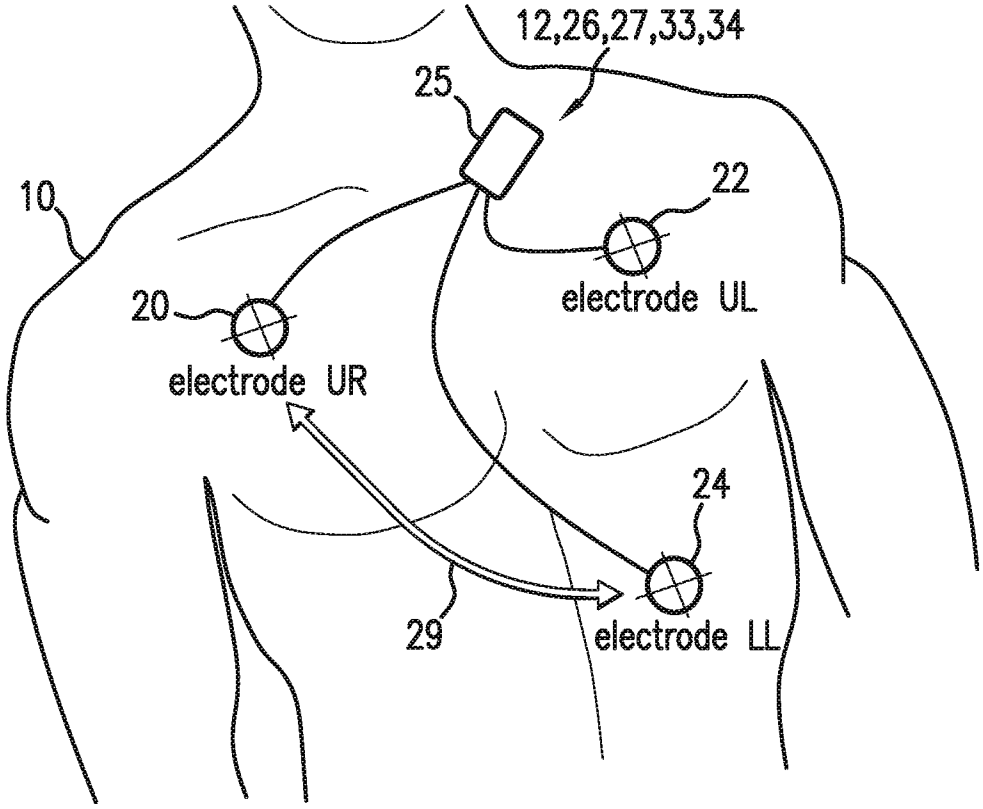

12,26,27,33,34
25
22
10
20
electrode UL
electrode UR
24
29
electrode LL

FIG. 1

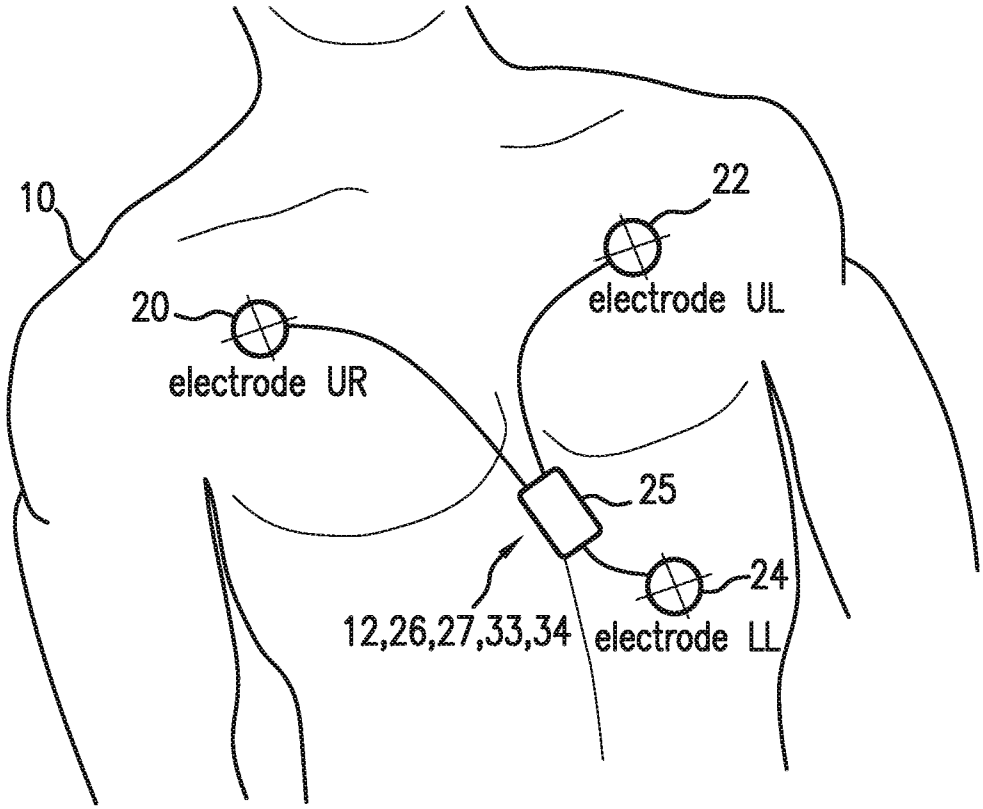

10
22
electrode UL
20
electrode UR
25
24
12,26,27,33,34
electrode LL

FIG. 2


253
25
24
10

FIG. 3B

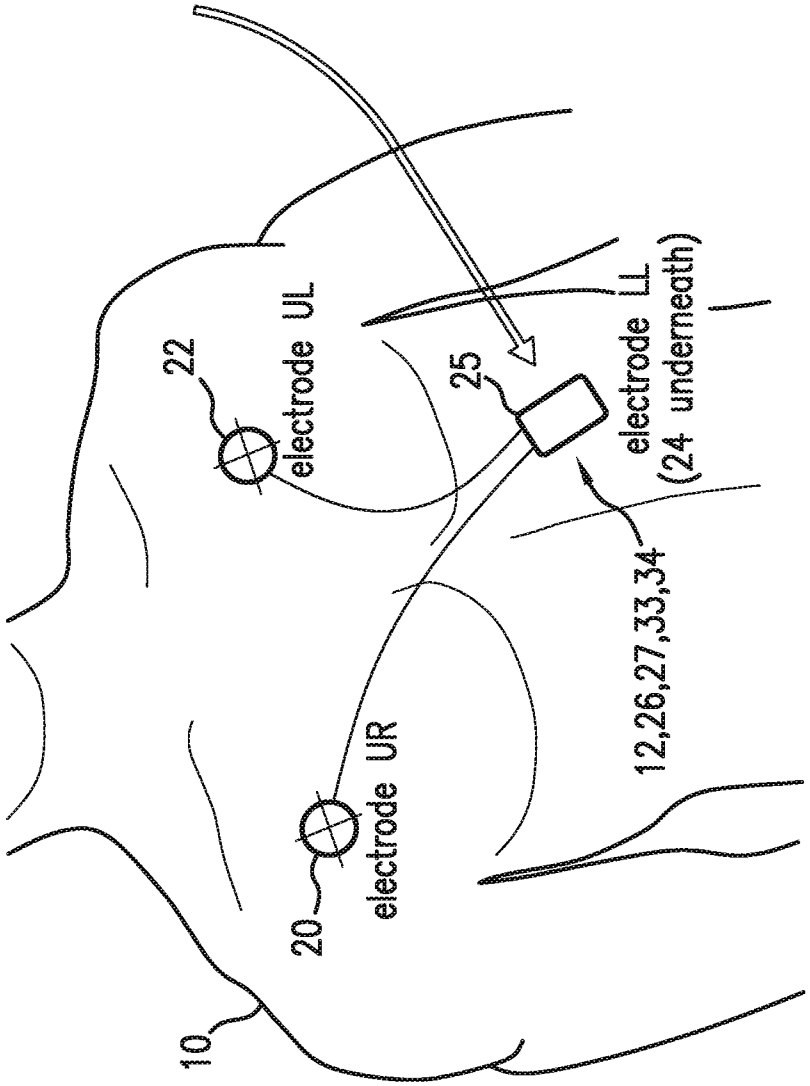

22
electrode UL
25
electrode LL
(24 underneath)
12,26,27,33,34
20
electrode UR
10

FIG. 3A

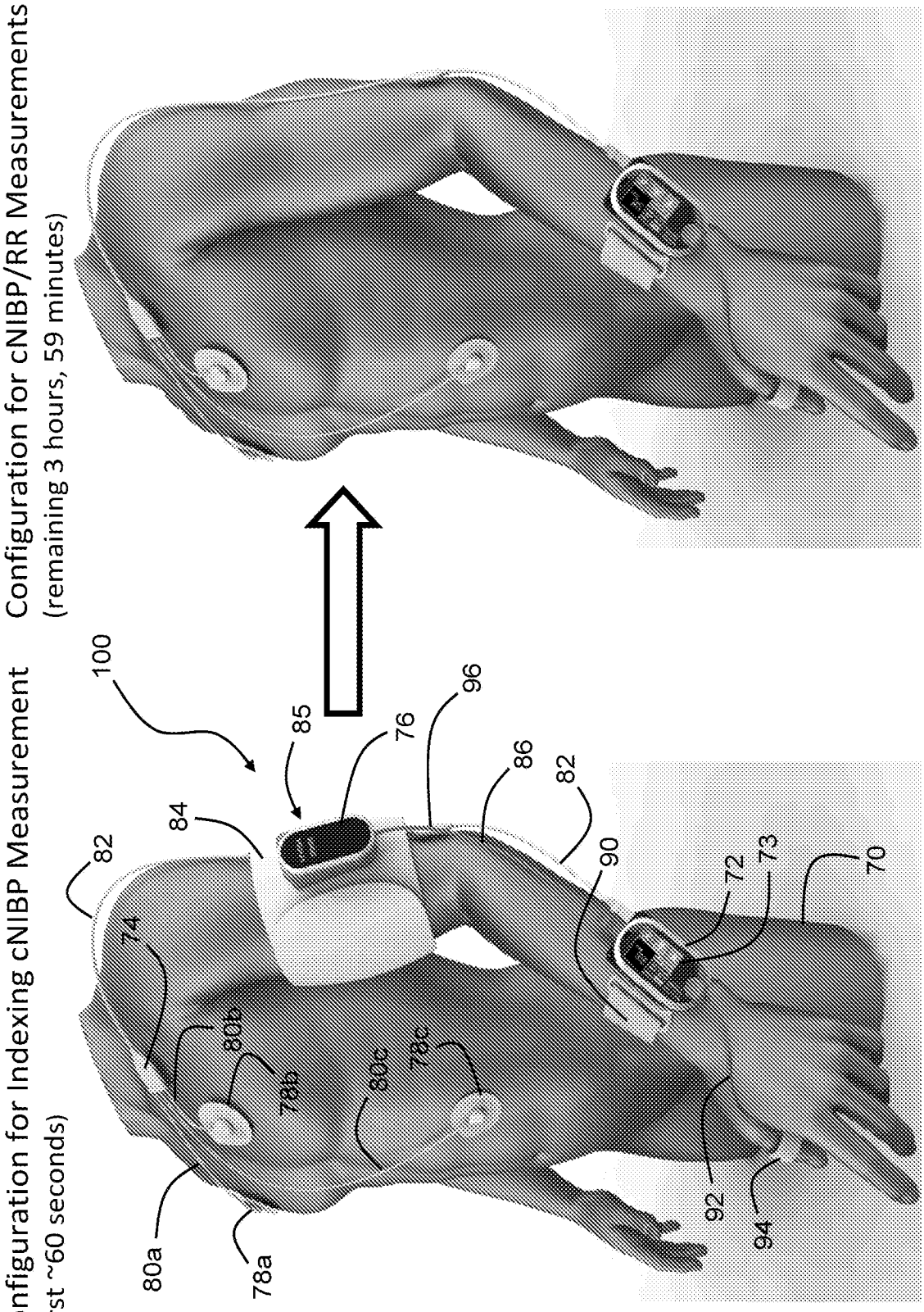

Configuration for Indexing cNIBP Measurement
(first ~60 seconds)
Configuration for cNIBP/RR Measurements
(remaining 3 hours, 59 minutes)
100
85
84
82
74
80b
78b
80c
78c
80a
78a
76
96
86
82
90
72
73
70
92
94

