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United States Patent [19]

Jeričević et al.

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

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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

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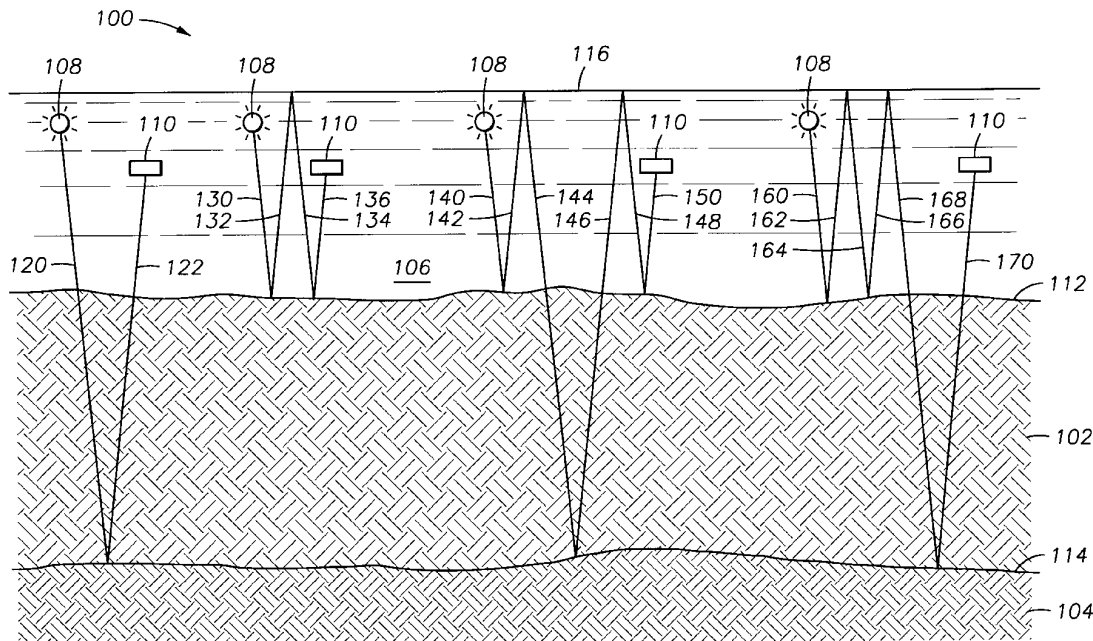|			
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Primary Examiner—Christine K. Oda
Assistant Examiner—Anthony Jolly

