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United States Patent [19]

Jeričević et al.

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[54] **ENERGY MINIMIZATION IN SURFACE MULTIPLE ATTENUATION**

[75] Inventors: **Željko Jeričević; William H. Dragoset, Jr.**, both of Houston, Tex.

[73] Assignee: **Western Atlas International, Inc.**, Houston, Tex.

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[51] **Int. Cl.^{6}** **G01V 1/38**

[52] **U.S. Cl.** **367/24**; 367/45; 367/24; 367/53

[58] **Field of Search** 367/21, 24, 38, 367/45, 53

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,138,583	8/1992	Wason et al.	367/21
5,448,531	9/1995	Dragoset et al.	367/21
5,587,965	12/1996	Dragoset, Jr. et al.	367/21
5,719,821	2/1998	Sallas et al.	367/21
5,729,506	3/1998	Dragoset et al.	367/21

Primary Examiner—Christine K. Oda
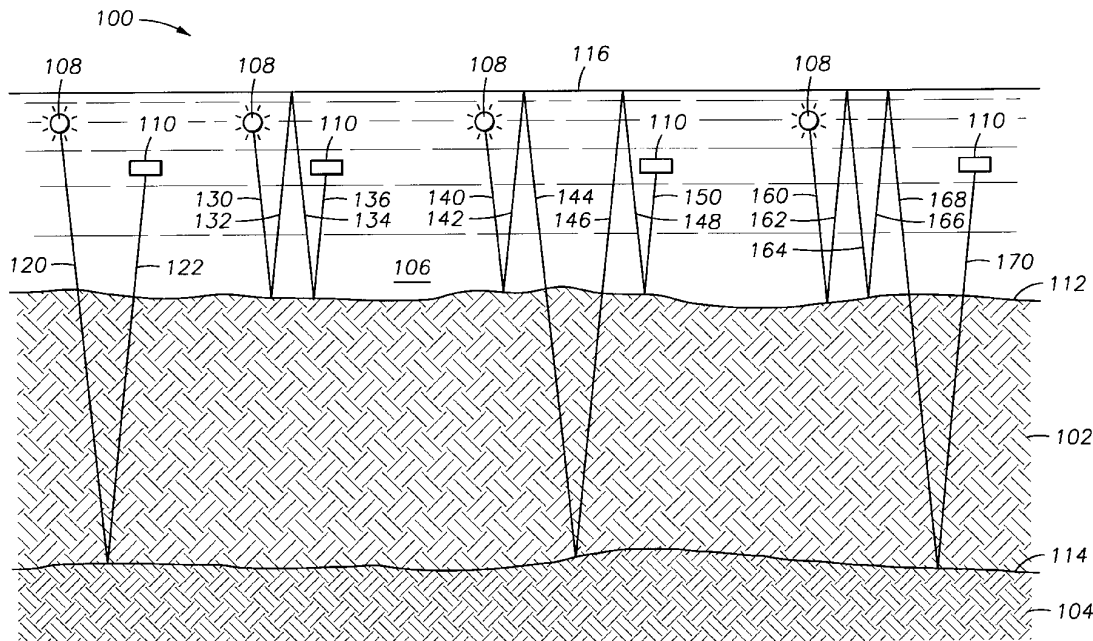*Assistant Examiner*—Anthony Jolly

[57] **ABSTRACT**

A marine seismic signal is transformed from time domain into frequency domain and represented by matrix D. The marine data signal is truncated in time, transformed into the frequency domain and represented by matrix D_T. Eigenvalue decomposition $D_{T=S \Lambda S}{}^{-1}$ of matrix D_T is computed. Matrix product D S is computed and saved in memory. Conjugate transpose [D S]* is computed and saved in memory. Matrix product [D S]*[D S] is computed and saved in memory. Matrix inverse S^{-1} is computed and saved in memory. Conjugate transpose $(S^{-1})*$ is computed and saved in memory. Matrix product $S^{-1}(S^{-1})*$ is computed and saved in memory. An initial estimate of the source wavelet w is made. Source wavelet w is optimized by iterating the steps of computing the diagonal matrix $[I-w^{-1}\Lambda]$, computing matrix inverse $[I-w^{-1}\Lambda]^{-1}$, computing conjugate transpose $[(I-w^{-1}\Lambda)^{-1}]*$, retrieving matrix products [D S]*[D S] and $S^{-1}(S^{-1})*$ from memory, and minimizing the total energy in trace of matrix product