FIG.4A

FIG.4B

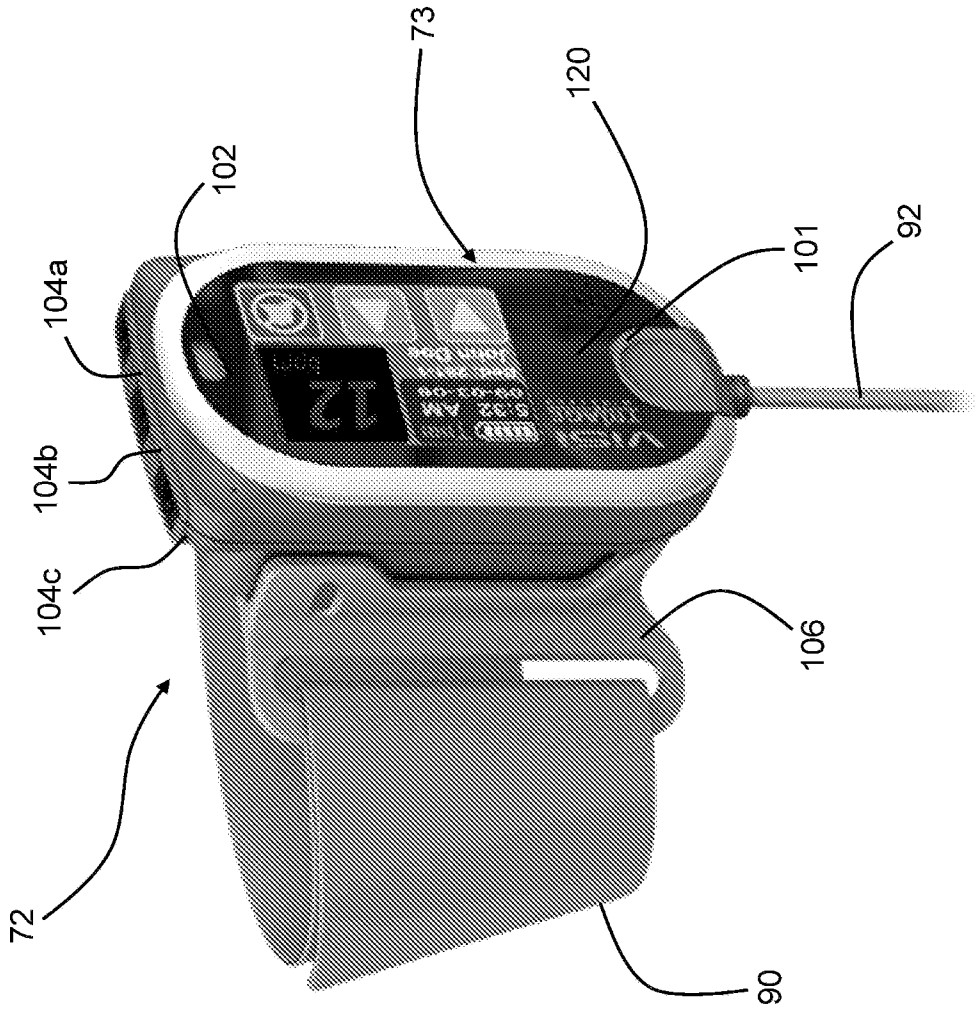


FIG.5

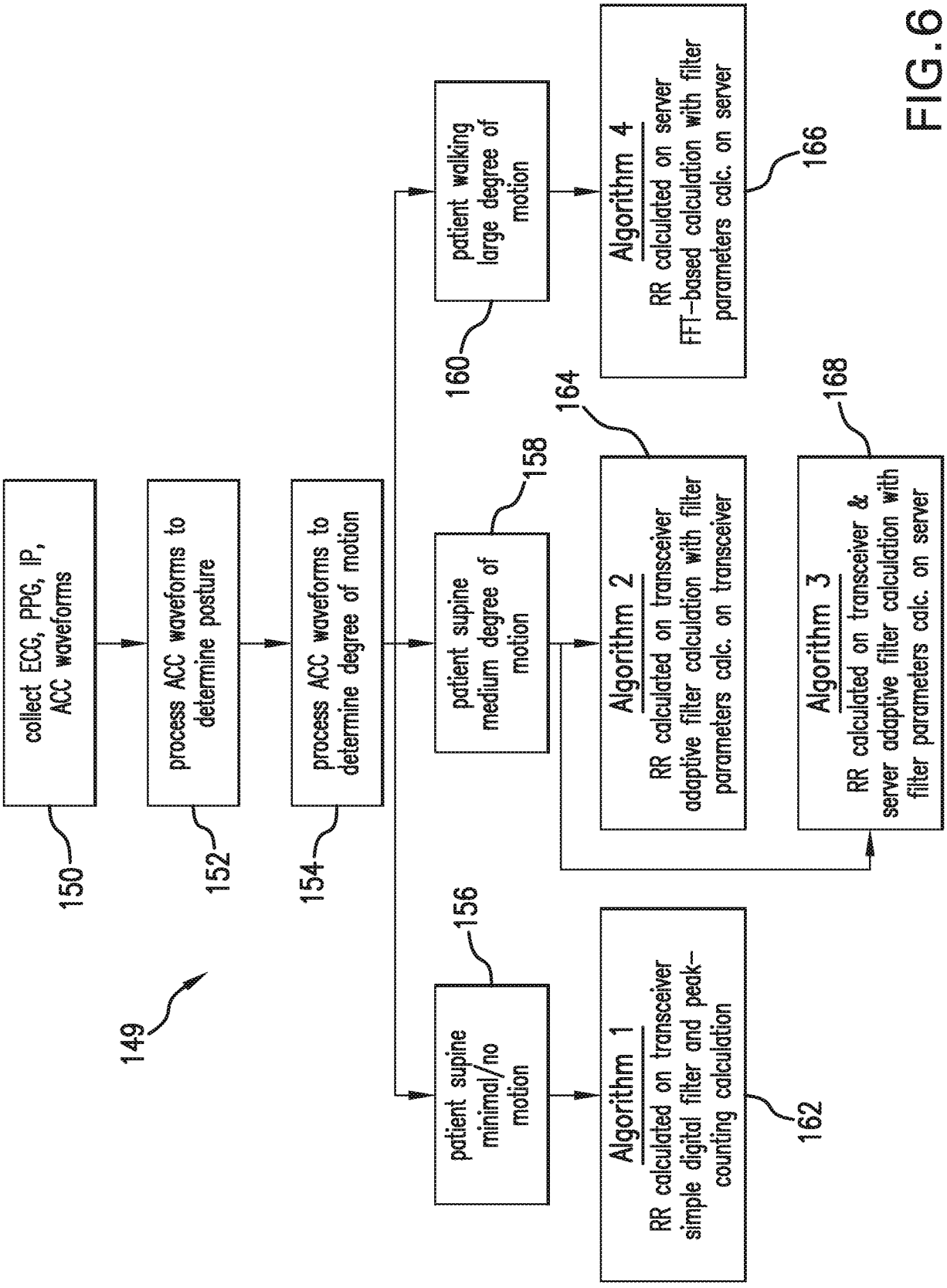

collect ECG, PPG, IP, ACC waveforms
process ACC waveforms to determine posture
process ACC waveforms to determine degree of motion
patient supine minimal/no motion
patient supine medium degree of motion
patient walking large degree of motion
Algorithm 1
RR calculated on transceiver simple digital filter and peak-counting calculation
Algorithm 2
RR calculated on transceiver adaptive filter calculation with filter parameters calc. on transceiver
Algorithm 3
RR calculated on transceiver & server adaptive filter calculation with filter parameters calc. on server
Algorithm 4
RR calculated on server FFT-based calculation with filter parameters calc. on server
149
150
152
154
156
158
160
162
164
166
168

FIG.6

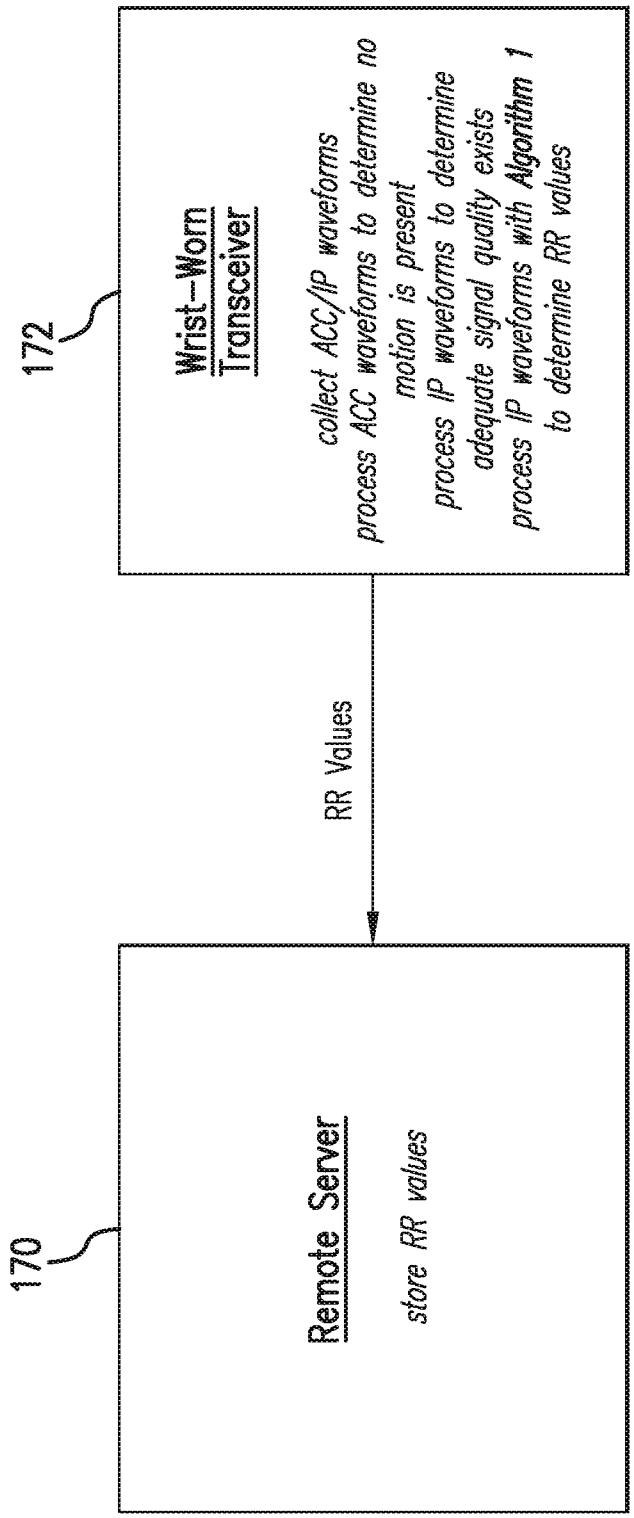

172
Wrist-Worn Transceiver
collect ACC/IP waveforms
process ACC waveforms to determine no motion is present
process IP waveforms to determine adequate signal quality exists
process IP waveforms with Algorithm 1 to determine RR values
RR Values
170
Remote Server
store RR values

FIG. 7

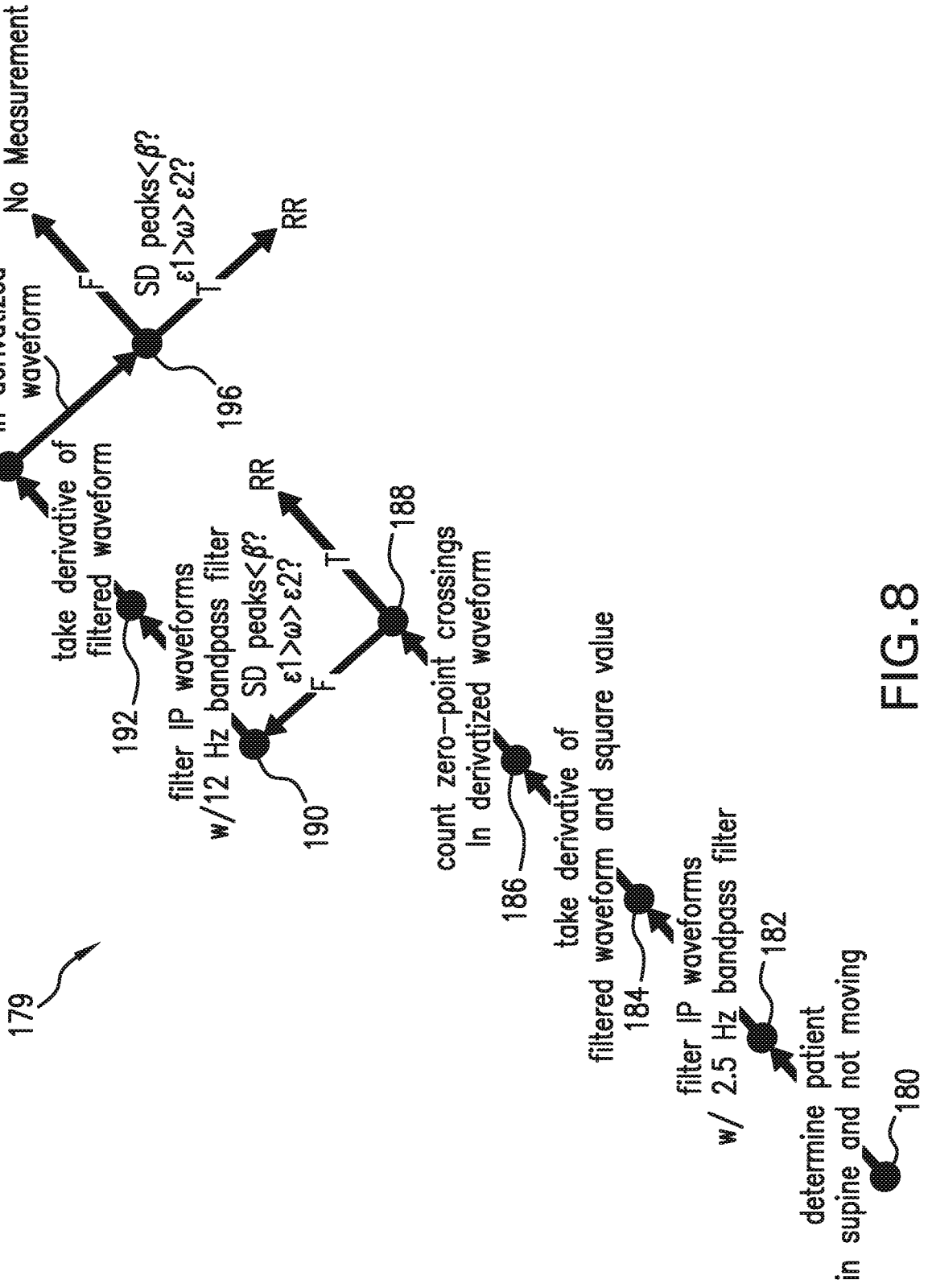

179
determine patient in supine and not moving
180
filter IP waveforms w/ 2.5 Hz bandpass filter
182
take derivative of filtered waveform and square value
184
count zero-point crossings in derivatized waveform
186
188
SD peaks<β? ε1>ω>ε2?
190
RR
F
T
take derivative of filtered waveform
192
filter IP waveforms w/12 Hz bandpass filter
194
count zero-point crossings in derivatized waveform
196
SD peaks<β? ε1>ω>ε2?
No Measurement
RR
F
T