[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.
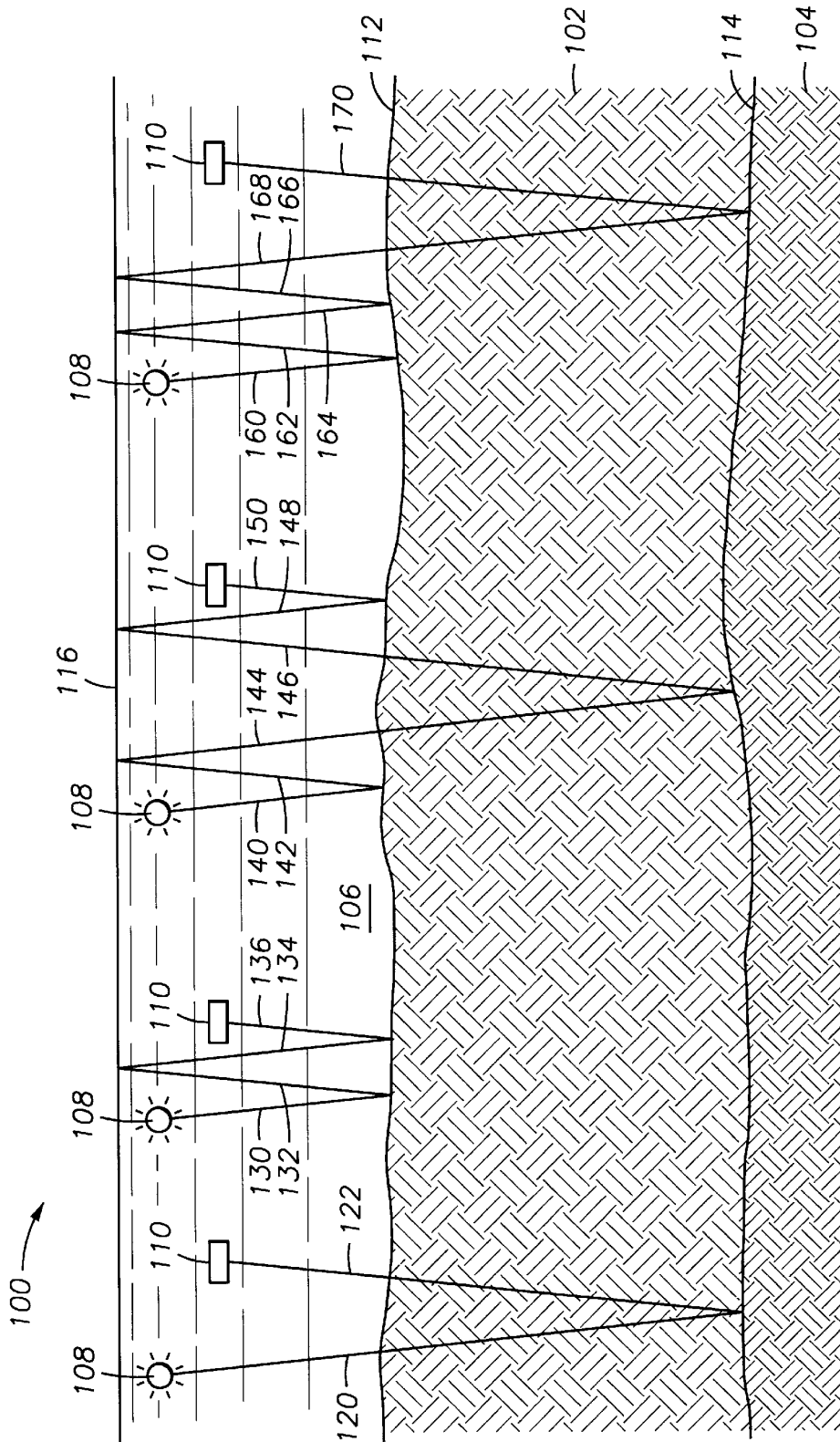
17 Claims, 4 Drawing Sheets

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

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                    ┌──────────────────────────────────────┐  ┌ 402
                    │  CONTINUE FROM STEP 312 (FIG.3)       │
                    └──────────────────────────────────────┘
                                   │
                         ┌──────────────────────┐  ┌ 404
                         │  ESTIMATE WAVELET w   │
                         └──────────────────────┘
                                   │
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COMPUTE DIAGONAL MATRIX $[\,I-w^{-1}\Lambda\,]$ ┌ 406