$$S^{-1}(S^{-1})*[(I-w^{-1}\Lambda)^{-1}]*[D\ S][D\ S][I-w^{-1}\Lambda]^{-1}.$$

Primary matrix P representing the wavefield free of surface multiples is computed by inserting computed value for w into the expression $[D\ S][I-w^{-1}\Lambda]^{-1}S^{-1}$. Primary matrix P is inverse transformed from frequency domain into time domain.
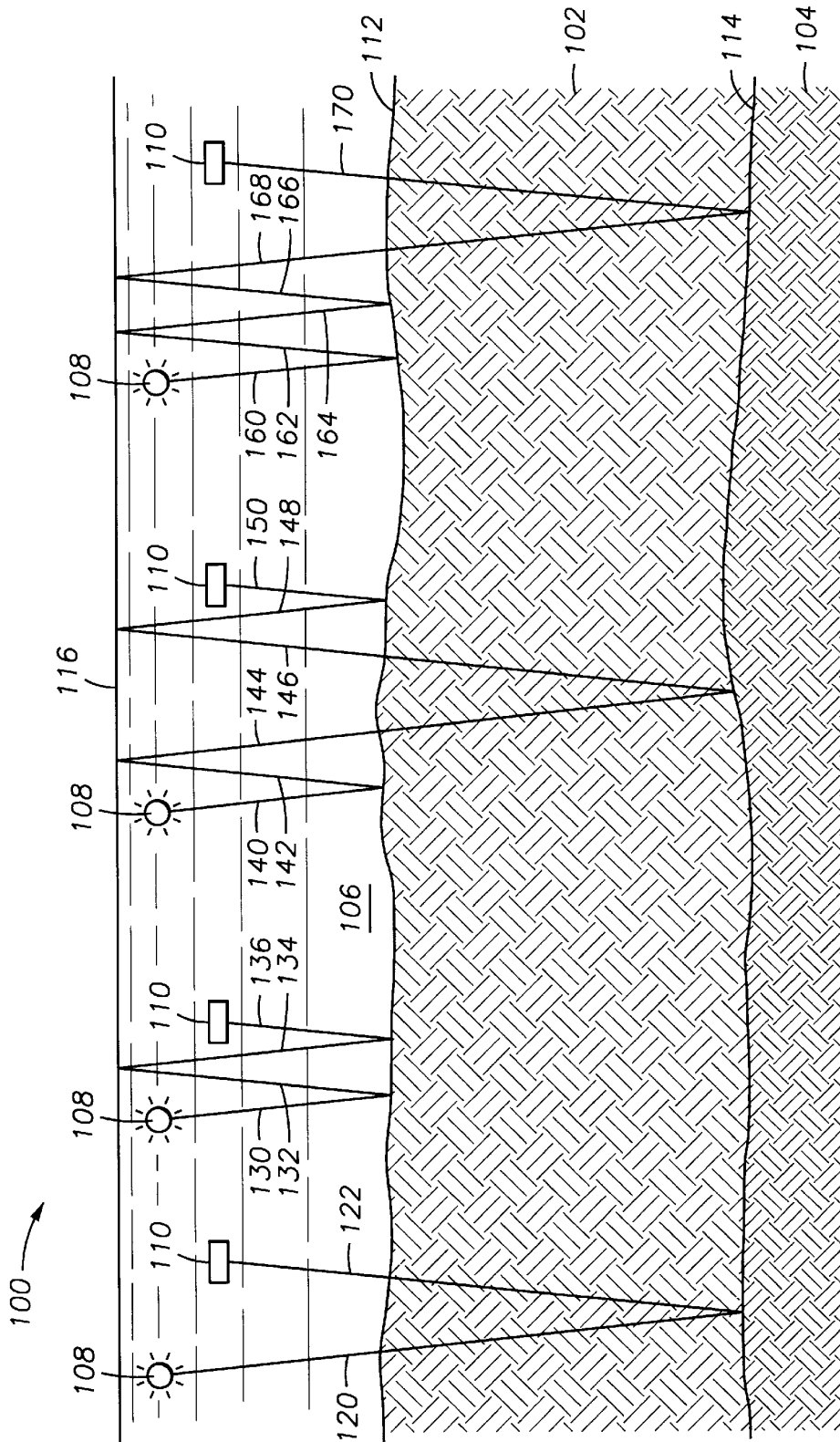
17 Claims, 4 Drawing Sheets