FIG.8

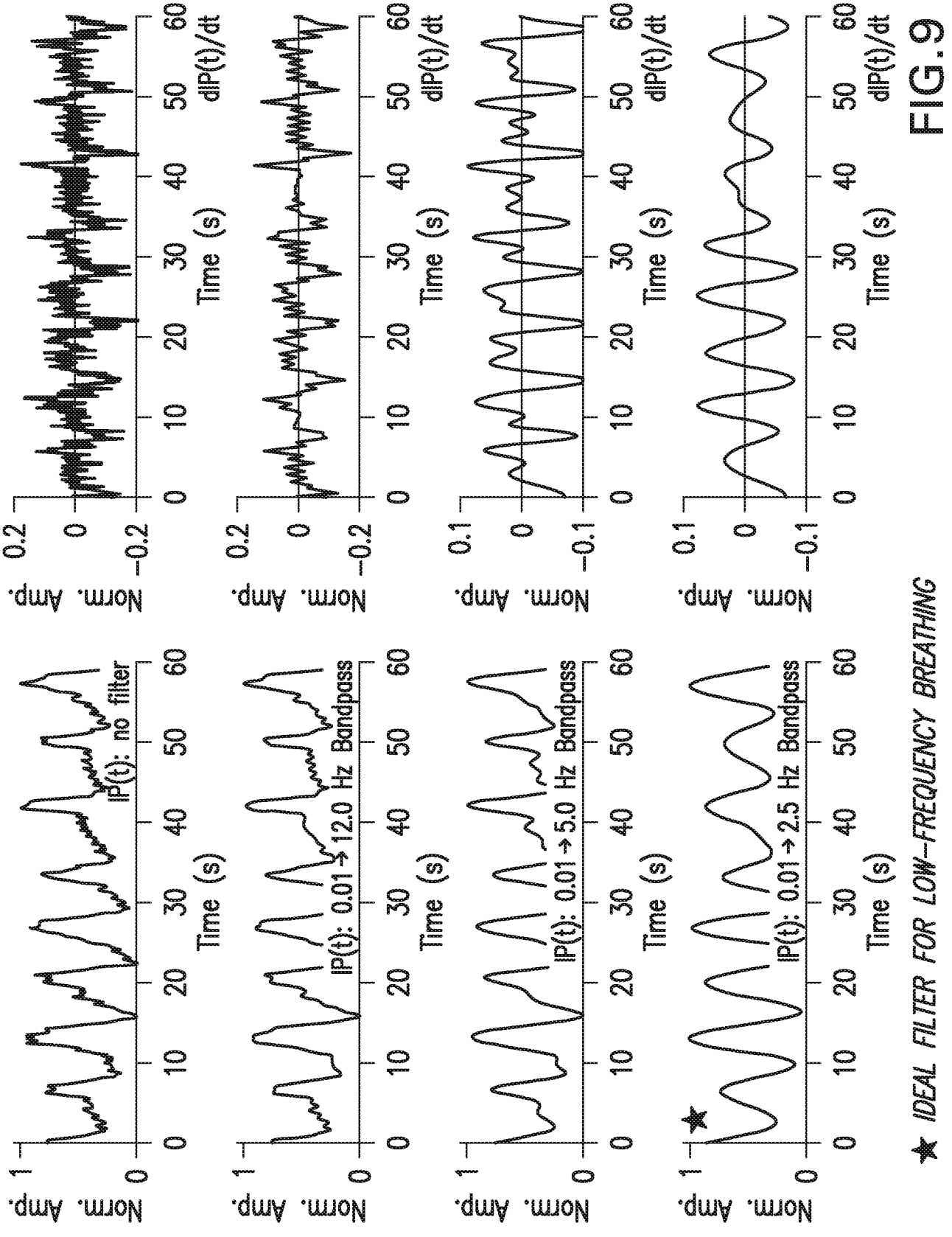

Norm. Amp.
Time (s)
dIP(t)/dt
IP(t): no filter
IP(t): 0.01→12.0 Hz Bandpass
IP(t): 0.01→5.0 Hz Bandpass
IP(t): 0.01→2.5 Hz Bandpass
★ IDEAL FILTER FOR LOW-FREQUENCY BREATHING

FIG.9

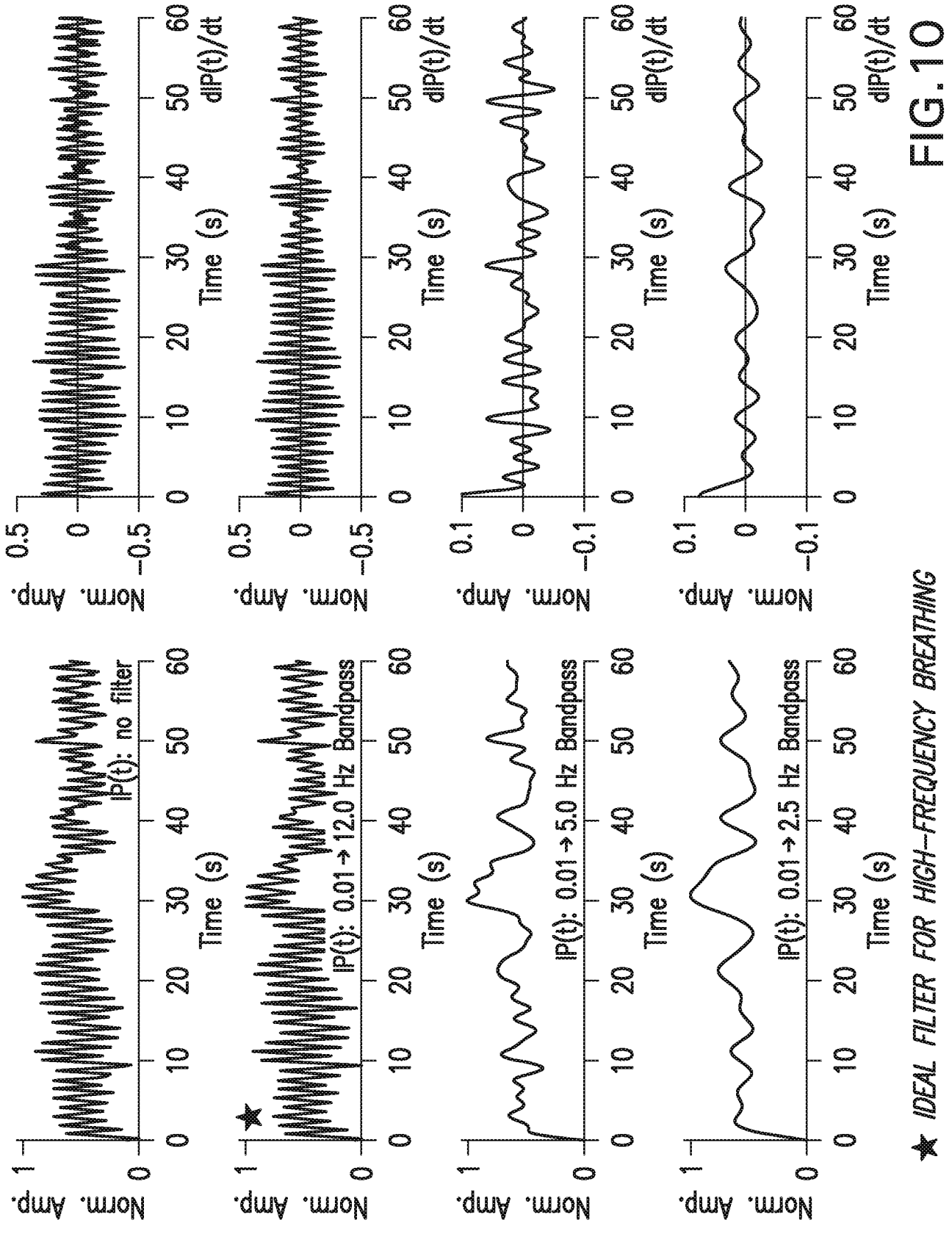

IP(t): no filter
IP(t): 0.01 → 12.0 Hz Bandpass
IP(t): 0.01 → 5.0 Hz Bandpass
IP(t): 0.01 → 2.5 Hz Bandpass
Norm. Amp.
Time (s)
dIP(t)/dt
★ IDEAL FILTER FOR HIGH-FREQUENCY BREATHING

FIG. 10

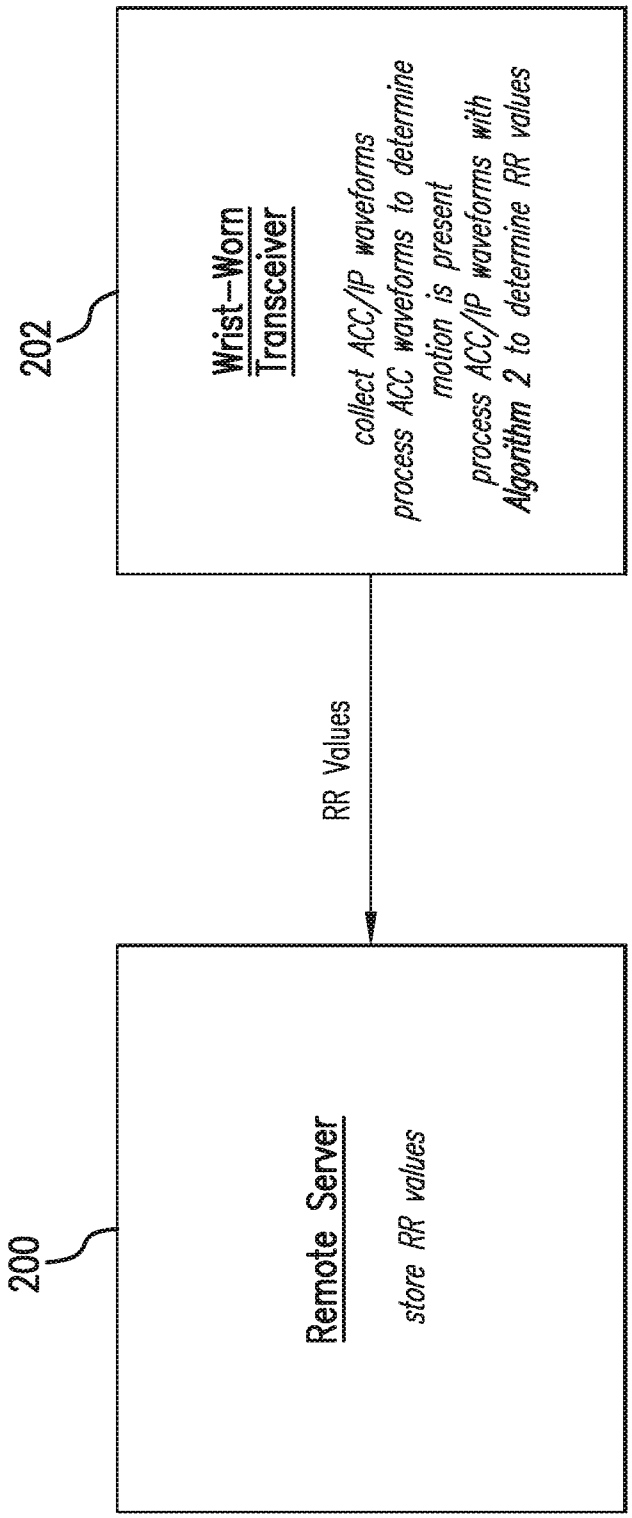

202
Wrist-Worn Transceiver
collect ACC/IP waveforms
process ACC waveforms to determine motion is present
process ACC/IP waveforms with Algorithm 2 to determine RR values
RR Values
200
Remote Server
store RR values

FIG. 11

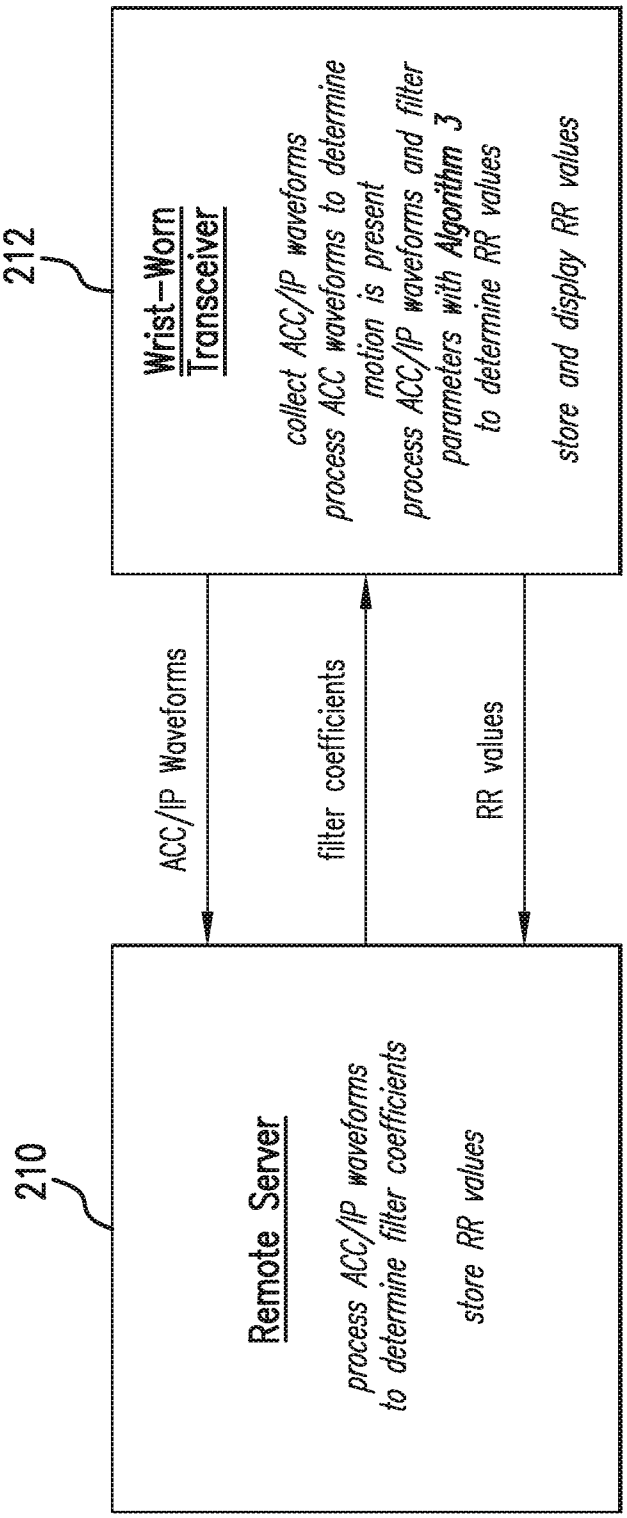

212
Wrist-Worn Transceiver
collect ACC/IP waveforms
process ACC waveforms to determine motion is present
process ACC/IP waveforms and filter parameters with Algorithm 3 to determine RR values
store and display RR values
ACC/IP Waveforms
filter coefficients
RR values
210
Remote Server
process ACC/IP waveforms to determine filter coefficients
store RR values

FIG. 12


219
determine patient is moving but not walking
220
measure IP/ACC waveforms
222
determine adaptive filtering coefficients (on transceiver/server)
224
adaptively filter IP waveform using coefficients
226
take derivative of filtered waveform and square value
228
count zero-point crossings in derivatized waveform
230
232
No Measurement
SD peaks<β?
ε1>ω>ε2?
F
T
RR

