or Sinusoids," Annals of Biomedical Engineering, vol. 26, pp. 315-327 (1998) ("**Adeney**," **X1008**) alone and/or in combination with Mao, K.Z., "Orthogonal Forward Selection and Backward

Elimination Algorithms for Feature Subset Selection," IEEE Transactions on Systems Man and Cybernetics Part B: Cybernetics, vol. 34, pp. 629-634 (2004) ("**Mao**," **X1010**).

III. Overview of the Technology in View of the '864 Patent, the Claims of the '864 Patent, and the Prior Art

A. The Technology at Issue in View of the '864 Patent: Representation and Evaluation of Electrophysiological Signals

The '864 patent claims priority to International Patent Appl. No. PCT/US2012/024037, filed on February 6, 2012, which claims priority to U.S. Provisional Appl. No. 61/462,640, filed on Feb. 4, 2011. Because the patentee stated that the application includes claims with an effective filing date after March 16, 2013, it is reviewed under the America Invents Act (*see* **X1012**, 225; **X1002**, ¶¶36-37).

The '864 patent generally relates to a method for evaluating an electrophysiological signal by using a model-derived reconstruction of the signal via any known mathematical algorithm, including the well-known fast orthogonal search ("FOS") algorithm (**X1001**, Abstract, 4:15-19; **X1002,** ¶¶38,55-58). Model-derived reconstruction of a signal under study – a process dating back several decades and a basic tenant of signal processing – allows a complicated signal to be broken into a mathematical approximation for some purpose, such as to compress the original signal or signals to a more compact form, to remove unwanted noise

from the original signal, or to simplify analysis of the original signal or signals by analyzing simpler or more accurate versions of them (**X1002, ¶¶**39-47). The process of describing a complicated signal using simpler ones is often referred to as decomposition, or model deriving (**X1002, ¶**39).

One of the earliest techniques of model-derived reconstruction of a signal is Fourier Analysis, which involves assessing a complex incoming waveform/signal and expressing it mathematically as a series of sinusoidal functions (sines and cosines), the frequencies of which form a harmonic series (**X1002, ¶¶**48-52). Weights are then assigned (as coefficients) to each of the sinusoidal functions to assign the contribution of that term in representing the original signal (**X1002, ¶**49). While variations of this technique exist (such as FOS), other model-derived reconstruction algorithms similarly decompose an original signal into a summation of simpler signals (**X1002, ¶¶**40, 52-54).

Many algorithms have been developed since Fourier analysis to accomplish the same purpose (**X1002, ¶¶**52-53). Well-known examples of these algorithms that pre-date the ’864 patent by many years include FOS (published in 1987 by Dr.

Korenberg),[2] Matching Pursuits ("MP") (published in 1993),[3] and other regression analysis methods such as LASSO (published in 1996)[4] (**X1002, ¶¶**53, 56).

While the '864 patent purports to provide improvements in the art, the systems and methods described therein were widely known and published decades before – in some instances by the patentee himself, Michael Korenberg, Ph.D. For example, the '864 patent purports to describe a new application of FOS for selecting and representing an electrophysiological signal as a sum of differentiable equations, when in fact, such applications of FOS were ***already disclosed*** by Dr. Korenberg years prior to the filing of the '864 patent, making those disclosures prior art to the '864 patent (**X1002, ¶¶**68-70, 85-87, 162, 166(12.a)).

The disclosure of the '864 patent provides significant admissions regarding prior methods and systems known in the art for reconstructing and assessing electrophysiological signals (**X1002**, ¶¶62-66). In pertinent part, the background section of the'864 patent provides the following regarding the state of the art at the time of the '864 patent application filing:

---

[2] See Korenberg, M. J., "Fast orthogonal identification of non-linear difference equation and functional expansion models," Proceeding of the Midwest Symposium on Circuits and Systems, Vol. 1, pp. 270–276 (1987).

[3] See **X1015**, 3397-415.

[4] See **X1016**, 267-88.

- "[I]mportant physiological information can be captured as electrophysiological signals … includ[ing] … electrocardiogram (ECG) signals … electroculogram (EOG) and electromyogram (EMG) signals, … a respiratory function signal, a pulse oximetry signal …. and quasi-periodic biological signals" (**X1001**, 1:22-33);
- "The [1989] article by Korenberg and Paarmann … specifically relates the application of Fast Orthogonal Search (FOS) to several of the above electrophysiological signals, including ECG, EEG, EOG, and EMG signals, and shows that FOS can recover signals heavily contaminated with noise" (**X1001**, 1:34-42);
- "The [1989] article discloses that FOS can be used to find accurate and parsimonious sinusoidal series models for such electrophysiological signals" (**X1001**, 1:50-52);
- "The sinusoidal series developed in the article, sums of cosines and sine functions, are examples of summation series of complex exponentials." (**X1001**, 1:54-56);
- "[A] cosine can be the real part, and a sine can be the imaginary part, of a complex exponential" (**X1001**, 1:54-58);
- "[T]he sinusoidal terms in such series are fractionally differentiable and integrable analytically, where the order of the fractional derivative or integral can be any real or complex number" (**X1001**, 1:58-61);
- "A derivative of negative order –a, where a>0, corresponds to an integral of positive order a" (**X1001**, 1:61-63);
- "In the [1994] article by Adeney and Korenberg … FOS and Iterative FOS (IFOS) are used to find a sum of complex sinusoids, which is also a summation series of complex exponentials" (**X1001**, 1:65-2:3);

- "With the ongoing proliferation of data acquisition devices, more and more physiological aspects are able to be captured as electrophysiological signals" (**X1001**, 3:24-26);
- "[T]here are various time domain and frequency domain signal processing techniques which are being used for the analysis of electrophysiological signals to obtain more detailed information" (**X1001**, 3:48-51).

As further described in the "Detailed Description" of the'864 patent,

> The FOS process creates a finite series, or sum, of weighted basis functions. The basis functions can be non-linear mathematical functions, in this case alternating sine and cosine functions that model the surface ECG as a finite series in which the sinusoidal frequencies are not necessarily integral multiples of a fundamental frequency. The FOS process can generate multiple sine and cosine … basis functions by searching through a set of frequencies and calculates the amplitude for each term until there is no significant energy left in the signal ... When all the terms are added together it may nearly duplicate the original ECG signal …. In one alternative, the latest sine/cosine pair added to a model has the frequency chosen such that the added pair will cause the greatest reduction in the mean square error (MSE) of approximating the target ECG signal. The process can continue until there is no sine/cosine pair remaining that can cause a reduction in MSE exceeding a predetermined bottom threshold. …. This FOS alternative was used in the above-referenced 1989 article by Korenberg and

> Paarmann, the above-referenced 1994 article by Adeney and Korenberg, and the above-referenced 2001 article by Chon.

(**X1001**, 7:15-45).

Accordingly, as admitted in the ’864 patent, by February 2011, FOS was a widely published and used algorithm for reconstructing an electrophysiological signal using a series of differentiable sines and cosine values (**X1002**, ¶56). Moreover, as confirmed by the attached declaration of David Anderson, Ph.D., a person of ordinary skill in the art (“POSITA”) at the relevant time (**X1002**, ¶¶4-6, 35), while the ’864 patent refers to FOS and its variations, a POSITA would have recognized FOS as just ***one*** type of signal reconstruction algorithms substitutable with other types of signal reconstruction algorithms (including MP, Fourier Analysis, ROS, and others) (*see* **X1002,** ¶56).

B. The Claims of the ’864 Patent

The independent claims of the ’864 patent are directed to broad concepts that are both well-known and well-described in the literature. The dependent claims provide well-known and obvious variations of known methods.

Claim 1: Claim 1 generally is directed to a method for determining an abnormality from an electrophysiological signal, such as an electrocardiogram (ECG), by obtaining the signal, representing the signal in a mathematical model where at least one term in the model is differentiable, obtaining a derivative of the differentiable term, and using the derivative over one cycle of the signal to detect

the abnormality. The claim does not require a specific mathematical representation, a specific type of electrophysiological signal, a specific type of abnormality, or a specific model term to which a derivative is performed (**X1002,** ¶58). Any mathematical analysis of a model-derived reconstructed electrophysiological signal will fall within the claim (*id.*). Because such methods were commonplace well before the '864 patent, Claim 1 and its dependent claims are not patentable.

Claim 9: Claim 9 generally is directed to the fast orthogonal search (FOS) algorithm and variants of FOS called robust orthogonal search – concepts that were both disclosed in **Korenberg**. Put succinctly, Claim 9 provides a method for building a model approximating a physiological signal by selecting one or multiple candidate terms to add to a mathematical model at successive stages, where the terms causes a greatest reduction and a relative maximum of the reduction in the measure of approximating the signal or a reduction of the measure above a specified threshold level (*id.*). Because this very method was described in **Korenberg**, Claim 9 and its dependent claims are not patentable.

Claim 19: Claim 19 generally is directed to a feature subset selection problem (also called a "sensor selection problem" in the art) (*id.*). The claim sets forth the well-known process of determining a subset of lead signals based on defining a candidate signal and determining a desired target output signal (*id.*).

This claimed method, and solutions to these types of problems generally, involve the use of model-derived reconstruction techniques to select a subset of sensor leads (e.g., ECG leads) from a larger set of sensor leads (*e.g.*, ECG leads) to approximate target signals (*e.g.*, representative signals) of these leads as linear combinations of the selected lead signals (*id.*). The '864 patent provides that this method of subset selection was known to be possible using FOS (*see* **X1001**, 26:45-27:42; **X1002, ¶**58). As such, Claim 19 and its dependent claims are not patentable.

C. Overview of Prior Art Relied Upon in this Petition

1) Admitted Prior Art in the '864 Patent

Statements by a patentee constitute prior art for purposes of the alleged claimed invention. *Std. Mfg. Co. v. United States*, 25 Cl. Ct. 1, 58 (1991); *Tyler Refrigeration v. Kysor Indus. Corp.,* 777 F.2d 687, 690 (Fed. Cir. 1985). The '864 patent admits, *inter alia*, that the following were well-known at the time of the '864 patent:

- Computer systems for assessing biological signals to detect abnormalities (**X1001**, 2:15-33; **X1006**, 9:32-59);
- Applications of the FOS algorithm to biological signals to prepare mathematical models of differentiable sinusoidal signals (**X1001**, 1:22-2:33); and

- Fractional derivatives of FOS terms (**X1001**, 1:58-64).
- Selection of a subset of terms based on multiple candidate terms using FOS and IFOS (**X1001**, 26:63-27:1).

2) The Korenberg Publication

The ’864 patent cites and incorporates by reference several manuscripts published by Dr. Korenberg between 1988 and 1994 that describes the FOS algorithm and variations thereof. One of these publications is **Korenberg** (**X1001**, 6:65-7:1). **Korenberg** is prior art to the ’864 patent under 35 U.S.C. § 102(a)(1) because it is a printed publication that was published more than one year prior to the effective filing date of the ’864 patent. *De Graffenried v. United States*, 20 Cl. Ct. 458, 469 n.8 (1990).

As explained below, **Korenberg** discloses both FOS (where multiple candidate signals that provide the most reduction to mean square error are selected over multiple iterations) as well as robust orthogonal search (ROS) – what the ’864 patent describes as “modified FOS” – where several candidate signals are selected at each iteration based on threshold values. According to **Korenberg**, “[a] key aspect is a rapid search for significant terms to include in the model for the system or the time-series. For example, the methods use fast and robust orthogonal searches for significant frequencies in the time-series” (**X1007**, 267). “Central to

the orthogonal search method is first to use Gram-Schmidt orthogonalization[5] to construct, from each candidate term, a function which is orthogonal to all previously chosen terms. Then the reduction in mean-square error achievable by selecting any given candidate is readily obtained" (**X1007**, 268-69; **X1002, ¶¶**67-69).