FIG. 1

FIG. 2

300

302
COMPUTE EIGENVALUE DECOMPOSITION $D_M = S \wedge S^{-1}$

304
COMPUTE PRODUCT $[D \cdot S]$, ADJOINT $[D \cdot S]^*$ AND PRODUCT $[D \cdot S]^* \cdot [D \cdot S]$

306
STORE PRODUCT $[D \, S]^* \cdot [D \cdot S]$ IN MEMORY

308
COMPUTE INVERSE S^{-1}, ADJOINT $(S^{-1})^*$ AND PRODUCT $(S^{-1}) \cdot (S^{-1})^*$

310
STORE PRODUCT $(S^{-1}) \cdot (S^{-1})^*$ IN MEMORY

312
CONTINUE TO STEP 402 (FIG. 4)

FIG. 3

400

402
CONTINUE FROM STEP 312 (FIG.3)

404
ESTIMATE WAVELET w

406
COMPUTE DIAGONAL MATRIX $[\ I-w^{-1}\Lambda\ ]$

408
COMPUTE DIAGONAL MATRIX INVERSE $[\ I-w^{-1}\Lambda\ ]^{-1}$

410
COMPUTE ADJOINT $[(I-w^{-1}\Lambda)^{-1}]^{*}$

412
RETRIEVE $[D\cdot S]^{*}\cdot[D\cdot S]$ AND $(S^{-1})\cdot(S^{-1})^{*}$ FROM MEMORY

414
COMPUTE TRACE OF MATRIX PRODUCT $TR\ \{S^{-1}\cdot(S^{-1})^{*}\ [(I-w^{-1}\Lambda)^{-1}]^{*}\ [D\cdot S]^{*}\cdot[D\cdot S]\ [\ I-w^{-1}\Lambda]^{-1}\}$