FIG. 13

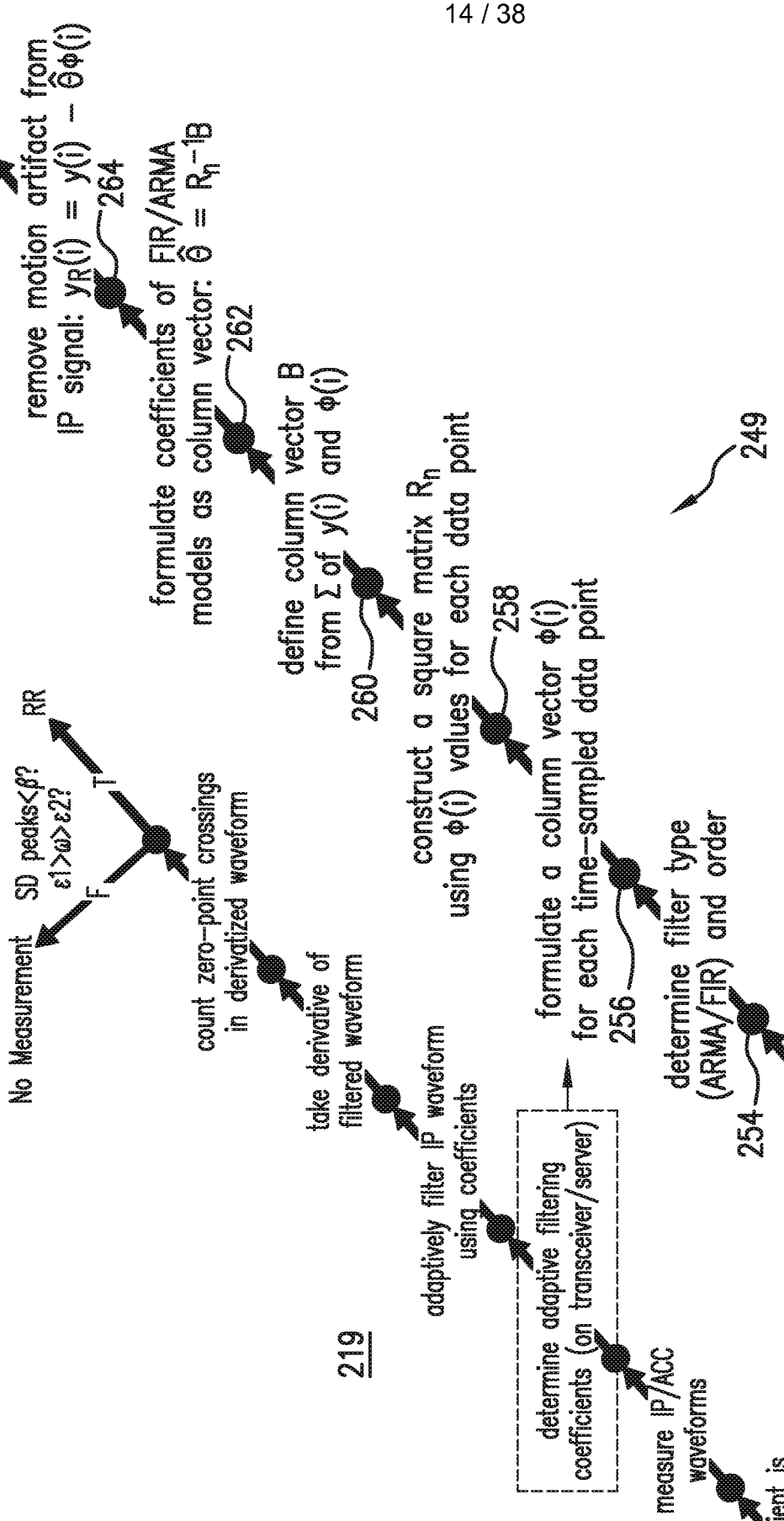

219
determine patient is moving but not walking
measure IP/ACC waveforms
determine adaptive filtering coefficients (on transceiver/server)
adaptively filter IP waveform using coefficients
take derivative of filtered waveform
count zero-point crossings in derivatized waveform
No Measurement
SD peaks<β?
ε1>ω>ε2?
F
T
RR
formulate a column vector Φ(i) for each time-sampled data point
construct a square matrix R_n using Φ(i) values for each data point
define column vector B from Σ of y(i) and Φ(i)
formulate coefficients of FIR/ARMA models as column vector: $\hat{\theta} = R_n^{-1}B$
remove motion artifact from IP signal: $y_R(i) = y(i) - \hat{\theta}\Phi(i)$
determine filter type (ARMA/FIR) and order
determine zero mean input/output signals for u(i), y(i)
u(i) → motion magnitude
y(i) → RR signal + motion-induced noise
250
252
254
256
258
260
262
264
249