In describing the robust orthogonal search algorithm, **Korenberg** states: "[c]learly many similar strategies utilizing [Equation] (43) to select terms can be set down: e.g. considering *two or more candidates at a time*" (**X1007**, 274 (emphasis added)).

3) The Jay Patent

Jay was published in 2001and predates the '864 patent by as many as 10 years.[6] It is thus prior art under 35 U.S.C. §102(a)(1). **Jay** discloses the use of FOS on a pulse-oximetry signal and assessment of an abnormality based on a cross-correlation of the signal over multiple cycles (**X1002, ¶¶**71-75). As admitted in the '864 patent:

> [T]he [Jay prior art] describes a method of evaluating an electrophysiological signal, including receiving an

[5] Gram-Schmidt orthogonalization is a well-established mathematical theorem. (**X1014**, 164-65, 343-48; **X1002**, n. 7).

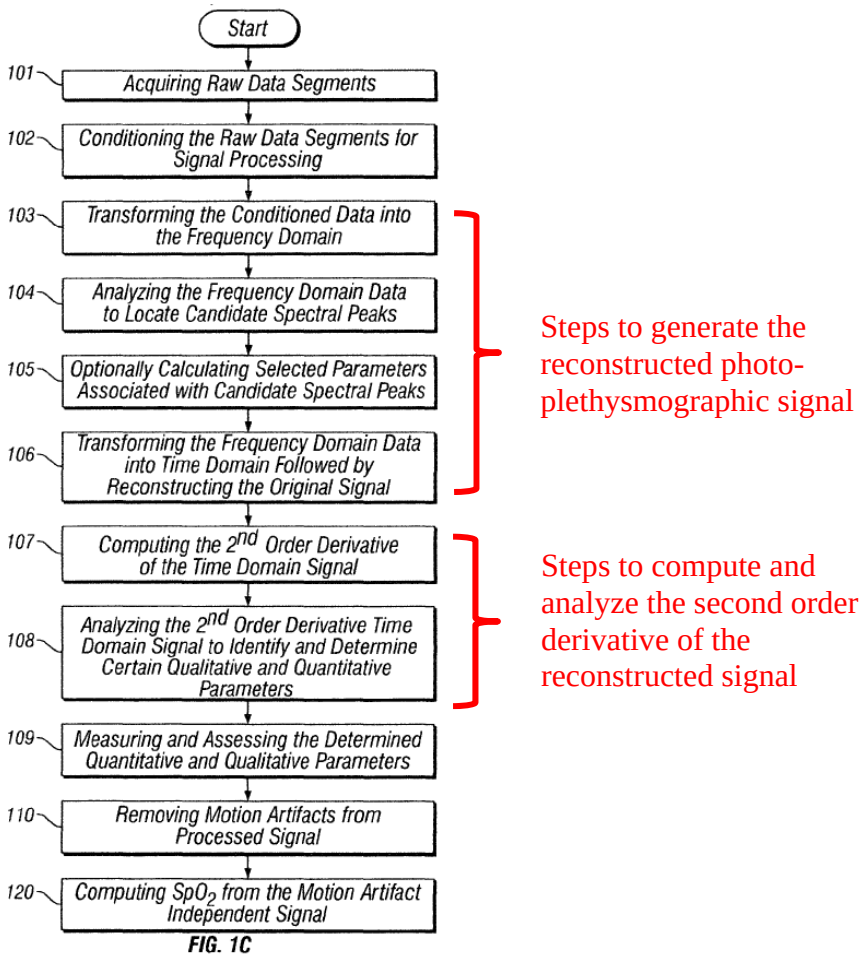
[6] Based on the earliest potential effective filing date of the '864 patent.

> electrophysiological signal, obtaining a model-derived reconstruction using a summation series of complex exponentials (here a sinusoidal series) over at least one cycle of the electrophysiological signal to identify a pathological condition (pulsus paradoxus), and display on a user interface data indicative of pulsus paradoxus, and predict the risk for adverse clinical outcomes, such as impending severe respiratory distress.

(**X1001**, 2:24-33).

4) The Scharf Publication

Scharf was published in 2006 and predates the ’864 patent by five years. It is prior art under 35 U.S.C. §102(a)(1). **Scharf** discloses a method and system for assessing periodic cardiovascular pulses in the human body by, *e.g.*, reconstructing a photo-plethysmographic (also known as pulse-oximetry signal) in the time domain, computing the second order derivative of the reconstructed signal, and analyzing that derivative of the signal to determine a plurality of unique cardiac morphologies and potential abnormalities (**X1005**, Abstract; *see also* **X1002**, ¶76). This method is shown in more detail in Figure 1C of **Scharf** reproduced below.



Scharf, Fig. 1C

To generate the reconstructed signal, **Scharf** discloses a method that involves "acquiring the raw photo-plethysmographic data, transforming the data into the frequency domain, analyzing the transformed data to locate a series of candidate cardiac spectral peaks …, reconstructing a photo-plethysmographic signal in the time domain with only the candidate cardiac spectral peaks " (**X1005**, Abstract). In Figure 1C above, the steps of generating the reconstructed photo-plethysmographic are highlighted (**X1002, ¶**77). Notably, while a specific method is provided for generating the signal in **Scharf,** a POSITA would have immediately

recognized that any signal reconstruction could have been utilized to generate the photo-plethysmographic (pulse-oximetry) signal, including by using FOS (**X1002,** ¶78). **Scharf** expressly notes that "other signal acquisition, measurement, and preconditioning systems, or signal transformation, and reconstruction methods could be used" (**X1005**, ¶0089). Thus, a POSITA would have known to substitute FOS for the FFT signal reconstruction provided in **Scharf** and would have been motivated to do so (**X1002,** ¶79). For example, **Korenberg** provides a lengthy explanation of why FOS provides superior performance and higher resolution as compared to FFT (**X1007**, 268), providing ample motivation for substituting FOS in **Scharf** (**X1002,** ¶79).

5) The Mao Publication

Mao was published in 2004 and predates the '864 patent by seven years. It is prior art under 35 U.S.C. §102(a)(1). Feature subset selection was a known problem in the art addressed by **Mao** (**X1002,** ¶¶80-81). According to **Mao**, "[s]electing a subset of features from a pool of many potential variables is a common problem in pattern classification." (**X1010**, 629). Furthermore, according to **Mao**:

> The goal of feature subset selection is to identify and to select the most important and nonredundant variables from the large pool of

> potential variables. Generally, a feature subset selection algorithm involves a feature evaluation criterion and a search algorithm.

(**X1010**, 629).

6) The Ahlström Publication

Ahlström is a manuscript published by the LiU-Tryck, Linköping University (Sweden) in 2008. It is prior art under 35 U.S.C. § 102(a)(1). **Ahlström** discloses common visualization techniques used to view time-series data in three-dimensional phase space plots (**X1011**, 77; *see also* **X1002,** ¶82). **Ahlström** further shows that cardiovascular models can be superimposed with data to emulate different physical phenomena, allowing for assessment of morphological changes in electrophysiological signals via a graphical view (**X1011**, 193; *see also* **X1002,** ¶83). **Ahlström** further shows normal and abnormal heart signals in state space (**X1011**, 126; *see also* **X1002**, ¶84.)

7) The Adeney Publication

Adeney was published in the Annals of Biomedical Engineering in 1998. It is prior art under 35 U.S.C. § 102(a)(1). The ’864 patent describes one “key idea” of **Adeney** relating to “Fitting Multiple Sets of Observations” as follows: “[W]hen data are available from multiple experiments, one may select the SAME basis functions (out of the candidates) to fit all the experimental data, but the coefficients used may vary from one experiment to another” (**X1001**, 26:47-27:15; **X1002**,

¶85). In this way, "all of the data" may be expressed "in terms of a single set of basis functions" (**X1008**, 325). This is another application of feature subset selection, the same problem and solution addressed in **Mao** (**X1002,** ¶86). While the particular method used to perform this task, as provided in **Adeney**, is FOS or IFOS, any method of assessing multiple incoming data using orthogonal searching could be employed (as evidenced by **Mao's** disclosure of a another orthogonal search algorithm) (**X1002,** ¶87).

D. Level of Ordinary Skill in the Art

In view of the disclosure of the '864 patent, the above-mentioned prior art, and the general skill level of those practicing in the field of electrophysiological signal reconstruction, a POSITA at the relevant time would have possessed the equivalent of a Bachelor of Science degree from an accredited institution in any number of related disciplines touching on electrophysiological signal processing, such as computer science, computer engineering, electrical engineering, and/or biomedical engineering (**X1002,** ¶¶28-35). A POSITA would also have experience with techniques to mathematically reconstruct and assess electrophysiological signals using linear algebra and calculus (**X1002,** ¶32).

IV. CLAIM CONSTRUCTION

In an IPR, claim terms in a patent are given their broadest reasonable construction in light of the specification of the patent in which they appear. 37

C.F.R. § 42.100(b). Under the broadest reasonable construction standard, claim terms are given their "ordinary and customary meaning" as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007). Only where a patentee provides an express definition of a term does that definition control. *Sinorgchem Co. v. ITC*, 511 F.3d 1132, 1136 (Fed. Cir. 2007).

The terms used in the '864 patent would have been readily understood by a POSITA at the relevant time and do not need construction, except as set forth in the chart below (**X1002, ¶¶**58-59). Petitioner reserves the right to contest any proposed constructions sought by Patent Owner.

Term of the '864 Patent	**A4L Proposed Construction**
"modified fast orthogonal search" or "MFOS"	As defined in the patent specification, this term should be found to mean "a variant of the fast orthogonal search algorithm in which a search through candidate terms is performed that selects two or more distinct candidate terms to add to the model at successive stages where one of the selected terms causes, out of the candidate terms searched, the greatest reduction in the measure of approximating the signal, and another of the selected terms is, out of the candidate terms searched, at a relative maximum of the reduction of the measure of approximating the signal" (**X1001**, 9:47-55; *see also* **X1002**, ¶60). A transform (of MFOS) would be understood by a POSITA to be an application of the (MFOS) algorithm to input signals (**X1002,** ¶61)

V. THE CLAIMS OF THE ’864 PATENT ARE NOT PATENTABLE

Because the ’864 patent claims broadly recite methods for reconstructing and assessing electrophysiological signals that read on well-known and obvious subject matter, they are unpatentable as set forth below.