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

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

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

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

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

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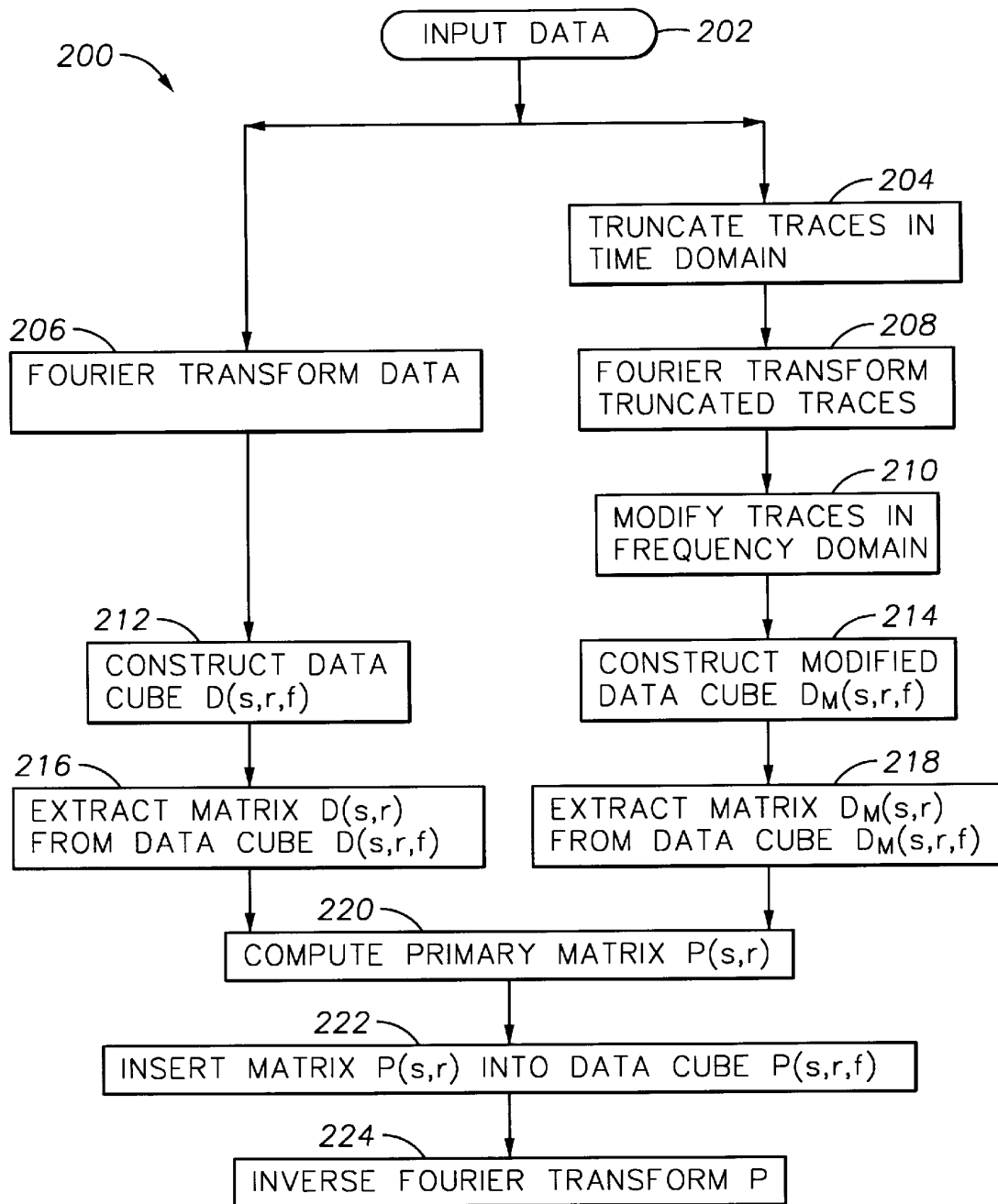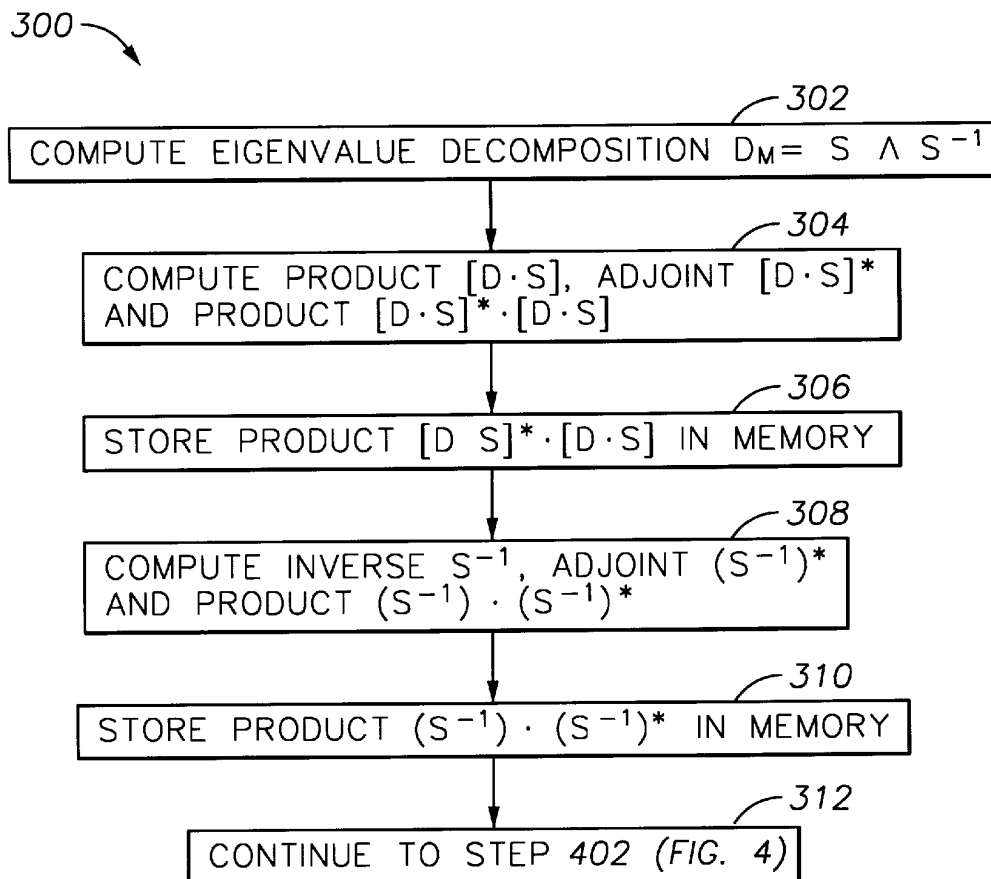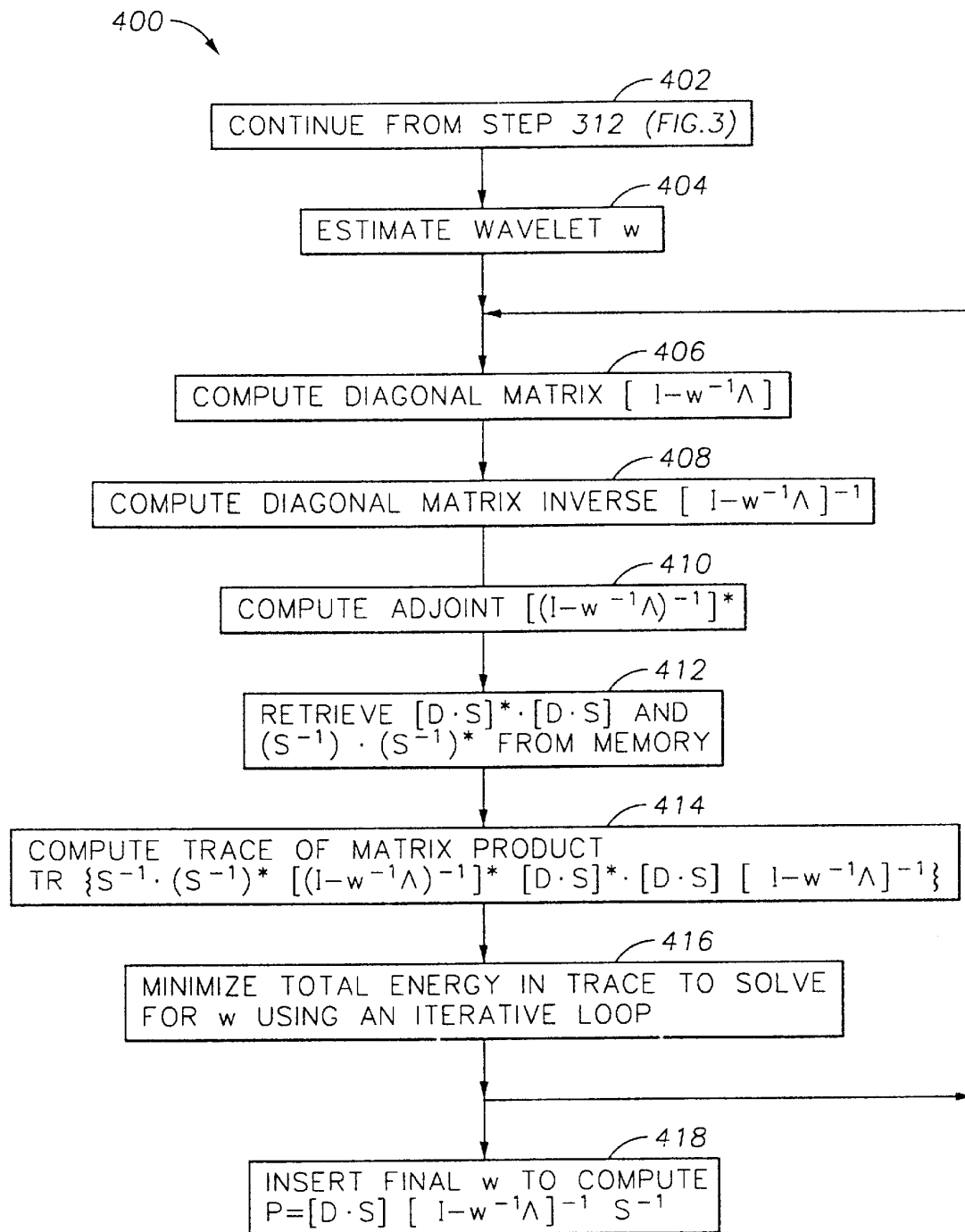$P=[D\cdot S]\,[\,I-w^{-1}\Lambda\,]^{-1}\,S^{-1}$ ┌ 418

FIG. 4

DOCKET ALARM

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