FIG. 14

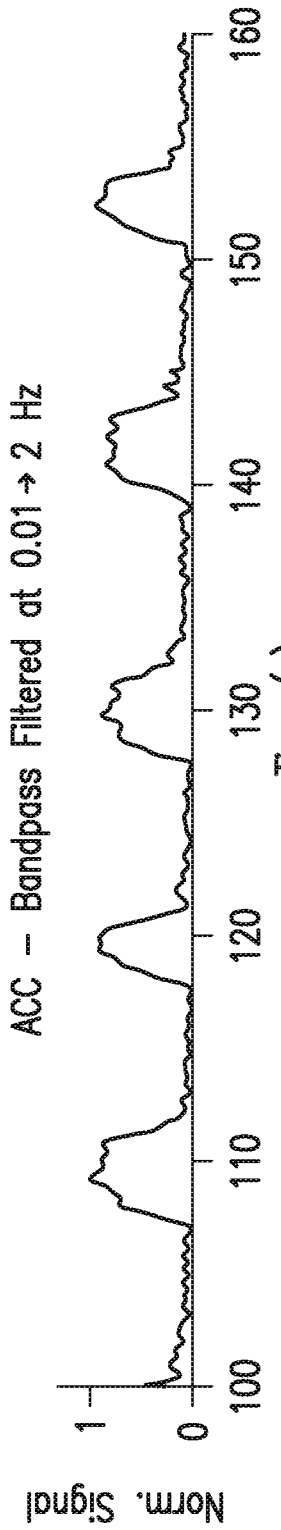


FIG. 15A

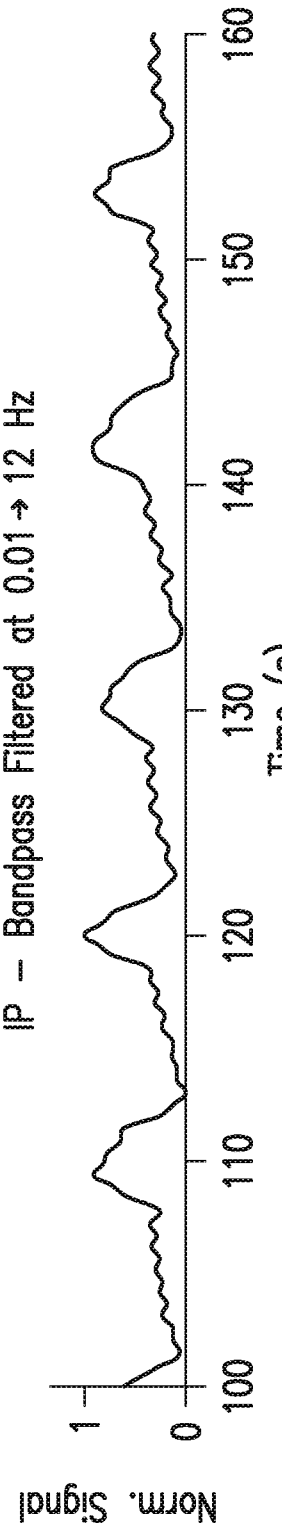


FIG. 15B

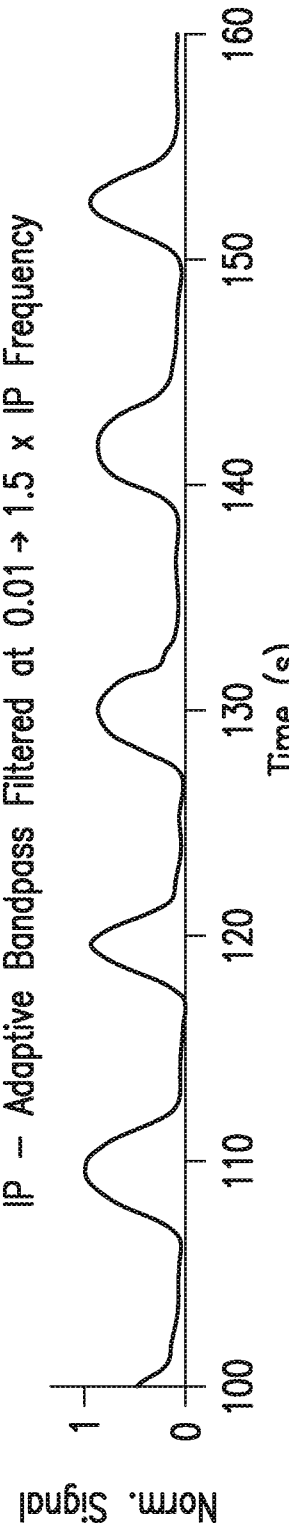


FIG. 15C

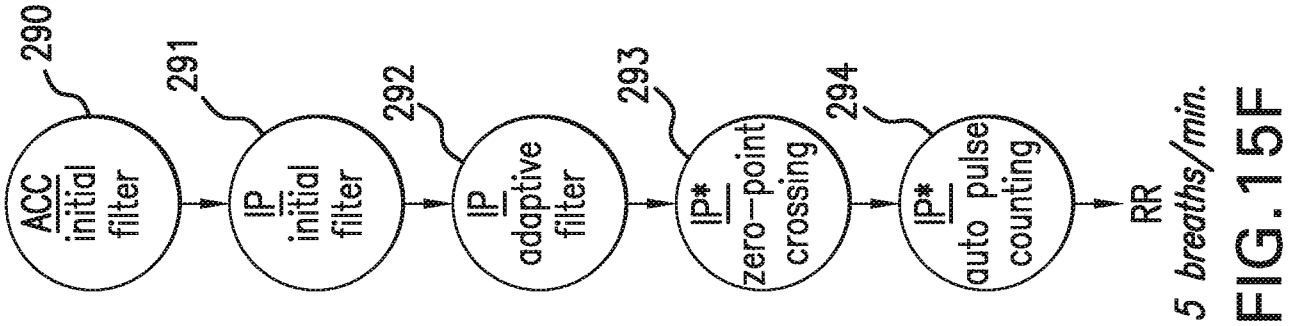


FIG. 15F

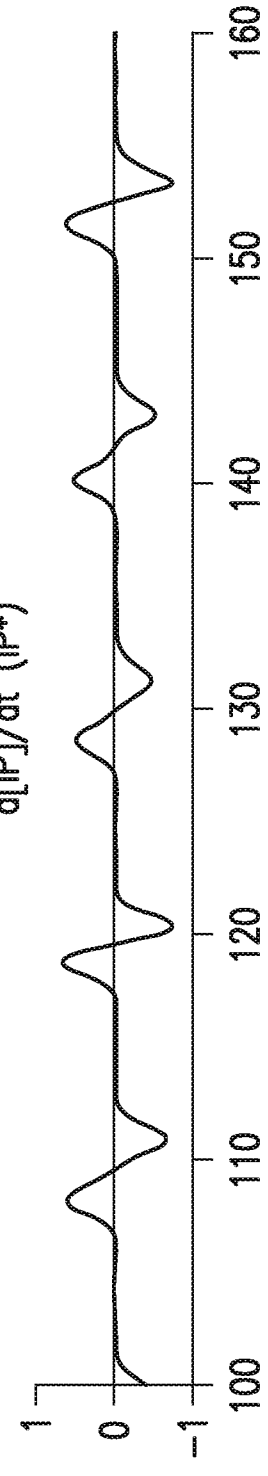


FIG. 15D

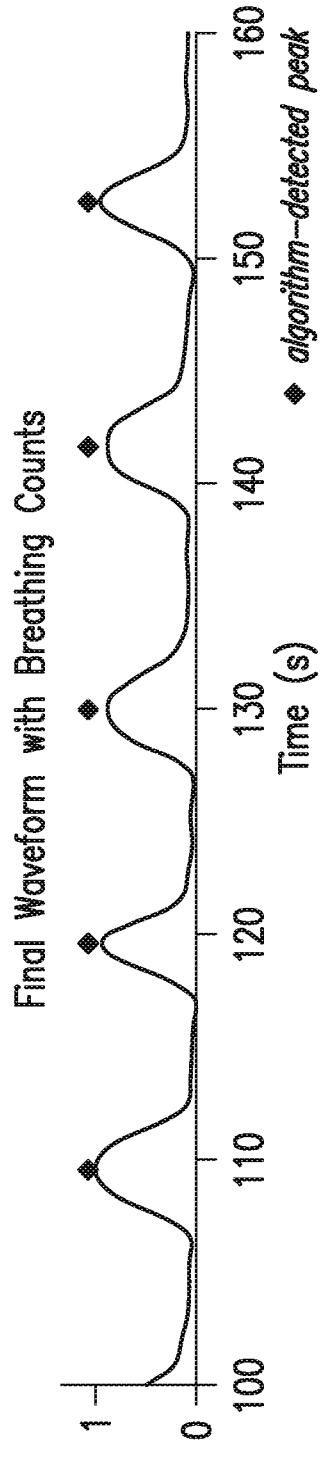


FIG. 15E

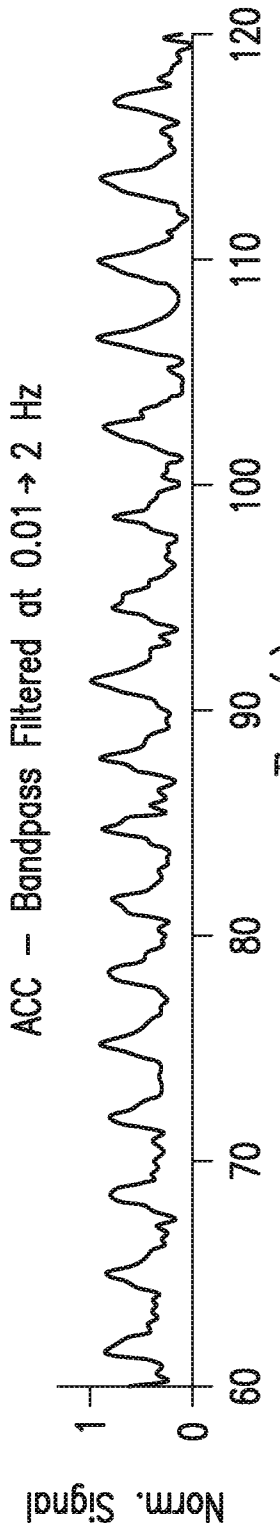


FIG.16A

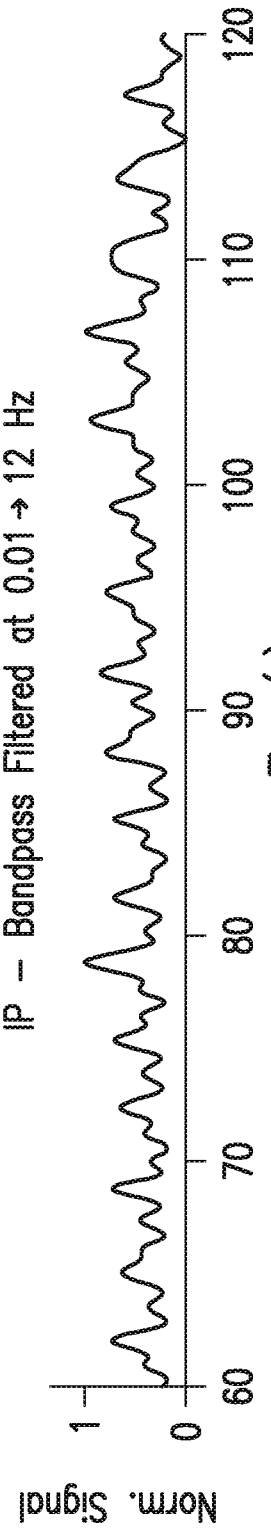


FIG.16B

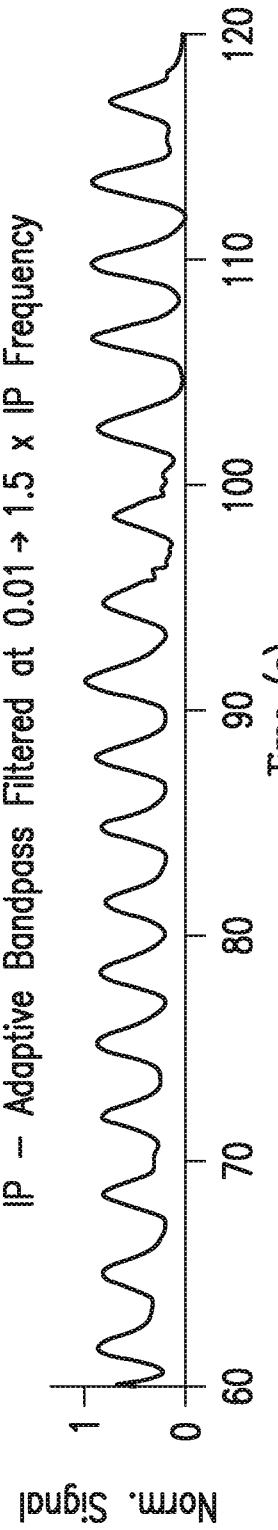


FIG.16C

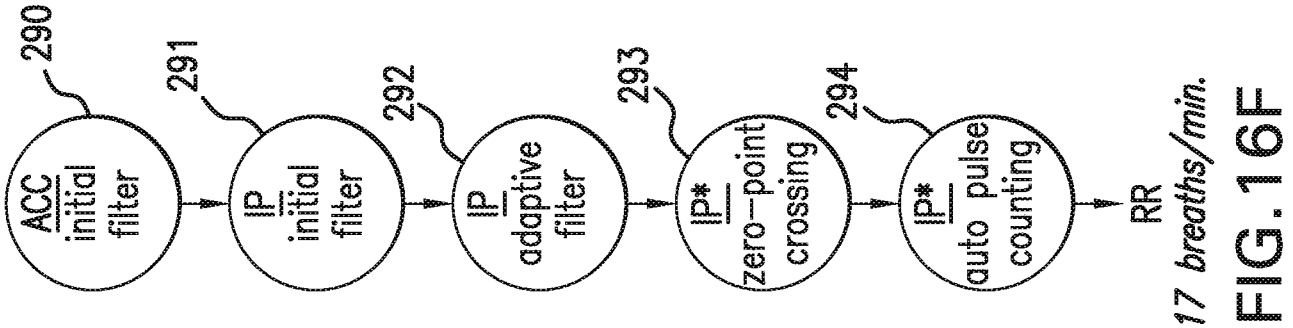


FIG. 16F

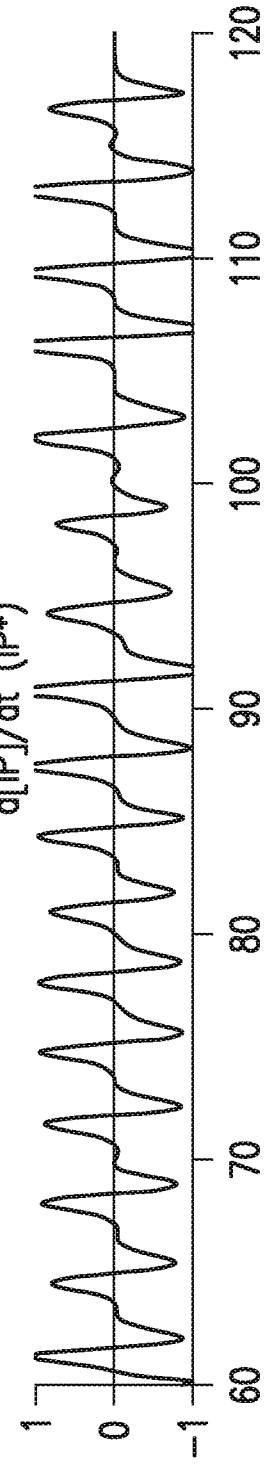


FIG. 16D

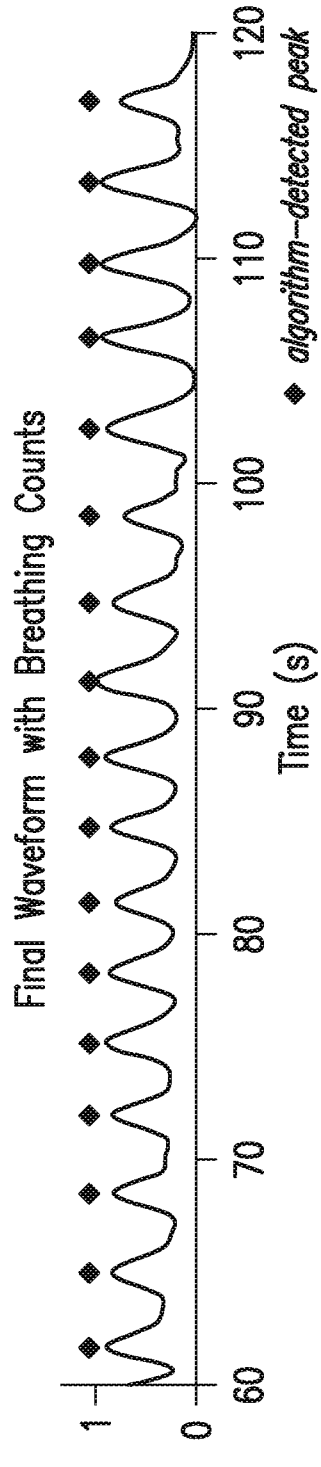


FIG. 16E

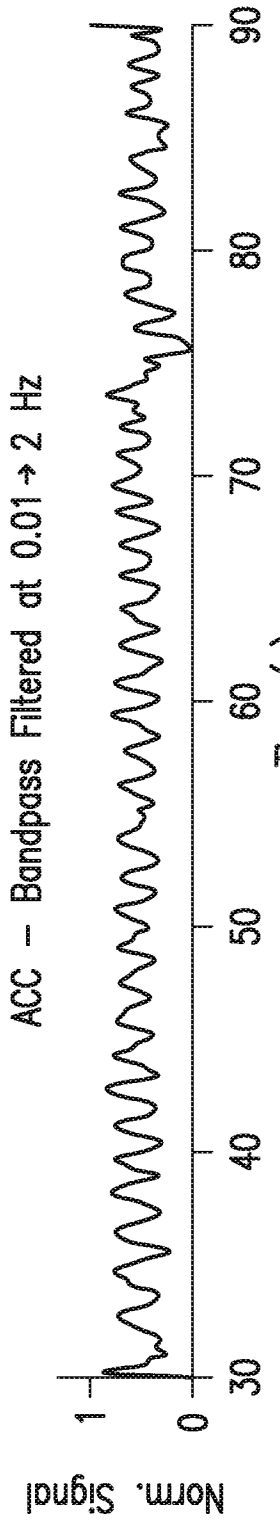


FIG.17A

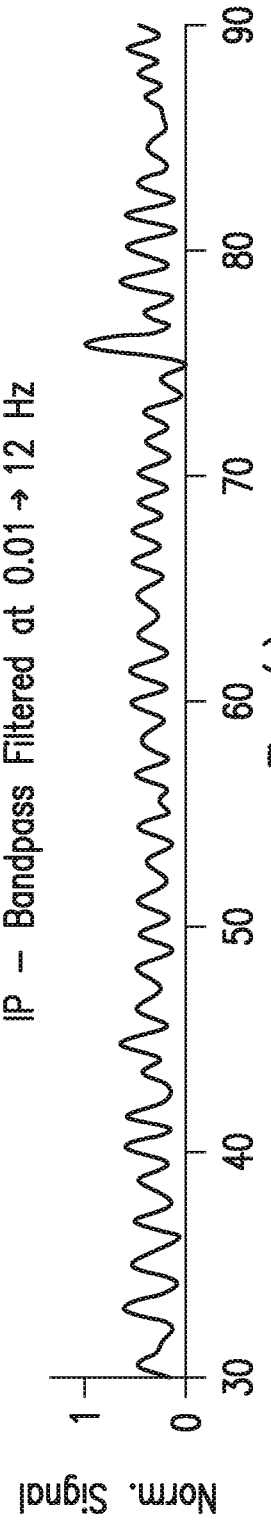


FIG.17B

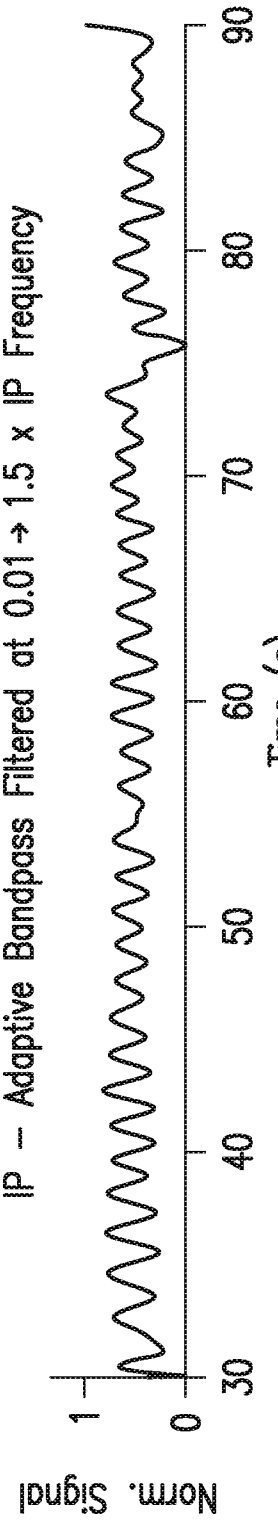


FIG.17C

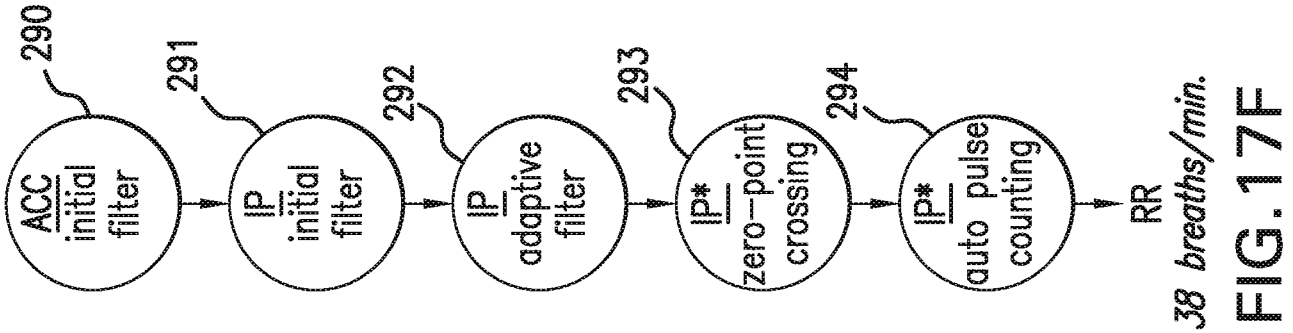


FIG. 17F