A. Ground 1: Claims 1, 2-6, and 13 Are Anticipated and/or Rendered Obvious in View Jay and Scharf

1) Independent Claim 1

a. The statement of intended use provided in Claim 1 of “using the derivative … in order to detect an abnormality” is non-limiting

The preamble of Claim 1 recites that the method is intended to be used to “detect[] an abnormality in a patient from an electrophysiological signal.” This intended use is repeated at the end of the claim (*i.e.*, “using the derivative over at least one cycle of the electrophysiological signal in order to detect the abnormality”). Because this is a non-limiting statement of intended use, it can be ignored in the invalidity analysis. *See In re Lowry*, 32 F.3d 1579, 1583-84 (Fed. Cir. 1994); *see also In re Anderson*, 662 F. App’x. 958, 963 (Fed. Cir. 2016) (finding “the speed being displayed on the display for use by a motorist in determining a route of travel’” a non-limiting statement of intended use).

b. All limitations of Claim 1 are anticipated by Scharf and/or rendered obvious in view of Jay and Scharf

Notwithstanding the above, the entirety of Claim 1 (including the intended use) would have been anticipated by **Scharf** and/or rendered obvious to one of ordinary skill in the art at the time of filing of the ’864 patent in view of **Jay** and **Scharf** (**X1002, ¶¶**88-89). Claim 1 recites the following:

> 1. A method of detecting an abnormality in a patient from an electrophysiological signal, comprising:
>
> a) obtaining an electrophysiological signal corresponding to the patient;
>
> b) finding, using a processor of a computing device, a model corresponding to the electrophysiological signal wherein at least one term in the model is differentiable;
>
> c) obtaining the derivative of the at least one term; and
>
> d) using the derivative over at least one cycle of the electrophysiological signal in order to detect the abnormality.

The Background section of the ’864 patent admits that **Jay** discloses the crux of the claimed method:

> [Jay] *describes a method of evaluating an electrophysiological signal, including receiving an electrophysiological signal, obtaining a model-derived reconstruction* using a summation series of complex exponentials (here a sinusoidal series) *over at least one cycle of the electrophysiological signal to identify a pathological condition*

> *(pulsus paradoxus), and display on a user interface data indicative of pulsus paradoxus, and predict the risk for adverse clinical outcomes, such as impending severe respiratory distress.*

(**X1001**, 2:25-33 (emphasis added)). Accordingly, by Dr. Korenberg's own admission, **Jay** discloses steps a) and b) of Claim 1 and recognizes how assessing a signal reconstruction using FOS over at least one cycle can be used to "predict the risk for adverse clinical outcomes" (**X1002**, ¶¶90-92).

Further, while **Jay** does not expressly provide for obtaining the derivative of at least one term and using the derivative over one cycle, such steps would have been obvious in view of **Scharf** (**X1002,** ¶¶95-96). As admitted in the '864 patent, the sinusoidal series disclosed in **Jay** includes differentiable terms, suggesting that derivatives may be taken of the derived signal reconstruction for further analysis (*see* **X1001**, 1:58-61; **X1002,** ¶93). As further admitted by Dr. Korenberg during the prosecution of the '864 patent, "Jay [] disclose[s] use of a fast orthogonal search, with a series of sinusoids fit to the data … ***that would be easily differentiated*** analytically" (**X1012**, 78 (emphasis added); **X1002**, ¶94).

To this end, a POSITA would recognize the benefit of obtaining a derivative of the FOS reconstruction provided in **Jay** based upon the disclosure in **Scharf** (**X1002,** ¶¶96-97). **Scharf** expressly discloses taking a second order derivative of a reconstructed photo-plethysmogram signal – which is the ***same*** biological signal

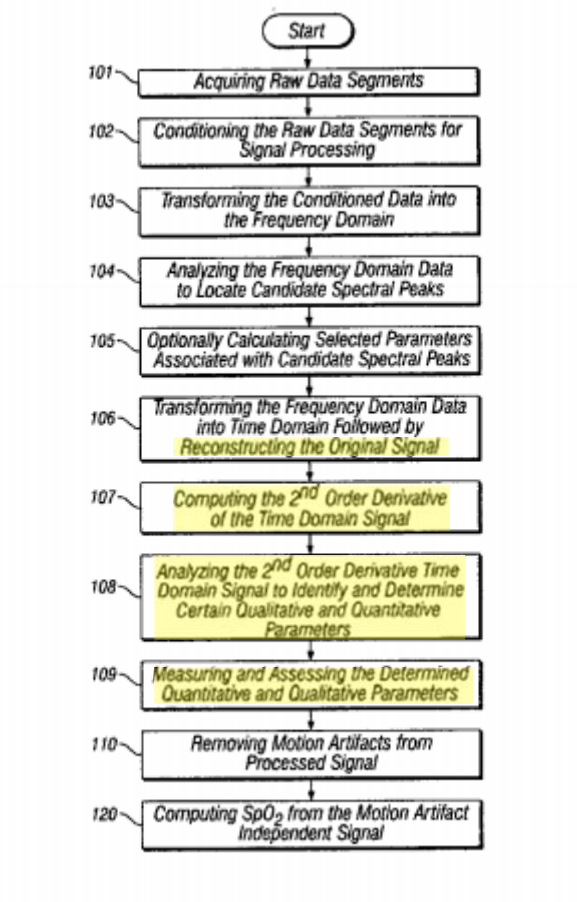
reconstructed using FOS in **Jay** (**X1002,** ¶97).[7] The benefit of taking such a derivative, as taught in **Scharf**, is that,

> The [second order derivative photo-plethysmogram (SDPTG)] ***facilitates efficient qualitative and quantitative morphological analysis of physiological signals*** since it visually represents physiological changes and other artifacts, better than that of normal waves.

(**X1005**, ¶0067 (emphasis added)). Thus, **Scharf** provides express motivation to perform a derivative of the FOS reconstructed photo-plethysmogram signal in **Jay** because doing so would "facilitate[] efficient qualitative and quantitative morphological analysis ... better than that of normal waves" (*id.*; *see also* **X1002,** ¶¶98-99).[8] It would therefore have been obvious to use the highlighted portions of Figure 1C of **Scharf** (**X1002**, ¶100), following the FOS signal reconstruction concept disclosed in **Jay**:

[7] A POSITA would understand that a pulse oximetry signal is also referred to as a photoplethysmograph (**X1002,** ¶97).

[8] **Jay** and **Scharf** are both directed to the measurement of signals through the use of pulse oximeters or photo-plethsymograms and, thus, a POSITA would have been aware of both references (**X1002**, ¶101).



Even still, **Jay** also discloses using cross-correlation of a base signal and a test signal to measure the similarity of two signals in order to assess abnormalities in the reconstructed signal (**X1006**, 6:52-53).[9] A POSITA would understand that a cross-correlation operator of two signals would be susceptible of noise such as those from motion artifacts in the measured signals (**X1002,** ¶102). As discussed in **Scharf**,

[9] Cross correlation is a well-established technique to determine similarity between two signals as a function of one signal displaced relative to the other signal (**X1002,** ¶102).

> [a]n artifact may include unwanted signals superimposed onto the PPG signal …. Motion artifacts can render it substantially difficult for the oximeter to accurately determine the patient's PPG signal, therefore causing errors in the pulse rate and oxygen saturation outputs

(**X1005**, ¶0004) (emphasis added). To this end, a POSITA would have been motivated to further remove artifacts in **Jay** by taking a second order derivative as provided in **Scharf** (**X1002,** ¶103). Combining **Scharf's** motion artifact removal disclosure would make it possible to obtain a cleaner reconstructed pulse-oximeter signal in **Jay** that could be displayed over at least one cycle to better provide "data indicative of pulsus paradoxus, and predict the risk for adverse clinical outcomes, such as impending severe respiratory distress" (**X1005**, ¶0067; **X1002,** ¶104).

Scharf further explains that "[i]naccuracies in AC component measurements cause inaccuracies in SpO_2 measurements because oximeters compute SpO_2 using the relative magnitudes of the AC components of the different optical photo-plethysmograms" (**X1005**, ¶0005; **X1002**, ¶105). Thus, by removing such inaccuracies in the SpO_2 measurements, better oximeter measurements can be made (**X1002,** ¶106). These more accurate reconstructed signals can then be used to assess for abnormalities (**X1005**, ¶0004; **X1002,** ¶106). As specifically provided, "measurements are non-invasive and can be applied to blood bearing tissue to *conduct heart and respiration rate monitoring, to perform blood pressure*

studies, and to determine blood hemoglobin oxygen saturation" (**X1005**, ¶0004; **X1002,** ¶106). Each of these would encompass using a model where a derivative of at least one term is used over at least one cycle in order to detect an abnormality (**X1002,** ¶106).

Accordingly, **Scharf** alone and/or **Jay** in view of **Scharf** renders Claim 1 unpatentable in multiple ways:

'864 Patent	**Jay (X1006) and Scharf (X1005)**
Claim 1 **1.pre)** A method of detecting an abnormality in a patient from an electrophysiological signal, comprising:	The preamble is not limiting. Nonetheless: **Jay** "discloses a device and method for measuring pulsus paradoxus" (**X1001**, 2:15-18; **X1006**, Abstract). **Scharf** discloses a method "to conduct heart and respiration rate monitoring, to perform blood pressure studies, and to determine blood hemoglobin oxygen saturation" (**X1005**, ¶0003) and provides that "SDPTG facilitates efficient qualitative and quantitative morphological analysis of physiological [by] visually represent[ing] physiological changes and other artifacts" (**X1005**, ¶0067).
1.a) obtaining an electrophysiological signal corresponding to the patient;	**Jay** discloses "using as input data a waveform indicative of patient pulsatile cardiovascular behavior from an optical plethysmograph, a pulse oximeter, or a blood pressure monitor." (**X1001**, 2:18-21; *see also* **X1006**, 3:40-54). **Scharf** also discloses obtaining an electrophysiological signal (**X1005**, ¶¶ 0019-0020, 0067).

1.b) finding, using a processor of a computing device, a model corresponding to the electrophysiological signal wherein at least one term in the model is differentiable;	Figure 5 of **Jay** discloses performing the FOS algorithm using a "CPU." **Jay** further discloses: > The fast orthogonal search algorithm finds the precise phases and amplitudes to associate with each selected period using the Weiner process, a least-squares minimization technique. This process can be readily visualized when fast-orthogonal search is running. A series of sinusoids are linked and are fit to the data. (**X1006**, 4:46-51). **Scharf** also discloses using Fourier transform terms to model the signal (**X1005** ¶¶0020, 0046; (**X1002,** ¶107 at pg. 50).
1.c) obtaining the derivative of the at least one term; and	**Scharf** discloses "*a second order derivative* photo-plethysmogram (SDPTG) …." (**X1005**, ¶¶0066-67). A POSITA would understand to combine this feature of **Scharf** with the FOS filtering disclosed in **Jay** to visually represent physiological changes and/or improve the measurement of the oximeter (**X1002,** ¶107 at pg. 51). That is, **Scharf** uses the SDPTG to identify model terms associated with the physiological signal and those associated with noise, allowing one to reconstruct using only the good model terms (*id.*). These "good" model terms and the associated reconstructed signal can be used in any way that Jay uses them (*id.*).
1.d) using the derivative over at least one cycle of the electrophysiological signal in order to detect the abnormality.	This statements is not limiting. Nonetheless: **Jay** discloses that "[t]he invention can assess the status of a patient in acute respiratory distress to determine severity of the condition, and one embodiment uses FOS to fit a sinusoidal series to the data for measurement of pulsus paradoxus …. To identify a pathological condition … and display on a

	user interface data indicative of pulsus paradoxus,, and predict the risk for adverse clinical outcomes, such as impending sever respiratory distress" (**X1001**, 2:21-33; **X1006**, 4:46-58). The analysis (including the derivative) performed by **Scharf** in a preferred embodiment uses 37 seconds of data for each segment. Since Scharf discloses that the beats per minute ranges from 29 bpm to 252 bpm, 37 seconds must necessarily have multiple cycles. (**X1005** ¶0044, ¶0046, ¶0049; **X1002,** ¶107 at pg. 52)).