416
MINIMIZE TOTAL ENERGY IN TRACE TO SOLVE FOR w USING AN ITERATIVE LOOP

418
INSERT FINAL w TO COMPUTE $P=[D\cdot S]\ [\ I-w^{-1}\Lambda]^{-1}\ S^{-1}$

FIG. 4

DOCKET ALARM
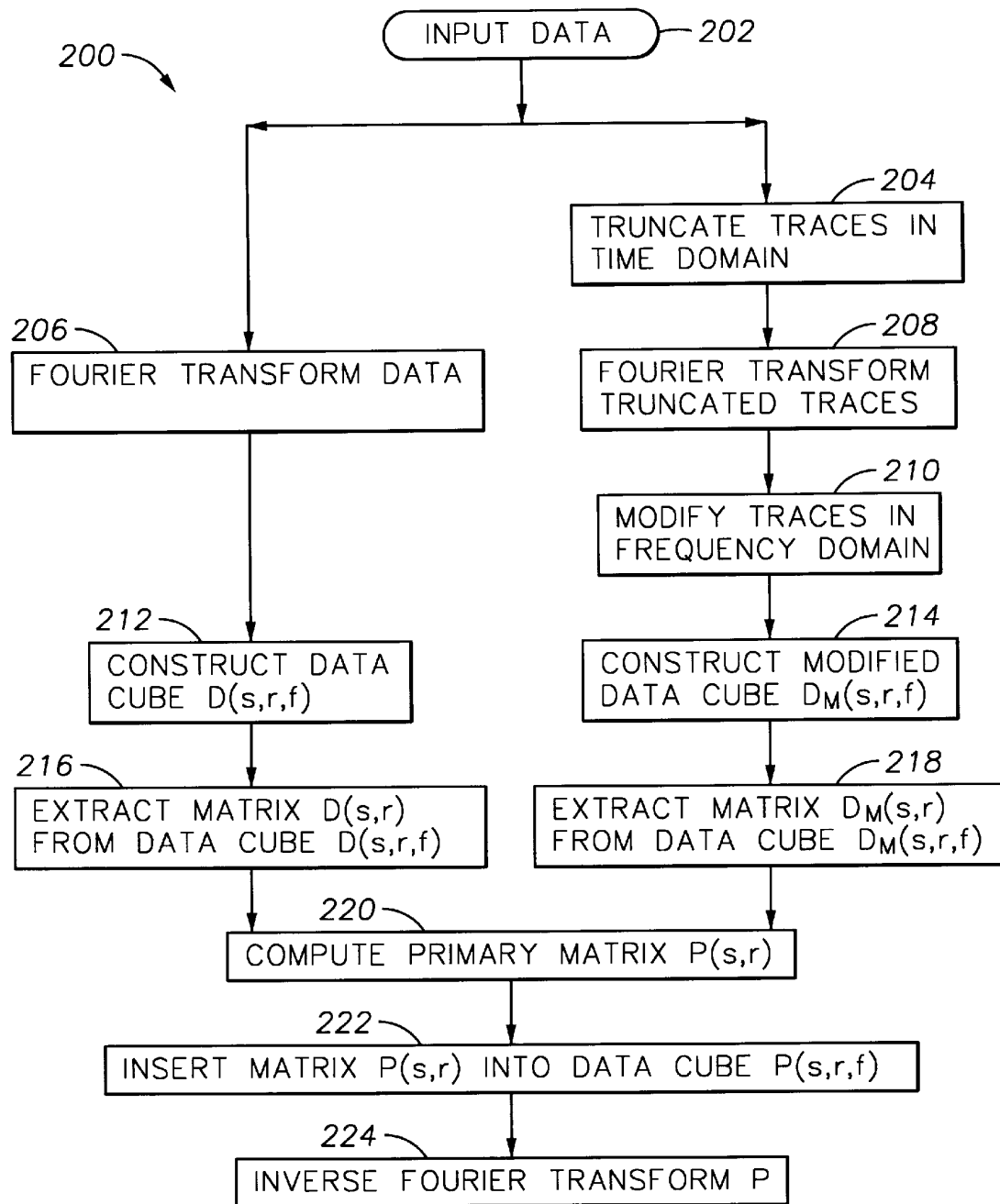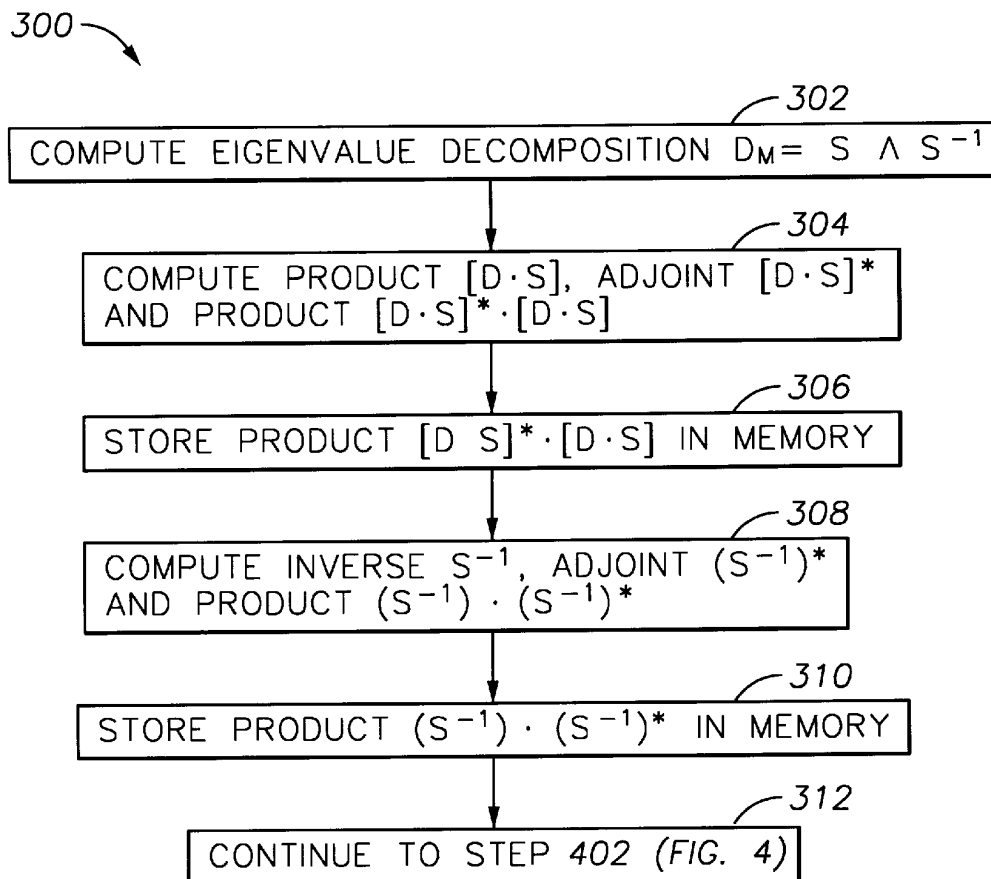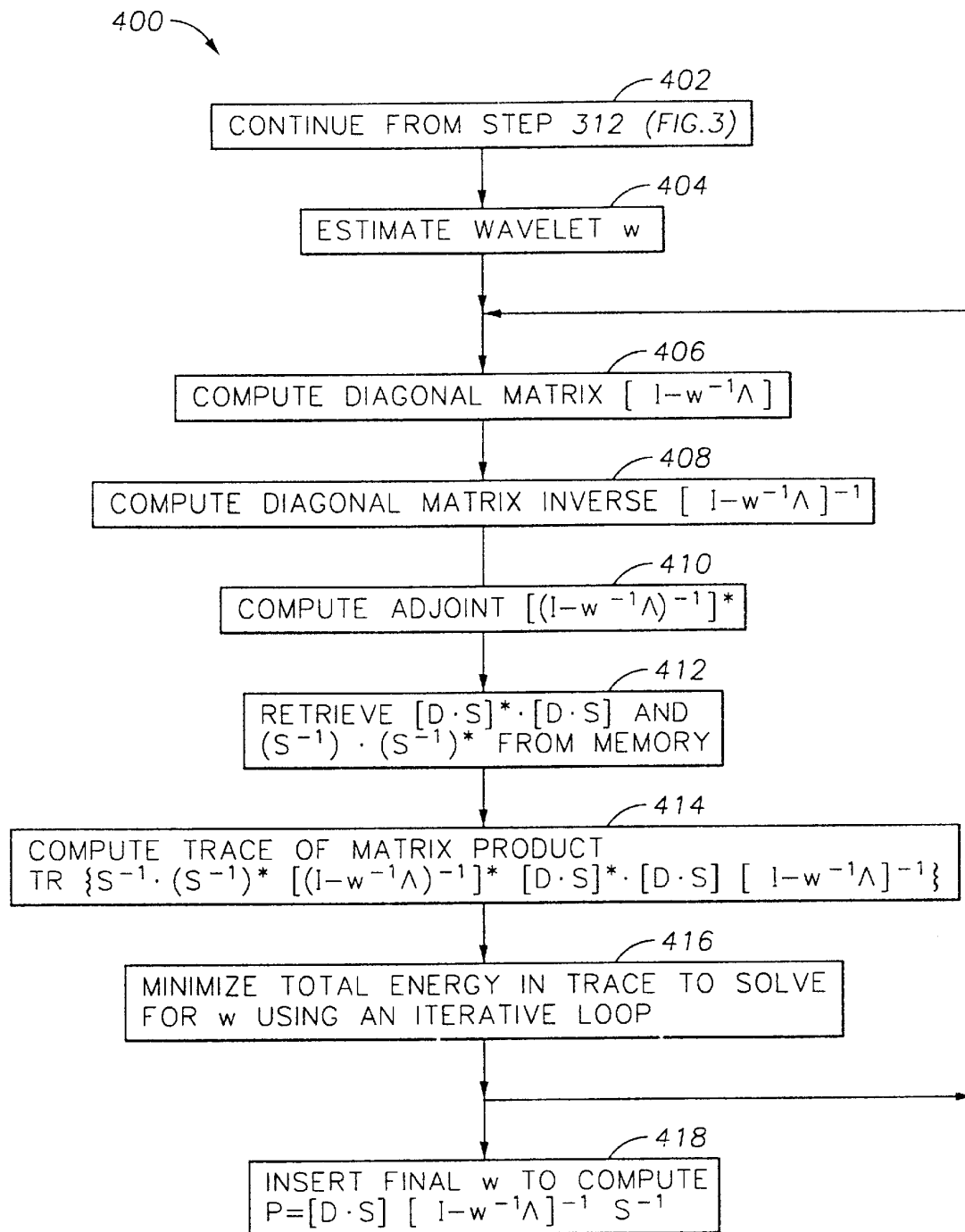
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