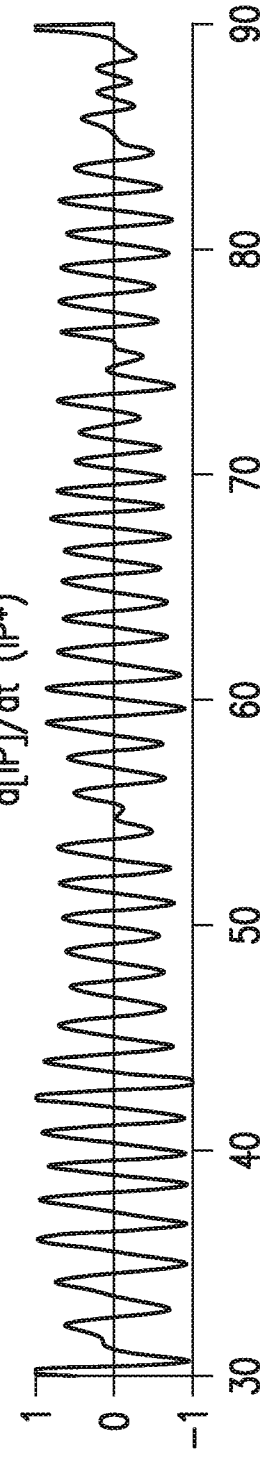


FIG. 17D

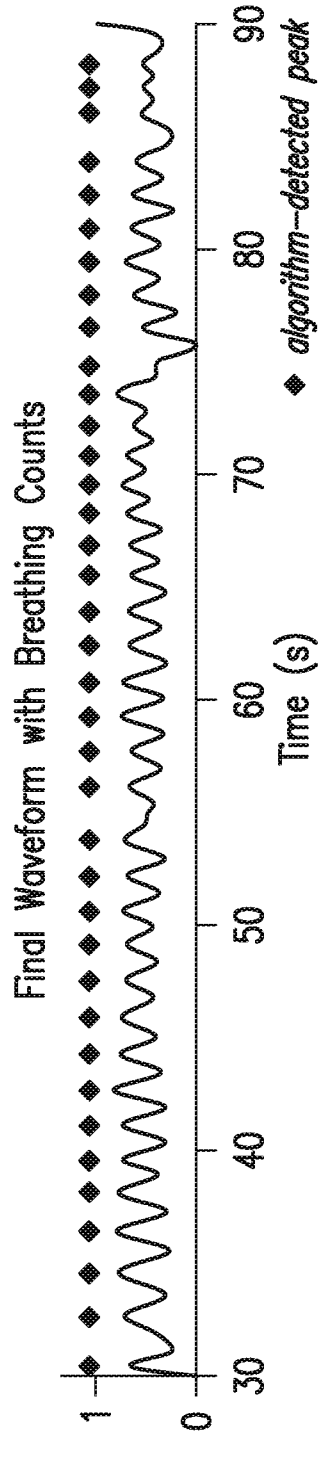


FIG. 17E

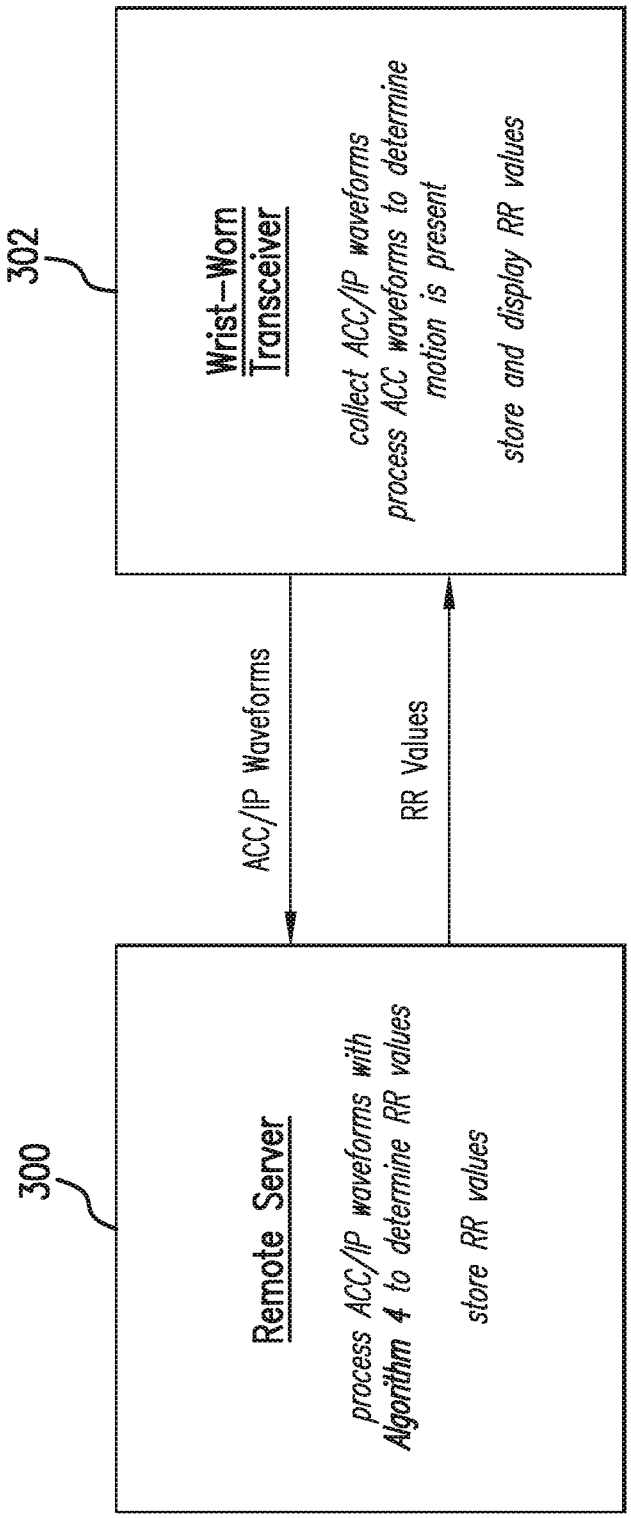

302
Wrist-Worn Transceiver
collect ACC/IP waveforms
process ACC waveforms to determine motion is present
store and display RR values
ACC/IP Waveforms
RR Values
300
Remote Server
process ACC/IP waveforms with Algorithm 4 to determine RR values
store RR values

FIG. 18

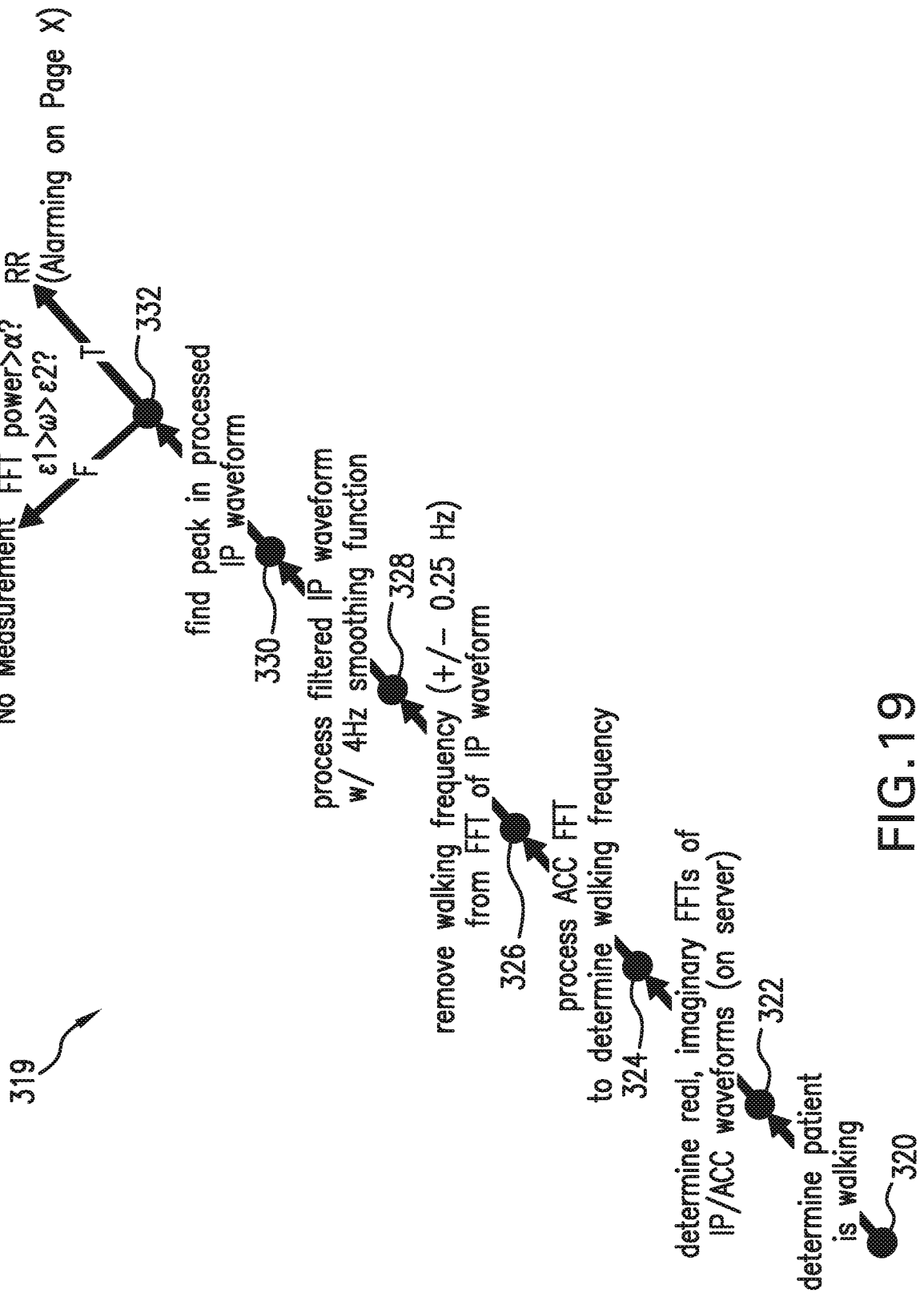

319
determine patient is walking
320
determine real, imaginary FFTs of IP/ACC waveforms (on server)
322
process ACC FFT to determine walking frequency
324
remove walking frequency (+/- 0.25 Hz) from FFT of IP waveform
326
process filtered IP waveform w/ 4Hz smoothing function
328
find peak in processed IP waveform
330
332
No Measurement
FFT power>α?
ε1>ω>ε2?
F
T
RR
(Alarming on Page X)