2) Dependent Claims 2-6

Dependent Claims 2 through 6 of the '864 patent recite basic elements of model-derived signal reconstruction using the FOS method publicly disclosed in **Korenberg** in 1989 and utilized in **Jay** (**X1002**, ¶¶108-109). As explained in the Background section of the '864 patent, **Korenberg** discloses how FOS produces "sums of cosine and sine functions [that] are examples of summation series of complex exponentials" (**X1001**, 1:54-58). The '864 patent confirms that FOS signal reconstruction produces a sinusoidal series that is "fractionally differentiable and integrable analytically, where the order of the fractional derivative or integral can be any real or complex number," and where "[a] derivative of negative order – a, where a >0, corresponds to an integral of positive order a" (**X1001**, 1:50-64). A POSITA would also understand that a derivative can have an order, including a second order (**X1002,** ¶110). A second order derivative of a function y can be

represented as y'' and a first order derivative of a function y can be represented as y' (*id.*). Example of derivative orders in the '864 patent includes first and second order derivatives. (**X1001**, 23:3, 23:19, 24:32-34; (*id.*)). Accordingly, because **Jay** employs signal reconstruction using FOS, the above characteristics of FOS are inherently disclosed in that reference and render Claims 2-6 obvious (**X1002,** ¶111).

Notwithstanding the above, these dependent claims are also expressly disclosed in **Scharf**. Claims 2-4 clarify orders of the derivative that are used in the subsequent analysis, including a derivative of an order that is a real number, a positive number, and a positive integer. Each of these limitations is disclosed by **Scharf's** second order derivative (order = 2) (**X1002,** ¶112). Further, as expressly disclosed in **Scharf**, while its method "is preferentially based upon second order derivative processing analysis, but can be equally applied using the first, third fourth or other similar derivative processing analysis" (**X1005**, Abstract).

Claims 5-6 each generally recite a ratio between two derivative operations. Indeed, there are no restriction to the orders that can be used as recited in the claims (**X1002**, ¶¶113-114). In particular, in certain instances (where the order a = 1), a POSITA would understand that the claimed ratio can be simplified to a normalized first order derivative (**X1002, ¶¶**115-116). That is, the "ratio" set forth in Claims 5 and 6 is simply another "similar derivative processing analysis" known

to a POSITA as referenced in **Scharf** (**X1002,** ¶117; *see* **X1005**, Abstract, ¶0020).

Claims 2-6 are thus obvious in view of **Jay** combined with **Scharf**:

'864 Patent	**Jay (X1006) and Scharf (X1005)**
Claims 2-4 **2.** The method of claim 1, wherein the derivative has an order, and wherein the order is a real number. **3.** The method of claim 2, wherein the order of the derivative is a positive number. **4.** The method of claim 3, wherein the order of the derivative is a positive integer.	**Scharf** discloses a ***second order derivative*** (X1005, ¶¶0020, 0023, 0067, 0081). The number "2" is a real number. The number "2" is a positive number. The number "2" is a positive integer. **Jay** discloses FOS, which satisfies the limitation (**X1006**, 9:36-39; **X1001**, 1:58-64).
Claim 5 **5.** The method of claim 1, wherein the at least one model term has a derivative of order a and also of order a-1, and wherein a ratio of the derivative of order a to the derivative of order a-1 exists over a plurality of points over at least one cycle of the electrophysiological signal.	A POSITA would understand that a ratio of the derivative of order "a" to the derivative of order "a-1" can simplify as a first order derivative of a signal. That is, for an order "a" value of "one", order "a-1" is "zero" (i.e., 1-1 = 0) (**X1002**, 118 at pg. 56). As admitted in the '864 patent, "[a] derivative of zero order of a function is just the function itself" (**X1001**, 1:63-64). According to **Scharf**, and as discussed above, a second order derivative can be computed "of the reconstructed [] signal … and … selecting the best physiologic candidate from the series of potential cardiac spectral peaks (primary plus harmonics) based upon a second derivative scoring system." (**X1005**, ¶20). However, **Scharf** clarifies that "[t]his scoring system is preferentially based upon second derivative processing analysis, but can be equally applied using the *first*, *third*, *fourth* or other similar

	derivative processing analysis" (**X1005,** ¶0020) (emphasis added). A first order derivative is thus disclosed in **Scharf**.
Claim 6 **6.** The method of claim 5, wherein the order a is a positive integer, and wherein the ratio is used over at least one cycle of the electrophysiological signal in order to detect the abnormality.	As noted above in the discussion of claim 5, a POSITA would understand that the order a provides a ratio of the derivative of order "a" to the derivative of order "a-1", which can simplify as a normalized first order derivative of a signal. **Scharf** discloses using the first order derivative over at least one cycle to assess cardiac spectral peaks to detect an abnormality (**X1005**, ¶0020; **X1002**, 118 at pg. 57). **Scharf** also discloses using ratios of derivative values for quantitative analysis of the derivative signals (**X1005**, ¶0070).

3) Dependent Claim 13

Claim 13 depends from Claim 1 and generally recites that the electrophysiological signal can further include ECG. Claim 13 further recites steps that are naturally performed in the FOS algorithm and its variants. A POSITA would understand, from manuscripts about FOS, that FOS uses an orthogonalization process that can create mutually orthogonal signals from lead signals; indeed, that is the basic function of the Gram-Schmidt process on which FOS is based (**X1002,** ¶¶119-120).

Jay and **Scharf** do not explicitly disclose that the FOS algorithm can be performed on an ECG. However, **Scharf** makes clear that "[o]ne of ordinary skill in the art would appreciate that [its] signal processing approach could be used in a

device that functionally processes physiological signals but is not referred to as an oximeter" (which could include an ECG) (**X1005**, ¶0089; **X1002**, ¶¶121-122). Further, **Jay** provides a motivation to apply its teachings to an ECG signal. **Jay** states that the "data source may be any device that outputs a waveform indicative of patient pulsatile cardiovascular behavior (**X1006**, Abstract), which a POSITA would understand an ECG to be a measure of (**X1002,** ¶123).

A POSITA would further understand that FOS as disclosed in **Jay** could be performed on an electrocardiogram. As stated in **Korenberg**:

> [FOS and ROS] are effective with short data records, and cope with noisy, missing and unequally-spaced data. For these reasons, the methods appear suitable for analysis of … *electrocardiogram (ECG)*

(**X1007**, 268 (emphasis added); **X1002**, ¶124).

A POSITA would thus have had reason to utilize the **Jay/Scharf** signal reconstruction approach of producing and assessing an accurate physiological signal based on ECG leads (**X1002,** ¶125). A POSITA would further recognize that a FOS reconstruction of ECG would involve at least two lead signals being replaced by two mutually orthogonal signals in the reconstruction (*id.*). According to the '864 patent:

> [O]ne can use FOS to select from 12 leads ECG the … leads that are the most important, and the FOS-selected leads may carry more information than those used in a vectorcardiogram.

> See paper … "Iterative Fast Orthogonal Search for Modeling by a Sum of Exponentials or Sinusoids" … especially on pages 324-325, the section on FITTING MULTIPLE SETS OF OBSERVATIONS.

(**X1001**, 26:45-27:42).

Accordingly, Claim 13 is obvious in view of **Jay** combined with **Scharf**:

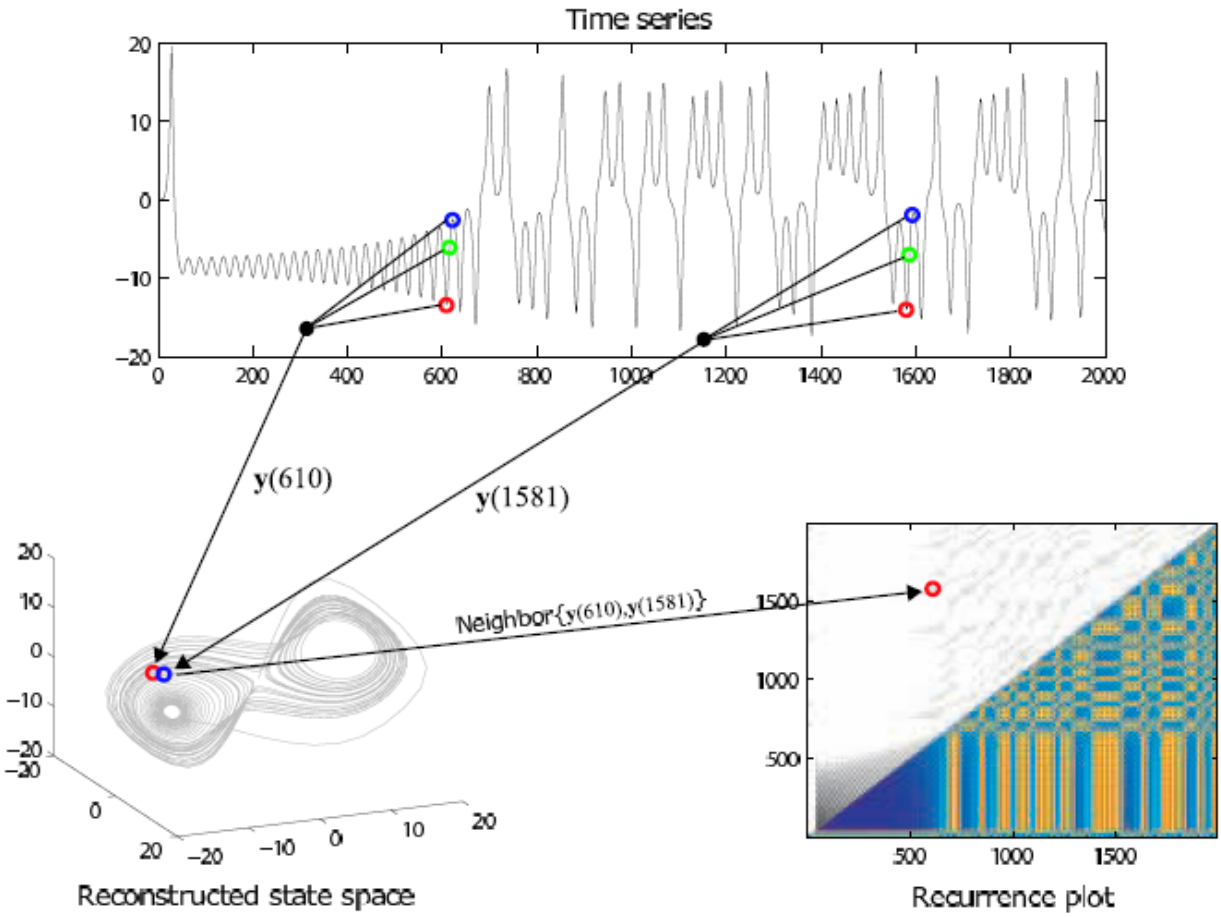
'864 Patent	**Jay (X1006) and Scharf (X1005)**
Claim 13 **13.a)** The method of claim 1, wherein the electrophysiological signal comprises a portion of an electrocardiogram including portions of at least two lead signals,	As discussed above, it would have been obvious to employ the methods of **Jay** and/or **Scharf** with ECGs. ECG data collection involves multiple leads (**X1002**, - ¶126 at pg. 60).
13.b) wherein an orthogonalization process is used to create at least two mutually orthogonal signals from the portions of the at least two lead signals, and	The FOS algorithm inherently replaces the signals with mutually orthogonal signals derived from the lead signals (**X1002**, ¶126 at pg. 61).
13.c) wherein the at least two mutually orthogonal signals are used in place of the portions of the at least two lead signals.	The outcome of the algorithm is the reconstructed signal, which models the incoming signals. It would have been obvious to reconstruct multiple signals with multiple ECG lead signals (**X1002**, ¶126 at pg. 61).

B. Ground 2: Claims 7-8, 14-15, and 17-18 Are Obvious Based on Jay in view of Scharf and Ahlström

1) Dependent Claims 7-8 and 14-15

Dependent Claims 7-8 and 14-15 of the '864 patent generally recite a method of analysis by visually presenting information derived from the reconstruction algorithm (**X1002**, ¶ ¶127-131). Claim 7 generally recites displaying the ratio (*i.e.*, ratio of the derivatives recited in Claims 5 and 6) to form a plot and to show highlighting of portions where the ratio is positive (*id.*). Claim 8 further clarifies (from Claim 7) that the plot is placed over a portion of a 3D outline of the heart (*id.*). Claim 15 is out of sequence with claim 14 and further clarifies (from claim 8) some characteristics of the highlighting (*id.*). Claim 14 generally recites the features of claims 5, 6, 7, 8, and 15 in a single claim (*id.*).

A POSITA would understand that the ratio, as recited in the claims, are displayed to facilitate analysis of the reconstructed signal in a plot including a three-dimensional (3D) phase space plot (**X1002,** ¶132). According to **Ahlström**, it was known that time-series data (such as a reconstructed signal) (see top sub-image of figure below) could be presented as a 3D phase space plot (see bottom left sub-image of figure below) (**X1011**, 77; **X1002**, ¶133).

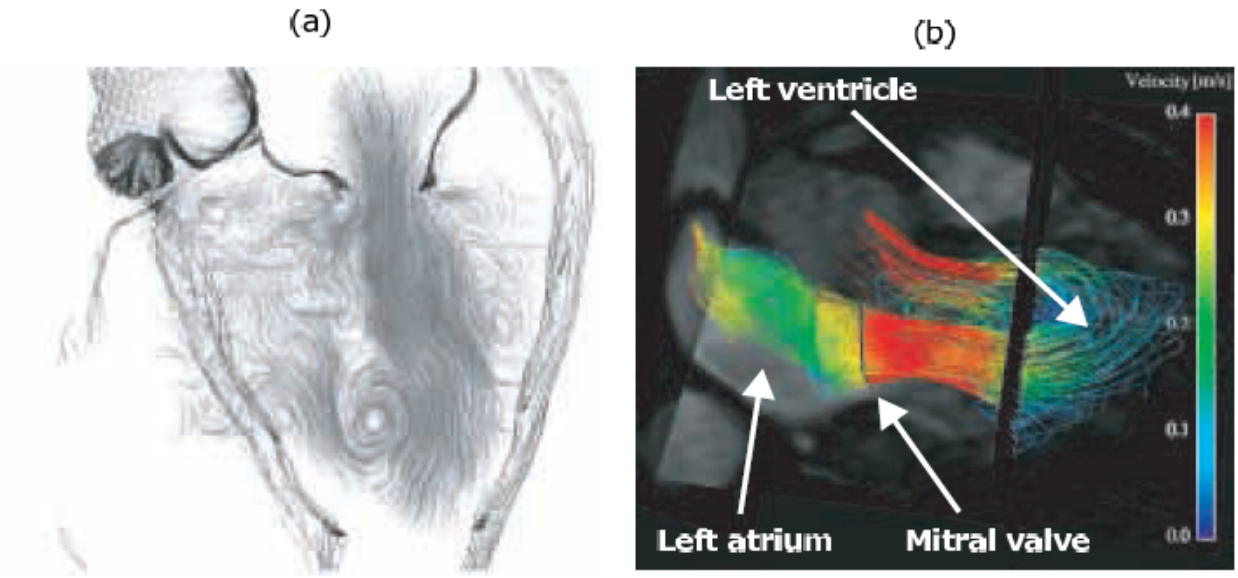


As shown above, the reconstructed state space of a Lorenz system (from the corresponding time-series data) is shown in the lower-left sub-image (**X1002,** ¶134). The state space representation makes its obvious where unstable areas are located (**X1002,** ¶135). Indeed, a POSITA would know that a Lyapunov exponent could be applied and calculated from the data to assess stability (*id.*). Lyapunov exponents were used well before the '864 patent to describe dynamic systems and predict stability, including in biological systems (*id.*). As explained in the '864 patent:

> Lyapunov exponents tell us the rate of divergence of nearby trajectories, a key component of chaotic dynamics. The Lyapunov exponent measures the average of the divergence or convergence of orbits starting from nearby initial points. Therefore, the Lyapunov exponent can be used to analyze the stability of limit cycles and … the presence of chaotic attractors.

(**X1001**, 11:28-43; **X1002**, ¶136).

Ahlström further discloses the use of cardiovascular models to illustrate different physical phenomena (**X1002,** ¶137). An example of one such model is reproduced below (**X1011**, 193; **X1002,** ¶137)).



The above color model includes colors to indicate segments of the plot having high and low areas of blood flow velocity (**X1011**, 193; **X1002,** ¶138). Another example illustrates the contrast of normal heart signals in state space relative to

heart murmur signals in state space (**X1011**, 126) shown below.

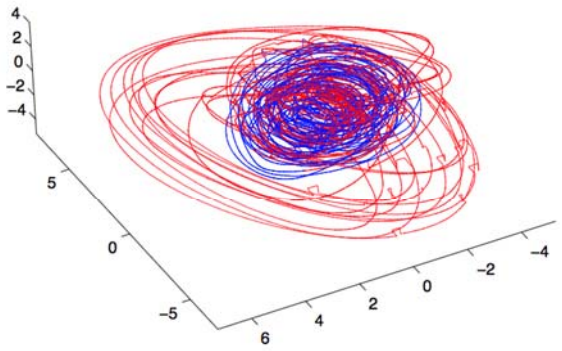


Fig. 5.1: Example of an embedded PCG signal. The heart sounds are encircling the more complex murmur.

This figure allows for assessment of abnormality in the signal, as the normal signal is shown in red and the abnormal signal is shown in blue (**X1002,** ¶139).

2) Dependent Claims 17-18

Claims 17 and 18 generally recite displaying a representation of a function of a derivative (where the derivative has an order that is a real number or a positive number) (**X1002**, ¶140). Claim 17 depends on claim 2 (which recites that the order is a real number). Claim 18 depends on claim 3 (which recites that the order is a positive number).

Each of these dependent claims recite well-known visual representations of biological data, and a POSITA would understand that a first order derivative (order = 1) has an order that is a real number and a positive number (**X1002**, ¶141). To

this end, claims 17 and 18 are obvious in view of **Ahlström** and **Scharf**, which shows presentation of a first and second order derivative, respectively.

'864 Patent	**Jay (X1006), Scharf (X1005), and Ahlström (X1011)**
Claim 7 **7.a)** The method of claim 6, wherein the ratio is displayed over at least one cycle of the electrophysiological signal to form a plot, and	**Scharf** discloses a plot of the derivative of an electrophysiological signal over one cycle of the signal. As discussed above, it would have been obvious to a POSITA to normalize the derivative by the signal to account for signal scaling variances (**X1002**, ¶142 at pgs. 65-66).
7.b) wherein one or more highlighted indicators are used in the plot to indicate those portions where the ratio is positive.	As discussed above (**X1011**, 77 and 193). A POSITA would have found it obvious to highlight instability, asserted as the positive ratio in the '864 patent (**X1002**, ¶142 at pg. 66).
Claim 8 **8.** The method of claim 7, wherein the electrophysiological signal is a portion of an electrocardiogram, and wherein the plot is placed over a portion of a **3-D outline of the heart**, and wherein one or more highlighted indicators are used to indicate the areas in the interior or exterior of the heart where damaged areas are in the heart.	As discussed above (**X1011**, 77 and 193). In view of **Ahlström,** such visual representations were conventional and known (**X1002**, ¶142 at pg. 66).
Claim 14 **14.a)** The method of	**Ahlström** discloses that all datasets used in his studies comprised multiple signals including ECG

claim 1, wherein the electrophysiological signal comprises portions of at least two signals measured at corresponding instants of time,	and PCG data (**X1011**, 7). For example "Data set II Contains PCG signals with various degrees of aortic stenosis present. Signals from 27 boxer dogs … were recorded with an electronic stethoscope … and a standard 3-lead ECG … was *recorded in parallel as a time reference*." (**X1011**, 8 emphasis added; **X1002**, ¶142 at pgs. 66-67). As provided below, Figure 5.1 of **Ahlström** further discloses plotting two signals measured at corresponding instants of time (**X1011**, 126; **X1002**, ¶142 at pg. 67).
14.b) wherein the derivative is used in a mathematical expression that is applied to each of the at least two signals at corresponding instants in time to obtain positive or negative indications of the abnormality,	**Ahlström** provides for multiple signals in Figure 5.1. "These classic PCG representations basically contain the same information, but for visual interpretation or time signal processing, they reveal different vibratory patterns [36]. Plotting these representations against each other, *a reconstructed state space expressed in derivative coordinates is obtained*, see figure 5.1." (**X1011**, 125 and Figure 5.1; **X1002**, ¶142 at pg. 67).
14.c) wherein the expression is used to form a plot corresponding to different instants of time, and	A POSITA would understand a phase plot as shown in Ahlström, Figure 5.1 is a plot corresponding to different instances of time (**X1011**, 125 and Figure 5.1; **X1002**, ¶142 at pg. 67).
14.d) wherein one or more highlighted indicators are used to indicate segments of the plot when the expression detects the abnormality, said highlighted indicators comprising at least one of: color coded indicators, including use of a first	As discussed above, **Ahlström**, Figure 5.1 shows a phase plot having segments corresponding to heart abnormalities colored differently than segments corresponding to normal heart function (**X1011**, 126; **X1002**, ¶142 at pgs. 67-68).

and a second color such that the first color dominates at instants when negative indications of the abnormality dominate, the second color dominates at instants when positive indications of the abnormality dominate, and the highlighted indicator is closer to neutral in hue at instants when positive indications of the abnormality are offset by negative indications of the abnormality; and shaded indicators, one or more type of broken line, and one or more type of line thickness.	
Claim 15 **15.** The method of claim 8, wherein the highlighted indicators comprise at least one of color coded indicators, shaded indicators, one or more type of broken line, and one or more type of line thickness.	As discussed above (**X1011**, 193). **Ahlström** discloses color and shade indicators, satisfying the "at least one of" language of Claim 15. **Ahlström** demonstrates using color to distinguish normal heart sounds from heart murmur in phase space plots (see **X1011**, 125-126; **X1002**, ¶142 at pg. 68).
Claim 17 **17.a)** The method of claim 2, wherein a function of the derivative is defined,	As discussed above in Section V.A.2, Claim 2 recites that the derivative has an order that is a real number including a second order derivative (as that taught by **Scharf**). A POSITA would understand that a second order derivative of a signal satisfies the "function of the

	derivative" as claimed (**X1002**, ¶142 at pg. 68).
17.b) wherein the function of the derivative assumes at least one value over a plurality of points over at least one cycle of the electrophysiological signal, and	A POSITA would understand that a function of a second order derivative would have a value at each of the plurality of points over a set of points (i.e., at least one value over a plurality a points over at least one cycle of the electrophysiological signal) (**X1002**, ¶142 at pg. 68).
17.c) wherein at least one representation of the at least one value is displayed over the plurality of points.	According to **Ahlström**, a derivative value is displayed over one of the points (**X1011**, 54-55, 77, 125-126; **X1002**, ¶142 at pg. 69).
Claim 18 **18.** The method of claim 3, wherein a function of the derivative is defined, wherein the function of the derivative assumes at least one value over a plurality of points over at least one cycle of the electrophysiological signal, and wherein at least one representation of the at least one value is displayed over the plurality of points.	As discuss above in Section V.A.2, claim 3 recites that the derivative has an order that is a positive number including a second order derivative (as that taught by **Scharf**). As discussed in 17.a to 17.c above: • a POSITA would understand that a second order derivative of a signal satisfies the "function of the derivative" as claimed; • a POSITA would understand that a function of a second order derivative would have a value at each of the plurality of points over a set of points (i.e., at least one value over a plurality a points over at least one cycle of the electrophysiological signal); and • according to **Ahlström**, a derivative value is displayed over one of the points (see **X1011**, 54-55, 77, and 125-26(**X1002**, ¶142 at pg. 69)).