FIG. 19

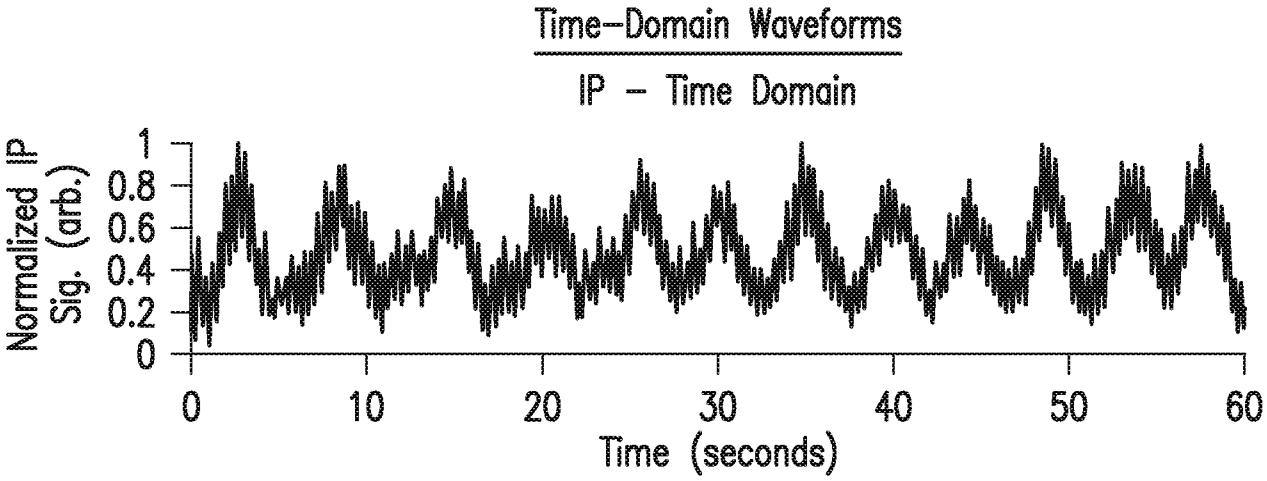


FIG.20A

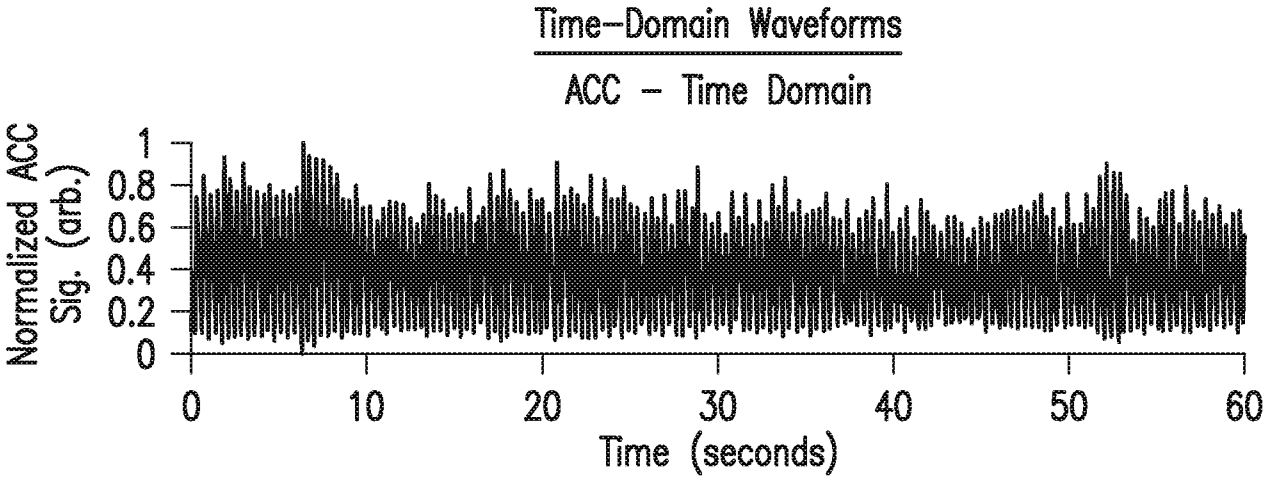


FIG.20B

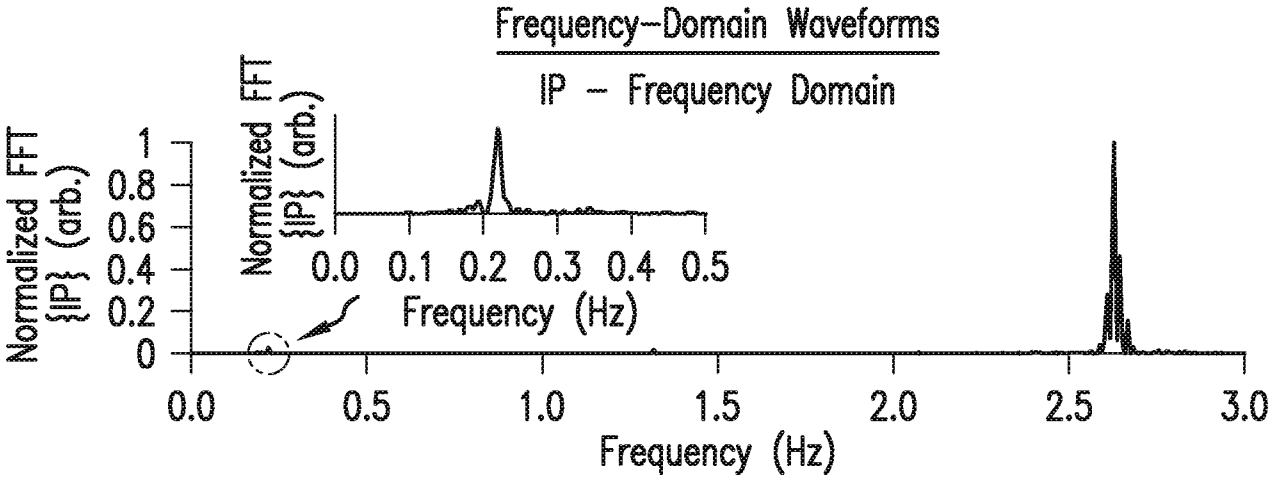


FIG.20C

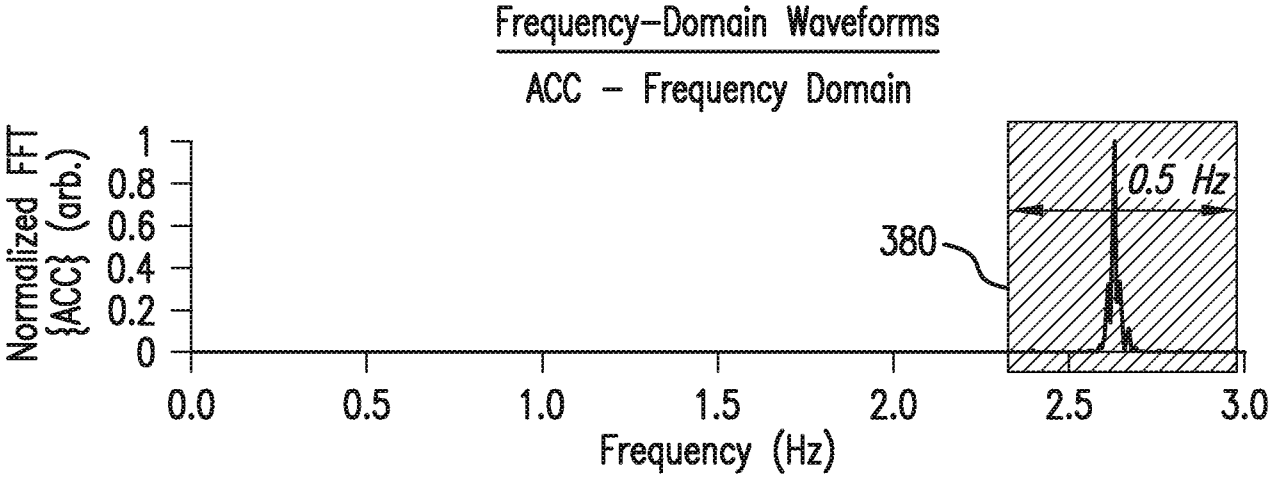


FIG.20D

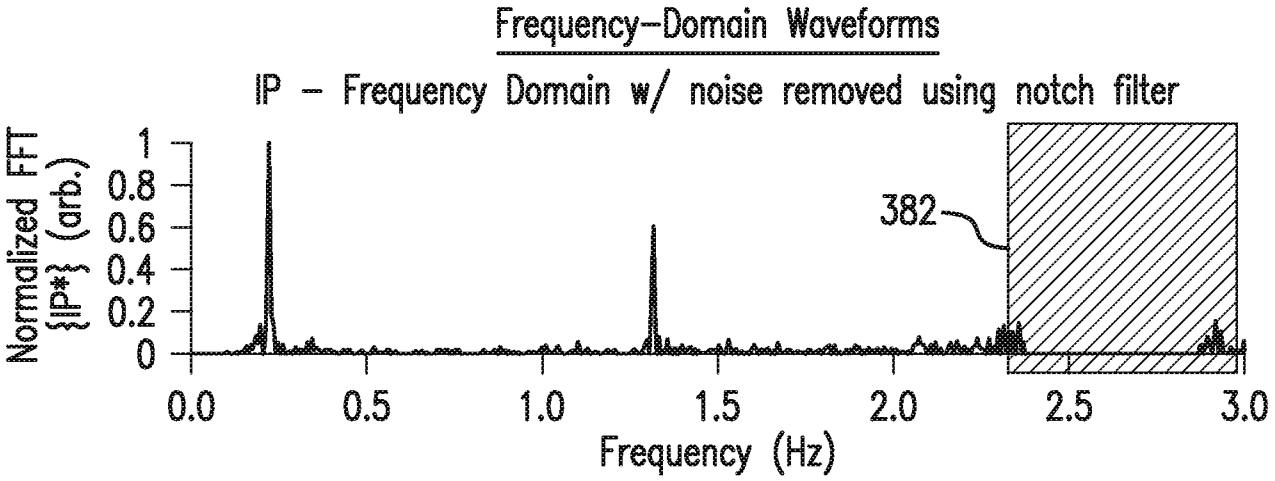


FIG.20E

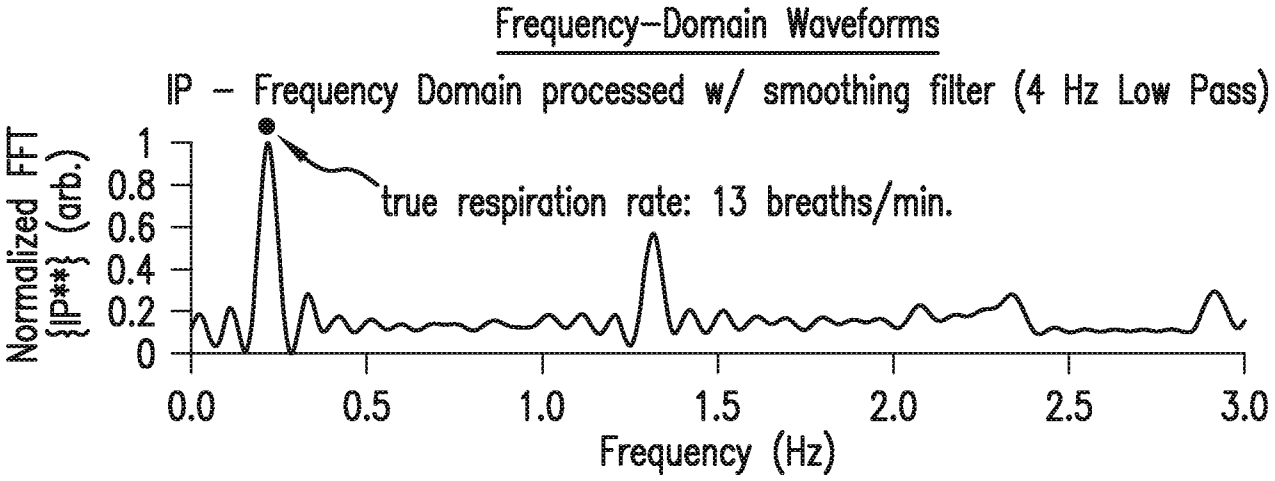


FIG.20F

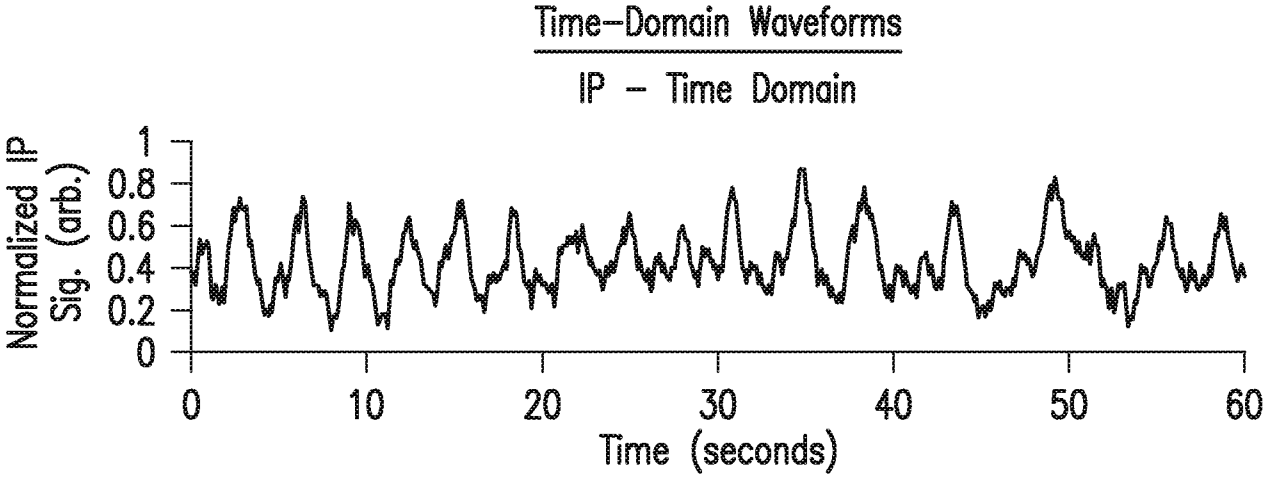


FIG.21A

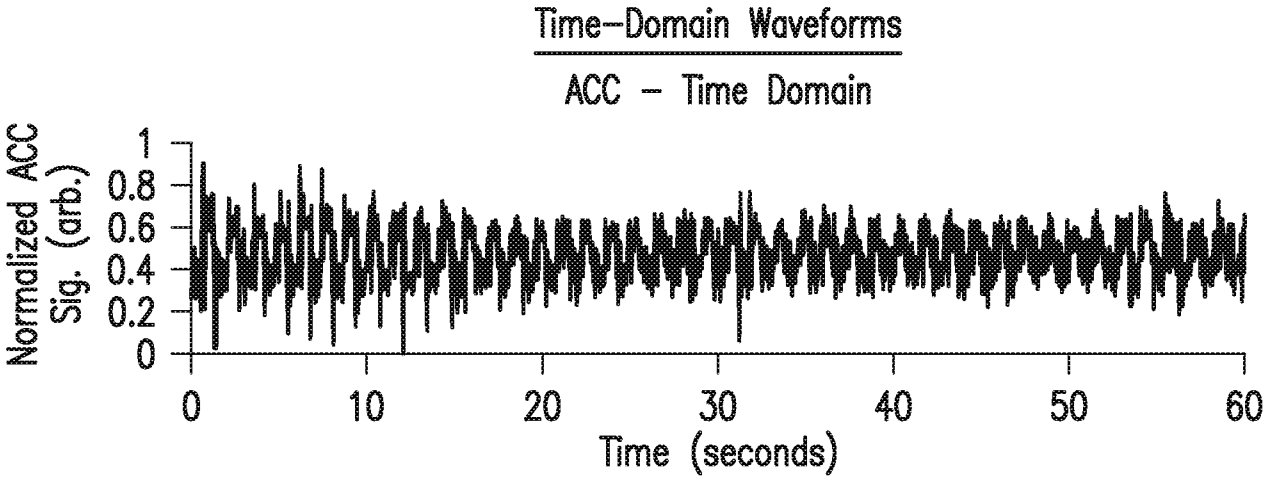


FIG.21B

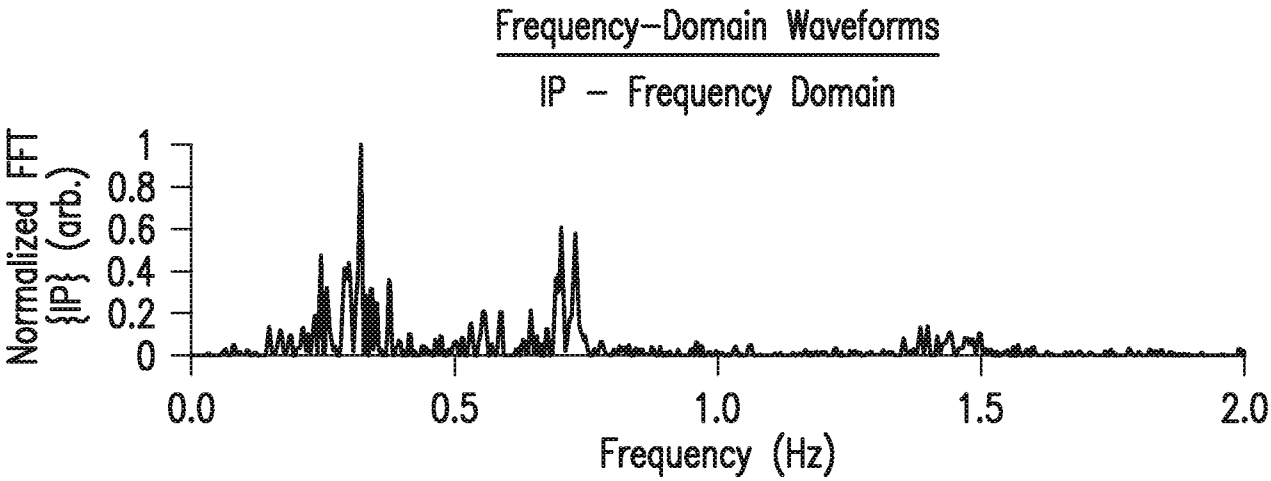


FIG.21C

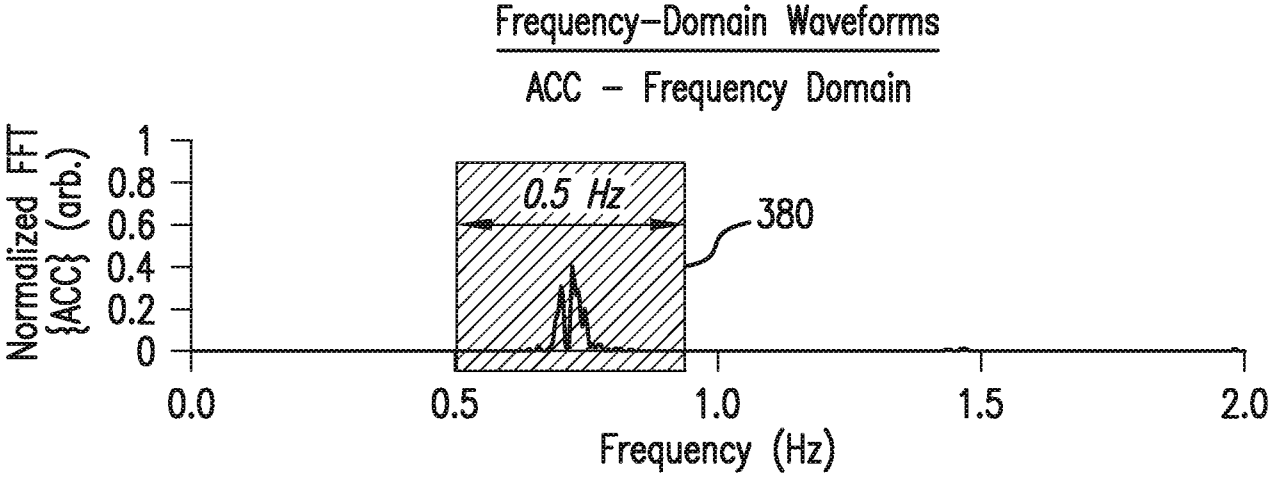


FIG.21D