C. Ground 3: Claims 9-12 and 16 are Anticipated and/or Rendered Obvious by Korenberg

1) Independent Claim 9

Claim 9 recites essentially five limitations:

(a) Choosing a measure of approximating an electrophysiological signal;

(b) Using a processor of a computing device in a search through candidate terms to select terms to add to the model at successive stage;

(c) Wherein at least two distinct candidate terms are selected;

(d) Where one of the selected terms causes, out of the candidate terms searched, the greatest reduction in the measure of approximating the signal; and

(e) Where another of the selected terms causes, out of the candidate terms searched, one of a relative maximum of the reduction of the measure of approximating the signal or a reduction of the measure of approximating the signal above a specified threshold level.

(**X1002**, ¶143).

Each of these limitations expresses known attributes of FOS as published by Dr. Korenberg at least in 1989. Indeed, **Korenberg** discloses each limitation (a) through (e) above (**X1002**, ¶144). Specifically, the heading of Section 2.3 of **Korenberg** states "Selecting Model Terms by Fast Orthogonal Search" (**X1007**, **269).** Within section 2.3, **Korenberg** describes a process of searching through candidate terms, referred to as model terms "$P_m(n)$", to add in successive stages to

a model (**X1007**, 269; **X1002**, ¶¶145-146). Pseudocode is then provided for implementation of such a search on a computer processor (**X1007**, 269; **X1002**, ¶147). At least two candidate terms are disclosed as being selected from the candidate terms, either in the same iteration or in successive iterations (**X1007**, 269; **X1002**, ¶147). **Korenberg** describes that "Two tests of fast orthogonal search were conducted… In both tests, 100 candidate frequencies, equally-spaced between 0 and 0.5 times the sampling frequency, were searched and up to 20 distinct frequencies were permitted in the final model" (**X1007**, 272; **X1002**, ¶147). This resulting sinusoidal series representation comprises at least two candidate terms (**X1002**, ¶147).

Further, **Korenberg** discloses that, in the FOS algorithm/computing processes, a measure of selecting a candidate term can be based on mean-square error and that such a selection will result in the greatest reduction in the mean-square error, constituting "the greatest reduction in the measure of approximating the signal" as recited in Claim 9 (**X1007**, 269; **X1002**, ¶148). The *reduction of mean-square error* is described as a measure of approximating the signal; that is, *reduction of mean-square error* is the criterion used in the selection of a candidate that in combination with other selected candidate can represent a given signal, where the parameter "Q" refers to a reduction in a mean-square error value, and

where "Q(M+1)" refers to a next reduction in the value of the mean-square error with the inclusion of a new candidate term (**X1007**, 269; **X1002**, ¶149).

Finally, **Korenberg** discloses that another of the selected candidate term can be used to establish both a reduction of the measure of approximating the signal above a specified threshold level or a relative maximum of the reduction of the measure of approximating the signal (**X1002**, ¶150). With respect to the action of causing *a reduction of the measure of approximating the signal above a specified threshold level*, **Korenberg** discloses a positive threshold level being used with respect to the Q value, which as discussed above as being a measure (*i.e.*, reduction in mean square error) of selecting a candidate (**X1007,** 270; **X1002**, ¶151). **Korenberg** further describes that this condition (*above a specified threshold level*) prevents division by a negligibly small number (**X1007,** 270; **X1002**, ¶151). **Korenberg** further describes that this condition allows for rapid construction of a model that is parsimonious (**X1007,** 270; **X1002**, ¶151). With respect to the action of causing *a relative maximum of the reduction of the measure of approximating the signal*, **Korenberg** discloses that candidate frequency can be chosen with "a largest $Q_1(1)$ value and all candidate frequencies occurring at "relative maxima" of $Q_1(1)$" (**X1007,** 270; **X1002, ¶**152).

Accordingly, **Korenberg** anticipates Claim 9 by providing the application of FOS and ROS to electrophysiological signal reconstruction (**X1002, ¶**153):

’864 Patent	Korenberg (X1007)
Claim 9 **9.a)** A method for building a model approximating an electrophysiological signal,	**Korenberg** discloses the FOS and ROS algorithm, which are known techniques for use to build a model to approximate an electrophysiological signal. (**X1007**, 268); **X1002**, 153 at pg. 73.
9.b) wherein the method includes choosing a measure of approximating the signal,	**Section 2.1** states, “[t]o expand the difference equation model by a further term using the orthogonal search method (Korenberg 1985; Mcllroy 1986), evaluate the quantity Q in [Equation] (6) for each candidate addition. *Choose the candidate for which Q is greatest, since this addition will result in the greatest reduction in mean-square error.* By continuing in this way, it is possible to efficiently construct accurate parsimonious models of real systems, particularly if a threshold level is used to reject unsuitable terms (McIlroy 1986).” (**X1007**, 269) (emphasis added). **Section 2.2** further recites, “for each candidate frequency not previously selected evaluate *Q1(i)*. *Choose the candidate for which Q1(i) is largest* (again, optionally, subject to exceeding a threshold level) …. Continue the process unless the mean-square error given by (16) (with $M = 2i$) is acceptably small, or the model has reached the maximum size allowable.” (**X1007**, 271 (emphasis added)). A POSITA would understand that mean-square error is a measure used for approximating the signal (**X1002, ¶**153 at pgs. 73-74).
9.c) wherein the method involves using a processor of a computing device in a search through candidate terms	**Korenberg** provides for selecting a term to add to a model at a given stage (**X1007**, 269-70 (emphasis added); **X1002, ¶**153 at pgs. 74-75). **Korenberg** discloses that FOS uses a processor of a

to select terms to add to the model at successive stages, and	computing device to select selection model terms (**X1007**, 269); **X1002,** ¶153 at pg. 76.
9.d) wherein at least two distinct candidate terms are selected,	A POSITA would have understood limitation 9.d to read on FOS (**X1002,** ¶153 at pg. 76). **Korenberg** discloses that candidate terms $P_m(n)$ are selected from m = 1, 2, …. (**X1007**, 270). There are at least two candidate terms selected (a first term for m =1, and a second term for m = 2). A POSITA would have understood that selected candidate terms are *distinct* from one another (**X1002,** ¶153 at pg. 76). **Section 4** recites applications of FOS to approximate two test-series data. In each of these examples, candidate having *distinct* frequency components are selected. (**X1007**, 271-72) (emphasis added). Further, **Section 5.1** states that ROS can consider "two or more candidates at a time." (**X1007**, 274). If two or more candidates are selected at any given stage, then at least two candidate terms would have been selected (**X1002,** ¶153 at pg. 77).
9.e) where one of the selected terms causes, out of the candidate terms searched, the greatest reduction in the measure of approximating the signal, and another of the selected terms causes, out of the candidate terms searched, at least one of: a relative maximum of the reduction of the measure of approximating the signal; and a reduction of the measure of	A POSITA would have understood limitation 9.e to read on FOS (**X1002,** ¶153 at pg. 77). Claim 9 does not specify a temporal requirement on the selection of candidate terms. Indeed, a first selected candidate term will "cause the greatest reduction in measure of approximating a signal" and, a second selected candidate selected after the first term will naturally cause "a relative maximum of the reduction of the measure of approximating the signal" (*id.*). According to **Section 2.2** (in describing FOS), "[t]he candidate with largest Q value is selected (optionally, subject to exceeding a specified positive threshold level)." (**X1007**, 270). Limitation 9.e can also be read to involve the selecting of two candidate terms at each successive

approximating the signal above a specified threshold level.	stage, where the first candidate term selected at a given stage causes the "greatest reduction in the measure" and the second candidate term selected at the same stage causes "a relative maximum of the reduction of the measure." This operation is also explicitly recited in **Korenberg** in its discussion of the ROS and FOS algorithm (**X1007**, 275; **X1002,** ¶153 at pg. 78).[10] A POSITA would understand that "greatest reduction in the measure" (9.e.) is taught by the choosing of a "candidate frequency with largest $Q_I(1)$ value" and that "a relative maximum of the reduction of the measure" is taught by the choosing "candidate frequencies occurring at "relative maxima" of $Q_I(1)$" (**X1002,** ¶153 at pg. 78). Further, **Section 5.1** in discussing ROS states, "Clearly many similar strategies utilizing (43) to *select terms can be set down: e.g. considering two or more candidates at a time*." (**X1007**, 274 (emphasis added)). **Section 2.3**, in discussing FOS, also states: [I]n practice it is efficient to build up the model by selecting one *further* term at a time. ... m.s.e.= $\overline{y^2(n)} - \sum_{m=0}^{M} g_m^2 D(m,m)$ (16) (**X1007**, 269 (emphasis added)). This same equation 16 is recited with respect to ROS (see Equation 44) for use in the selection of candidate terms (**X1007**, 274; **X1002**, ¶153 at pg. 79).

[10] It is noted that discussion of limitation 9.e is also relevant to "modified fast orthogonal search (MFOS) transform" as recited in claim 12.

2) Dependent Claims 10-12 and 16

Dependent Claim 10 generally recites use of the FOS and ROS algorithms to determine terms to approximate or estimate a signal and using a subset of the terms to separate the noise component from the signal (**X1002,** ¶154-155). Dependent claim 10 further recites "separating a noise component from the plurality of terms selected for the model; and d) forming a reconstructed electrophysiological signal whereby the noise component is removed by using a subset of the plurality of terms selected for the model." This too is provided by FOS and ROS as known to a POSITA at the time of the filing of the '864 patent and **Korenberg** (**X1002,** ¶¶156-157). Specifically, **Korenberg** discloses that FOS and ROS can be used to generate an approximated signal in which noise is removed or reduced from the original signal being modeled (**X1002,** ¶¶157-158). **Section 4.2 of Korenberg** is titled "Estimating Noise-Free Time-Series." Page 272, in the right column, provides:

> Here we attempt to recover the time-series as it existed *prior to corruption by the noise process*. To do this, we *again applied fast orthogonal search* to test time-series …. However, *we used a higher threshold (4% of the noisy time-series variance) as the minimum reduction in mean-square error required before addition could be made to the model.* Using the estimated constant, and the sinusoidal components identified in [Equation] (24), we synthesized our estimate z(n) of the *noise-free time-series* Z(n).

(**X1007**, 272-73) (emphasis added). Further, **Korenberg** concludes: "Thus fast orthogonal search can be used to *reduce dramatically the degree of noise corruption*" (**X1007**, 273 (emphasis)). A POSITA would thus understand that **Korenberg** disclosed how noise can be excluded from the model when selecting terms, just as set forth in Claim 10 (**X1002**, ¶159).

Similarly, Claim 11 is also anticipated in view of **Korenberg**. Indeed, the output of the FOS method includes complex exponentials as admitted in the Background section of the '864 patent (**X1001**, 1:50-58; **X1002,** ¶160).

Claim 12 recites a "modified fast orthogonal search (MFOS) transform" which, as discussed in the claim construction section above, provides for selection of two candidate terms at each successive stage based on a threshold used for a stop condition for the algorithm or a best (greatest reduction) and next best measure (relative maximum of the reduction) of the selection of a candidate term. As discussed in Section 9.e above, **Korenberg** discloses this method as ROS (**X1002,** ¶162). That is, **Korenberg** disclosed applying FOS in order to obtain "a parsimonious sinusoidal series representation or model of biological time-series data" (**X1007**, 267; **X1001**, 1:42-51)). This disclosure provides expressly for "an early selection of model terms … for both system identification and time-series analysis" (**X1007**, 275), which can be performed "to select the candidate frequencies at once." As described, "[s]imply choose the candidate frequencies

with largest Q(1) value and all candidate frequencies occurring at 'relative maxima' of Q(1), which exceed a specified threshold level" (**X1007**, 275). This modified FOS provided for in **Korenberg** is indistinguishable from MFOS provided in the '864 patent (**X1002, ¶**162). Further, because representing a time series data set by a model uses fewer numerical terms, it is inherent that **Korenberg** discloses a desired compression ratio (**X1002, ¶**163).[11] Accordingly, **Korenberg** anticipates or at a minimum renders obvious Claim 12.

Finally, Claim 16 narrows the independent Claim 9 by requiring that the measure of approximating the signal involves "*at least one of* the error, the square error, the mean square error, the weighted mean square error, the maximum square error, and the perpendicular distance to a hyperplane." Because claim 16 recites "at least one of … and …," only one of the element in the recited list is needed to be anticipated by the prior art. *See, e.g., SuperGuide Corp. v. DirecTV Enters.*, 358 F.3d 870, 886 (Fed. Cir. 2004). As discussed above in relation to independent Claim 9, **Korenberg** discloses that the measure of approximating the signal can be

[11] Claim 12 does not specify what is meant by a "desired compression ratio." Nonetheless, because **Korenberg** teaches using FOS to remove noise during a model-derived reconstruction of a signal, a compression ratio is achieved through the mathematical formula that represents an improvement over the noisy signal. Thus, a "desired compression ratio" is inherently disclosed in **Korenberg**.

"mean square error," thus Claim 16 is likewise anticipated and/or rendered obvious (**X1002,** ¶164-65).

Accordingly, dependent Claims 10-12 and 16 are anticipated and/or rendered obvious by **Korenberg**:

'864 Patent	**Korenberg (X1007)**
Claim 10 **10.a)** The method of claim 9, further comprising: a) receiving the electrophysiological signal at a computing device;	As discussed in 9.a above, **Korenberg** discloses that the methods of FOS and ROS appear suitable for analysis of biological data include electrocardiogram (ECG), which is a type of electrophysiological signal (**X1007**, 268).
10.b) selecting, at the computing device, a plurality of terms for the model approximating the electrophysiological signal;	As discussed above in 9.b above, **Sections 2.1 and 2.2 of Korenberg** disclose that candidate can be chosen to construct an accurate parsimonious models of real systems. (**X1007**, 269 and 271). A POSITA would understand that choosing terms to construct a model of a real systems such, as a biological system, involves selecting a plurality of terms for the model approximating an electrophysiological signal as recited in the claim (**X1002,** ¶166 at pg. 83).
10.c) separating a noise component from the plurality of terms selected for the model; and	FOS and ROS naturally separate noise components from the signal components (**X1002,** ¶166 at pg. 83). A POSITA would understand that selected terms in FOS and ROS can model the signal component in the original signal as well as the noise component in the same signal depending on the aggressiveness of the model in approximating the original signal (*id.*). According to **Korenberg**, a low threshold can be used for the minimum reduction in mean-square

	error to obtain a more accurate estimation of a signal and a high threshold can be used to approximate a noise-free series from noisy data (**X1007**, 273). **Section 4.2** in discussing FOS describes estimating an original time series signal in which noise in the signal is reduced or removed (**X1007**, 272-73).
10.d) forming a reconstructed electrophysiological signal whereby the noise component is removed by using a subset of the plurality of terms selected for the model.	**Korenberg**, in equation (5), gives the reconstruction equation explicitly showing the combination of the plurality of model terms for signal reconstruction and a separate term representing the noise. A POSITA would understand to use this equation to reconstruct the signal without the noise term (**X1002**, ¶166 at pgs. 84-85). The step of forming a reconstructed signal from selected terms of a model is within the skill of a POSITA (**X1002,** ¶166 at pg. 84). For example, as discussed above, **Korenberg** discloses that an example noise-free time series generated from FOS as : $Z(n) = 0.1 \cos(0.2\pi n)+\cos(0.4\pi n)+\cos(0.42\pi n)$ (**X1007**, 273). It is within the skill of a POSITA to generate a "reconstructed electrophysiological signal" as a time series signal having elements 1..x data points by evaluating the above FOS generated times series Z(n) for n values of 1 to x (**X1002,** ¶166 at pg. 85). With respect to the whereby clause ("whereby the noise component is removed by using a subset of the plurality of terms selected for the model"), as discussed in 10.c above, FOS and ROS naturally separate noise components from the signal components based on the degree that a given signal is approximated by the model generated from FOS or ROS (*id.*).

	Further, a POSITA would understand that model terms can be selected via FOS and ROS and then subsequently ignored (*id.*). **Korenberg** provides a definition for signal-to-noise ratio as "SNR = $\frac{variance\ [Z(n]}{variance\ [z(n)-Z(n)]}$." (**X1007**, 273). A POSITA would understand that the FOS or ROS algorithm would select as model terms in accordance with a specified threshold (stop condition) and to ignore certain terms produced by the algorithm to achieve a certain level of SNR (**X1002,** ¶166 at pg. 85).
11. The method of claim 9, wherein at least one of the at least two candidate terms that are selected is a complex exponential.	A complex exponential is a term well-understood in mathematics and signal processing. It is equivalent to two terms, a cosine term and a sine term each having the same frequency (**X1002,** ¶166 at pgs. 85-86; *see also* **X1001**, 1:32-58). **Korenberg** discloses performing spectral estimation using FOS (section 4) and generating sets of sine and cosine terms having the same frequencies (**X1002,** ¶166 at pgs. 85-86). A POSITA would understand that the outcome of the FOS based spectral estimation disclosed in **Korenberg** provides the cosine and sine parts of a complex exponential (**X1002,** ¶166 at pg. 86).
12.a) The method of claim 9, further comprising: applying a modified fast orthogonal search (MFOS) transform to the electrophysiological signal to generate a plurality of terms corresponding to the electrophysiological signal; and	As discussed in 9.e. above, **Korenberg** discloses selecting of two candidate terms at each successive stage, where the first candidate term selected at a given stage causes the "greatest reduction in the measure" and the second candidate term selected at the same stage causes "a relative maximum of the reduction of the measure," which defines MFOS as discussed in the claim construction above. A POSITA would have understood Section 6 of **Korenberg** to disclose that "greatest reduction in the measure" (9.e.) is taught by the choosing of a "candidate frequency with largest $Q_1(1)$ value" and that "a relative maximum of the reduction of the

	measure" is taught by the choosing "candidate frequencies occurring at "relative maxima" of $Q_1(1)$" (**X1007**, 275; **X1002,** ¶166 at pg. 86). Further, and as noted above, **Section 5.1** in discussing ROS states, "we can rapidly build up an accurate parsimonious model for a system of unknown structure. Clearly many similar strategies utilizing (43) to *select terms can be set down: e.g. considering two or more candidates at a time*," thus describing MFOS as recited in the '864 patent (**X1007**, 274 (emphasis added); **X1002,** ¶166 at pgs. 86-87).
12.b) forming a reconstructed electrophysiological signal whereby a noise component is separated from the electrophysiological signal using a subset of the plurality of terms, corresponding to the electrophysiological signal, which have at least a desired compression ratio.	As discussed in 10.d above, the step of forming a reconstructed signal from selected terms of a model is within the skill of a POSITA (**X1002,** ¶166 at pg. 87). As discussed in 10.d above, FOS and ROS naturally separate noise components from the signal components based on the degree that a given signal is approximated by the model generated from FOS or ROS (*id.*). Further, a POSITA would understand that model terms can be selected via FOS and ROS and then subsequently only a subset of the selected model terms are used (*id.*). A POSITA would understand a compression ratio to be a quantity of reduction in data-representation size produced by a data compression algorithm (*id.*). Given a known set of dictionary of candidate terms and the size of the original signal, a POSITA would understand the model order that can be used to achieve a specified compression ratio (*id.*).
16. The method of claim 9, wherein the measure of approximating the signal	As discussed above in 9.e, **Korenberg** discloses choosing a candidate frequency with the *largest $Q_1(1)$ value* (**X1007**, 275). A POSITA would

involves at least one of the error, the square error, the mean square error, the weighted mean square error, the maximum square error, and the perpendicular distance to a hyperplane.	understand that $Q_1(1)$ is the first selected candidate term as noted by the subscript "1" (*id.*). According to **Sections 2.2 and 2.3**, in describing FOS: Choose the candidate for which Q is greatest, since this addition will result in the greatest reduction in *mean-square error*. (**X1007**, 269 (emphasis added)). A POSITA would understand that "m.s.e." noted in Equations 16 and 44 of **Korenberg** refers to mean square error (**X1002,** ¶166 at pg. 88; **X1007**, 269, 274). A POSITA would also understand how to apply mean square error as a measure to approximate a signal using the FOS or ROS algorithm in view of the above teachings of **Korenberg** (**X1002,** ¶166 at pg. 88).

D. Ground 4: Claims 19-20 are Anticipated and/or Rendered Obvious by Adeney Alone or in Combination with Mao

1) Independent Claim 19

Claim 19 is anticipated and/or rendered obvious by Adeney (**X1008**) alone or in combination with **Mao (X1010)**. Claim 19 is directed to a well-known type of problem referred to as a feature subset selection problem (also referred to as a sensor selection problem) (**X1002,** ¶167). Claim 19 recites the following:

> A method of using a model-building procedure to select a concise subset of electrocardiogram (ECG) leads to use out of a larger set of ECG leads, comprising:
>
> a. for each lead in the larger set, using the corresponding lead signal to define a candidate signal;

b. for each lead in the larger set, using the corresponding lead signal to define a desired target output signal from an experiment; and

c. selecting the same subset of lead signals, out of the candidate signals, to approximate all the target signals from all the experiments by linear combinations of the selected lead signals, while allowing the coefficients of the selected lead signals to vary in approximating the target signals from one experiment to another.

A POSITA would have readily known from **Adeney** that there existed a "need to identify significant sinusoidal components within time-series data arises frequently in biological signal processing, for example, in the spectral analysis of electrocardiograms, respiration and heart rate data, and electroencephalograms" (**X1008**, 315; **X1002, ¶**169). **Adeney** further discloses the "use of FOS and IFOS procedures for finding a single model from the results of multiple experiments" (**X1008**, 315). Adeney does so by "express[ing] all of the data in terms of a single set of basis functions (*e.g.*, a single set of time constraints or sinusoidal frequencies)," using FOS or IFOS to "fit the entire batch of data" (**X1008**, 325).

Based on this disclosure alone, **Adeney** anticipates and/or renders Claim 19 obvious **(X1002, ¶¶**170-171**)**. Indeed, the '864 patent admits that a sensor selection method was obvious in view of **Adeney**, expressly stating:

> [O]ne can use FOS to select from 12 leads ECG … leads that are the most important, and the FOS-selected leads may carry more information than those used in a vectorcardiogram. See

> paper … "Iterative Fast Orthogonal Search for Modeling by a Sum of Exponentials or Sinusoids" … especially on pages 324-325, the section on FITTING MULTIPLE SETS OF OBSERVATIONS.... A key idea here is that when data are available from multiple experiments, one may select the SAME basis functions (out of the candidates) to fit all the experimental data, but the coefficients used in the linear combination of basis functions may vary from one experiment to another. Suppose there are 12 leads, and for each lead 7000 points of data (the number of sampled points is immaterial). Maybe some of the leads carry most of the useful information and others are virtually redundant. In this example there is a 7000 row by 12 column data matrix. …. Each column is a 7000×1 vector that will be one of 12 candidate functions. In the 1st experiment, the 1st column is the desired (target) output, in the 2nd experiment the 2nd column is the desired output, etc. One chooses one concise set out of the candidate functions to fit the data from ALL experiments (the coefficients will change from one experiment to the next, but this is allowed—use Eqs 17,18 in the above-referenced 1998 Korenberg and Adeney paper).

(**X1001**, 26:54-27:15).

Accordingly, while **Adeney** did not expressly provide for using FOS or IFOS to select a subset of incoming ECG candidate leads when discussing "FITTING MULTIPLE SETS OF OBSERVATIONS," the reference's express link to the analysis of "biological time-series data … using … FOS" and that there

existed a "need to identify significant sinusoidal components within time-series data … in the spectral analysis of" electrophysiological data, including "electrocardiograms," ensures that a POSITA would have found it obvious to apply the teachings of **Adeney** to the sensor selection problems relating to multiple incoming ECG leads (**X1008**, 315; **X1002,** ¶172).

Further, a POSITA would have understood **Adeney** would equally apply to a multiple lead configuration using the same input structure to the FOS or IFOS algorithm (**X1002**, ¶173). Indeed, a POSITA would have understood that each lead would effectively represent an "experiment" in the terms described in **Adeney** and would have further found it beneficial to utilize **Adeney** for performing a subset selection as explained in **Adeney** (*id.*). It is inherent that a few of the leads having these common basis functions would be representative of the set of multiple leads (*id.*).

Further, a POSITA would have understood that the mathematical description recited in **Mao** would be one way of selecting the most important and non-redundant leads from a large pool of potential biological candidate leads, such as from multiple ECG lead inputs (**X1002, ¶¶**174-175). **Mao** expressly teaches feature subset selection:

> Selecting a subset of features from a pool of many potential variables is a common problem in pattern classification… The goal of feature subset selection is to identify and to select the most important and

> non-redundant variables from the large pool of potential variables. Generally, a feature subset selection algorithm involves a feature evaluation criterion and a search algorithm.

(**X1010**, 629).

Further, Section II of **Mao** describes a *feature subset selection procedure* using an orthogonal forward selection algorithm with the purpose of selecting a subset of features (such as ECG leads) in an attempt to maximize a measure of fitness or goodness for the subset (**X1002,** ¶176). A POSITA reviewing **Mao** would have further understood the following terms in **Mao** to equate to the claim terms in Claim 19 as follows (**X1002,** ¶177):

Mao 2004	**'864 Patent**
Feature	Lead
Feature vector, $\boldsymbol{x_i, i = 1, \dots, n}$ (each is N-dimensional)	Lead Signal from lead *i*
Sample, $\boldsymbol{x(k),\ k = 1, \dots, N}$ (each is *n*-dimensional)	A vector containing samples from all leads at sample time *k*
N (number of samples)	The number of samples (e.g. 7000)
n (*dimensionality* of sample vector)	The number of Leads (e.g. 12)

Accordingly, it can be seen that **Mao** anticipates and/or renders obvious Claim 19 as shown in the below claim chart:

'864 Patent	**Adeney (X1008) and Mao (X1010)**
Claim 19 **19.pre)** A method for building a model approximating an	**Adeney** provides a method for approximating a biological signal using FOS and IFOS and states expressly that "the need to identify significant sinusoidal components within time-series data arises

electrophysiological signal,	frequently in biological signal processing," including ECGs (**X1008**, 315). **Adeney** reiterates that "Accurate sinusoidal series models of biological time-series data may be obtained using … FOS" and confirms that the publication discloses the "use of FOS and IFOS procedures for finding a single model from the results of multiple experiments" (**X1008**, 315). **Adeney** does so by selecting "basis functions by minimizing the m.s.e. over all of the available data" (**X1008**, 325; **X1001**, 28:36-65 ("It is very important that ONE concise set of basis functions is selected to fit the data from ALL the experiments.")). The Orthogonal Forward Feature Subset Selection Procedure is an algorithm for selecting a subset of features (such as those of ECG leads) from a larger set to approximate an electrophysiological signal (**X1002**, ¶178 at pgs. 93-94). This algorithm describes a method for building up a signal model as summarized in steps 1, 2, and 3 of Section II.B. of **Mao** (**X1010**, 630). **Mao** also states that "[t]he basic idea of the orthogonal feature subset selection algorithms is to find an orthogonal space in which to express features and to perform feature subset selection." (**X1010**, 629).
19.a) for each lead in the larger set, using the corresponding lead signal to define a candidate signal;	**Adeney** provides for using "FOS and IFOS procedures for finding a single model from the results of multiple experiments" (**X1008**, 315). As previously provided, **Adeney** does so by selecting "basis functions by minimizing the m.s.e. over all of the available data" (**X1008**, 325). A candidate is thus identified based on the lead signals. In **Mao**, each feature vector is a candidate signal considered when forming the subset of features in the algorithm (**X1010**, 630). The feature vectors in **Mao** correspond to the candidate signals in '864 (**X1002,** ¶178 at pgs. 94-95).

19.b) for each lead in the larger set, using the corresponding lead signal to define a desired target output signal from an experiment; and	The target signals are defined identically to the candidate signals introduced in claim term 19.a above with the exception that each is declared to be the target "output signal from an experiment." A POSITA would understand the term "experiment" used here means an attempt to approximate a signal (the target output signal) using a low-rank approximation (that is, using a subset of a larger set of signals to approximate it) (**X1002,** ¶178 at pg. 95). **Adeney** discloses this (**X1008**, 315 ("use of FOS and IFOS [] for finding a single model from the results of multiple experiments")) (**X1002**, ¶178 at pgs. 95-96).
19.c) selecting the same subset of lead signals, out of the candidate signals, to approximate all the target signals from all the experiments by linear combinations of the selected lead signals, while allowing the coefficients of the selected lead signals to vary in approximating the target signals from one experiment to another.	**Adeney** discloses the "use of FOS and IFOS procedures for finding a single model from the results of multiple experiments" relating to biological time-series data, including ECGs (**X1008**, 315). **Adeney** discloses using FOS to perform subset selection given multiple data input points (**X1008**, 324-25 ("we wish to express all of the data in terms of a single set of basis functions"). **Adeney** further clarifies that "the same basis functions are used for each experiment, but the coefficients may change from one experiment to another" (**X1008**, 325). Thus, **Adeney** discloses allowing the coefficients of the lead signals to vary in approximating the target signals (**X1002**, ¶178 at pgs. 95-96). As stated in the '864 patent, "a key idea here is that when data are available from multiple experiments, one may select the SAME basis functions (out of the candidates) to fit all the experimental data, but the coefficients used in the linear combination of basis functions may vary from one experiment to another" (**X1001**, 28:44-48). **Mao** likewise describes building up a subset of feature vectors using a Gram-Schmidt orthogonalization process with each additional feature being chosen to maximize performance (Step

	2 of **X1010**, 630). A subset of the original measurement signals is selected from the signals identified as candidate signals (**X1002,** ¶178 at pg. 96). **Mao** then explains that by selecting a subset of columns of Q (orthogonalized candidate signals), a corresponding subset of candidate features vectors can be identified. Using a matrix factorization framework, the subset of candidate signals selected as described by **Mao** approximate all the target signals by linear combinations of the lead signals (**X1002,** ¶178 at pg. 97).

2) Dependent Claim 20

Dependent claim 20 provides that the selection of the same subset of lead signals uses "at least one of fast orthogonal search (FOS), modified fast orthogonal search (MFOS), least angle regression (LARS), LASSO, and iterative fast orthogonal search (IFOS)." Each of these techniques was well-known prior to the earliest effective filing date of the '864 patent, as previously explored (see Section III.A., *infra*) (**X1002**, ¶¶179-180). Additionally, the application of FOS and IFOS was expressly disclosed as being applicable to the selection of candidate terms in **Adeney** (*see, e.g.*, **X1008**, 315). Accordingly, a POSITA would have found it obvious to use FOS or IFOS to perform the selection of subset signals based at least on **Adeney** (**X1008**, 325; **X1002,** ¶181). Claim 20 requires only that one of the elements in the recited list be found in the prior art (even it would have been

obvious to use any of the listed methods). *See, e.g., SuperGuide*, 358 F.3d at 886. As a result, Claim 20 is unpatentable.

Further, a POSITA would understand that the Orthogonal Forward Feature Subset Selection algorithm of **Mao** is functionally equivalent to FOS, thus providing motivation to use FOS instead (**X1002, ¶¶**182-183). There are two differences between the **Mao** method and FOS; first, **Mao** discloses using a different feature selection criteria (classification performance rather than minimum mean-square-error) than that used in ’864 and its references (**X1002, ¶¶**184-187). The second difference is that FOS optimizes some of the computation involved in orthogonal searching (hence the moniker fast orthogonal search) (*id.*). Thus, a POSITA would have recognized that FOS could be used in **Mao** to achieve increased computational speed and linear approximation of all target signals (**X1002, ¶**187).

VI. CONCLUSION

Petitioner submits that the above asserted grounds render all claims of the ’864 patent *not patentable*. Petitioner accordingly and respectfully requests that an *Inter Partes* Review of the ’864 patent be granted and that a final written decision be issued invalidating claims 1-20 of the ’864 patent.

DATED: July 6, 2017.

Respectfully submitted,

/David S. Moreland/

David S. Moreland
Reg. No. 60,134
MEUNIER CARLIN & CURFMAN LLC
999 Peachtree St. NE
Suite 1300
Atlanta, GA 30309

CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. §§ 42.6(e), 42.105, I certify that on July 6, 2017, a copy of this Petition and all exhibits were served on the following counsel of record for the patent owner by depositing with the U.S. Postal Service, Priority Mail Express:

DOWELL & DOWELL, P.C.
2560 HUNTINGTON AVE, SUITE 203
ALEXANDRIA VA 22303

/T. Paul Tanpitukpongse/
T. Paul Tanpitukpongse
Reg. No. 71,589

CERTIFICATION OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24(d), I certify that the foregoing Petition contains 13,992 words, excluding the parts exempted by 37 C.F.R. § 42.24(a), which is less than the 14,000 words allowed under the rule.

/T. Paul Tanpitukpongse/
T. Paul Tanpitukpongse
Reg. No. 71,589