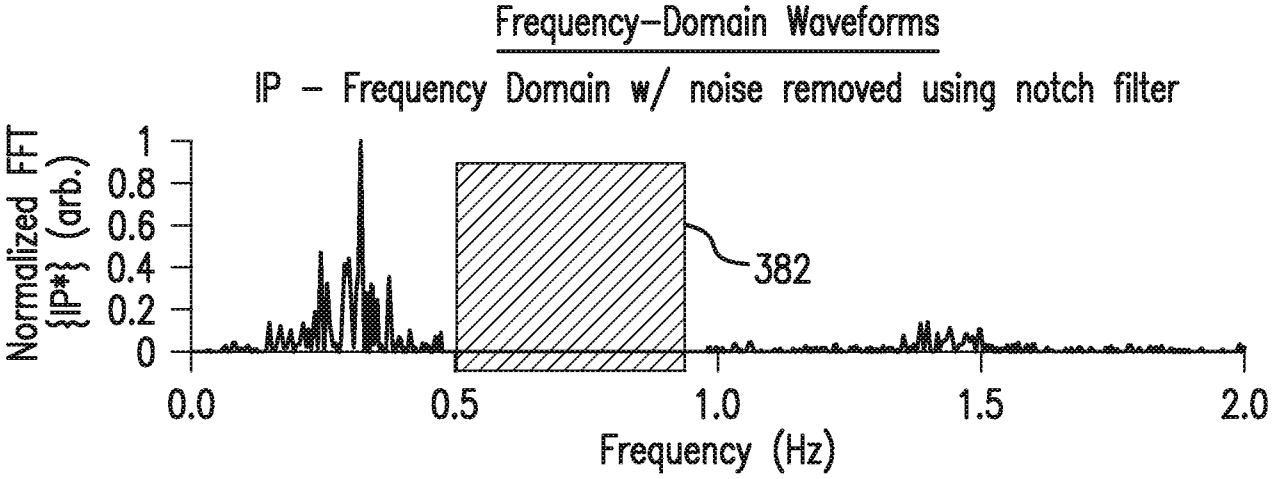


FIG.21E

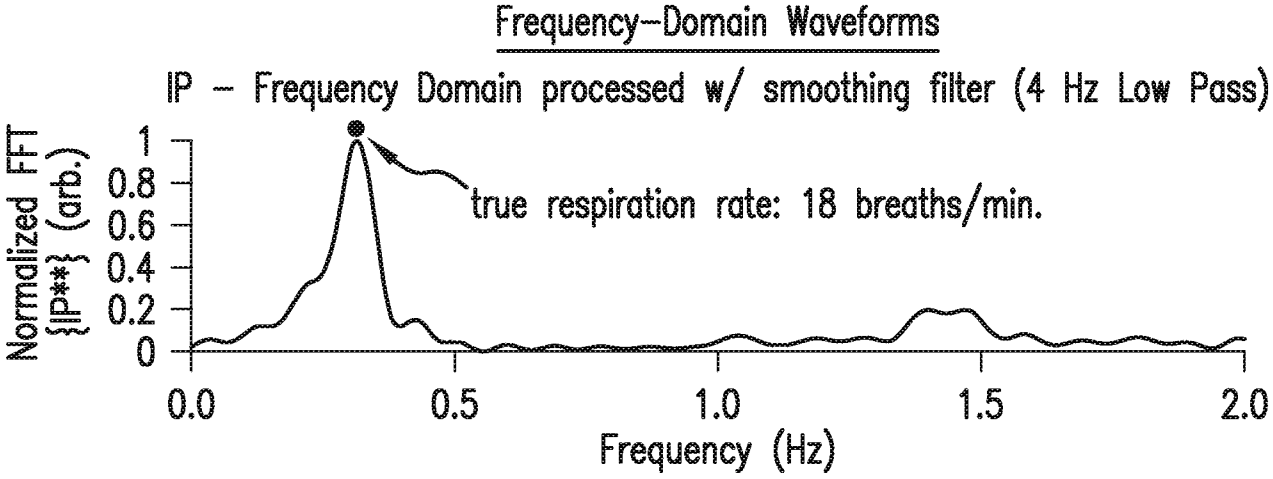


FIG.21F

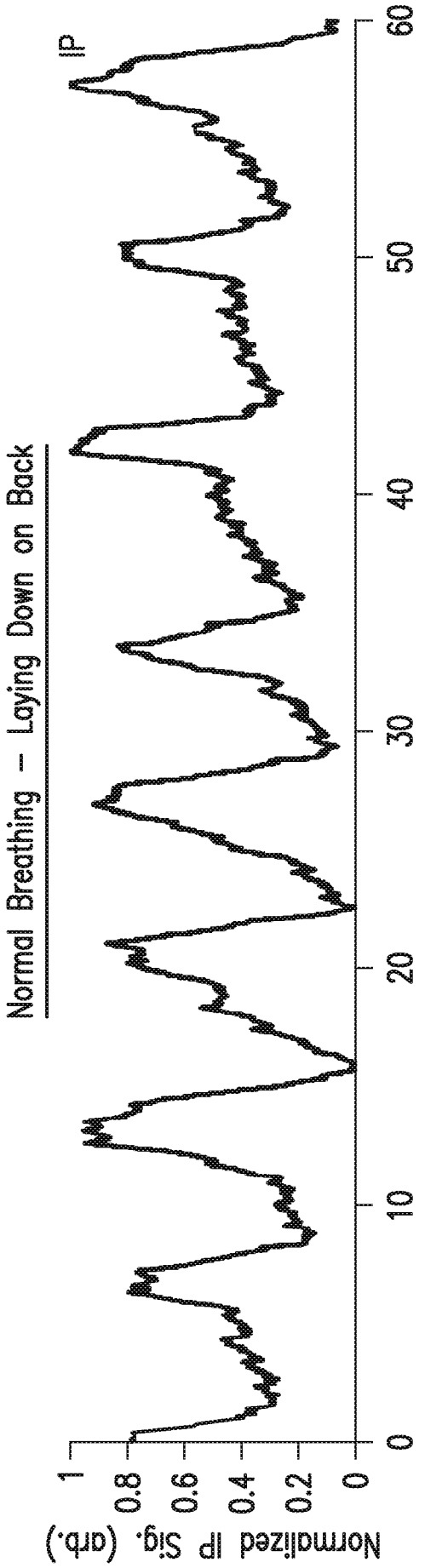


FIG.22A

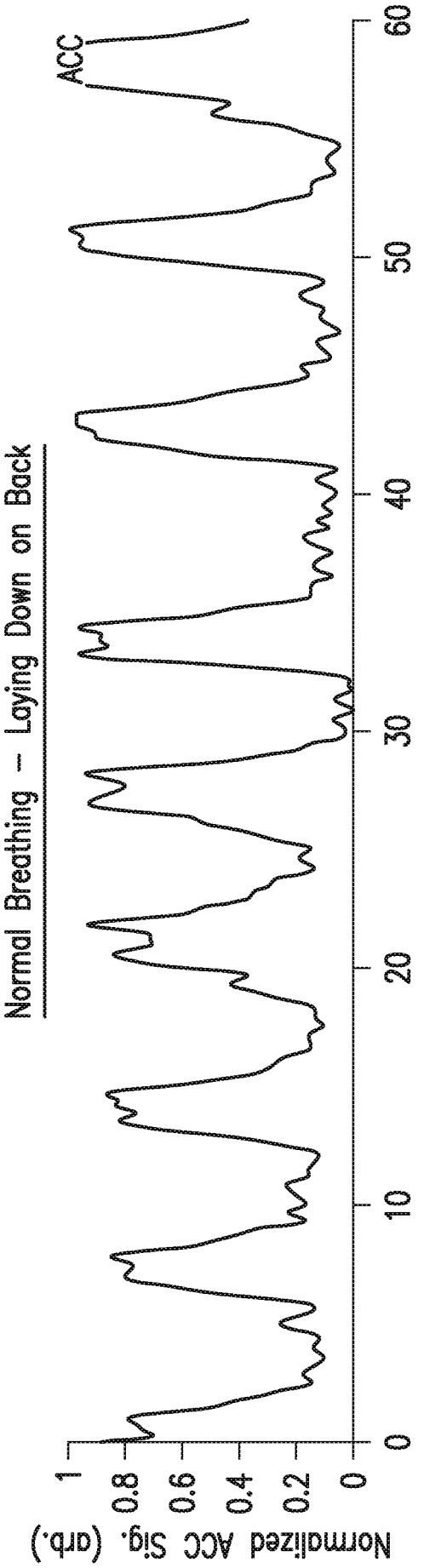


FIG.22B

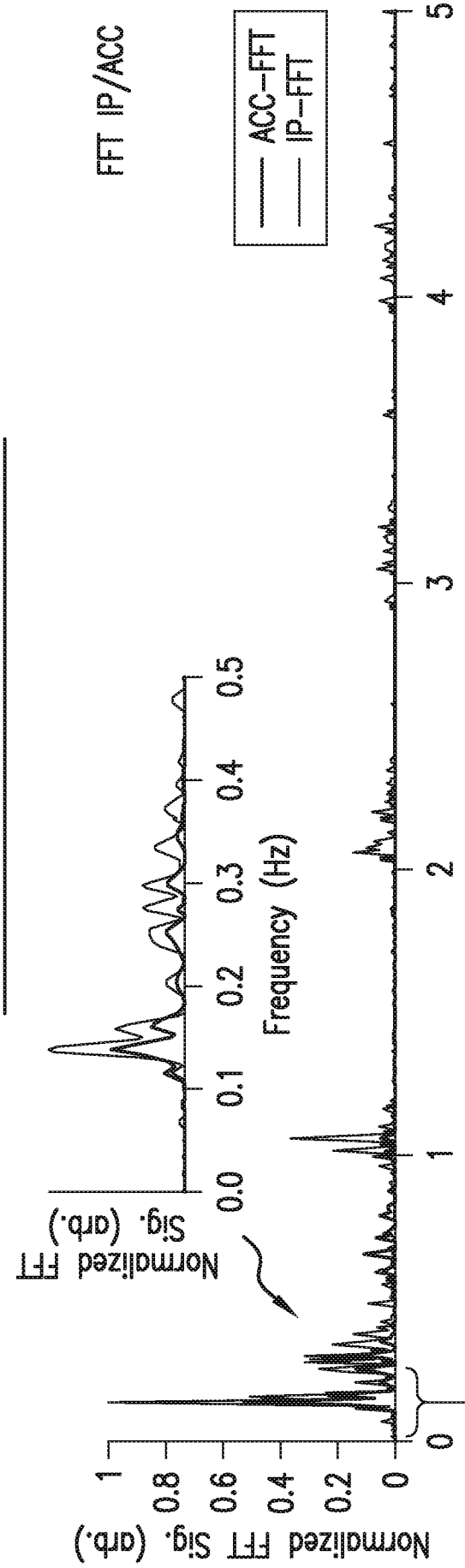

Normal Breathing – Laying Down on Back
FFT IP/ACC
ACC–FFT
IP–FFT
Normalized FFT Sig. (arb.)
Frequency (Hz)
Normalized FFT Sig. (arb.)
actual RR determined by
et–CO2 (7–9 breaths/min.)
Frequency (Hz)

FIG.22C

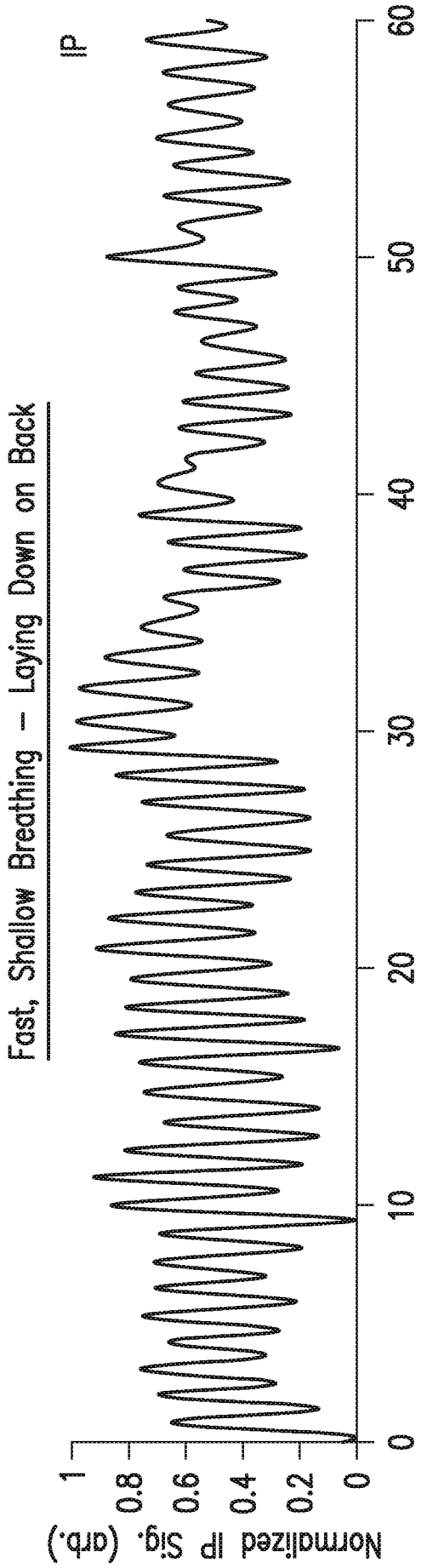


FIG.23A

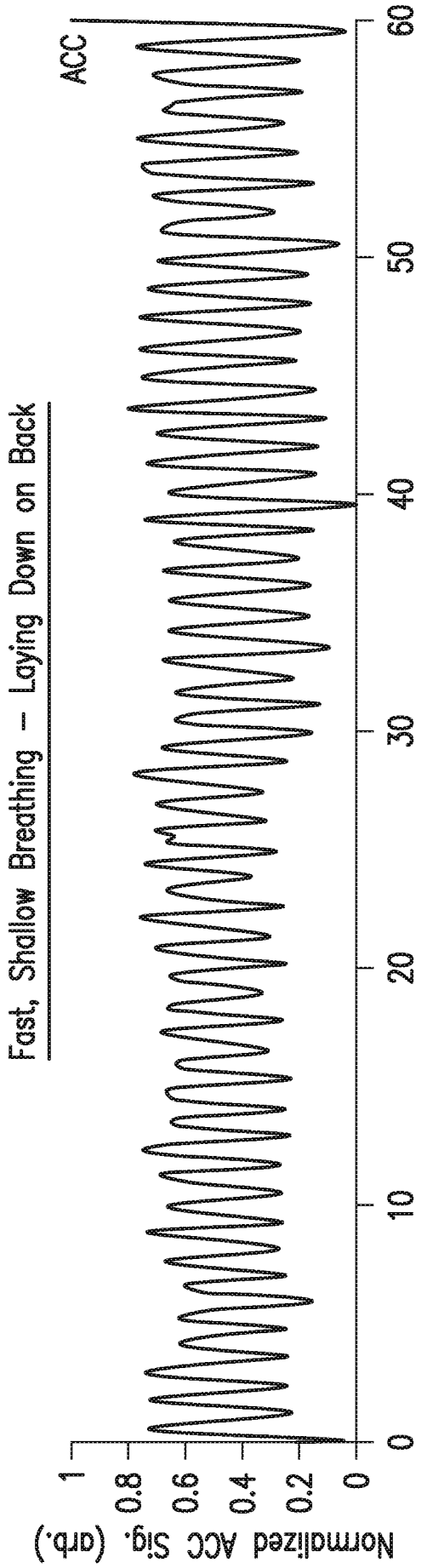


FIG.23B

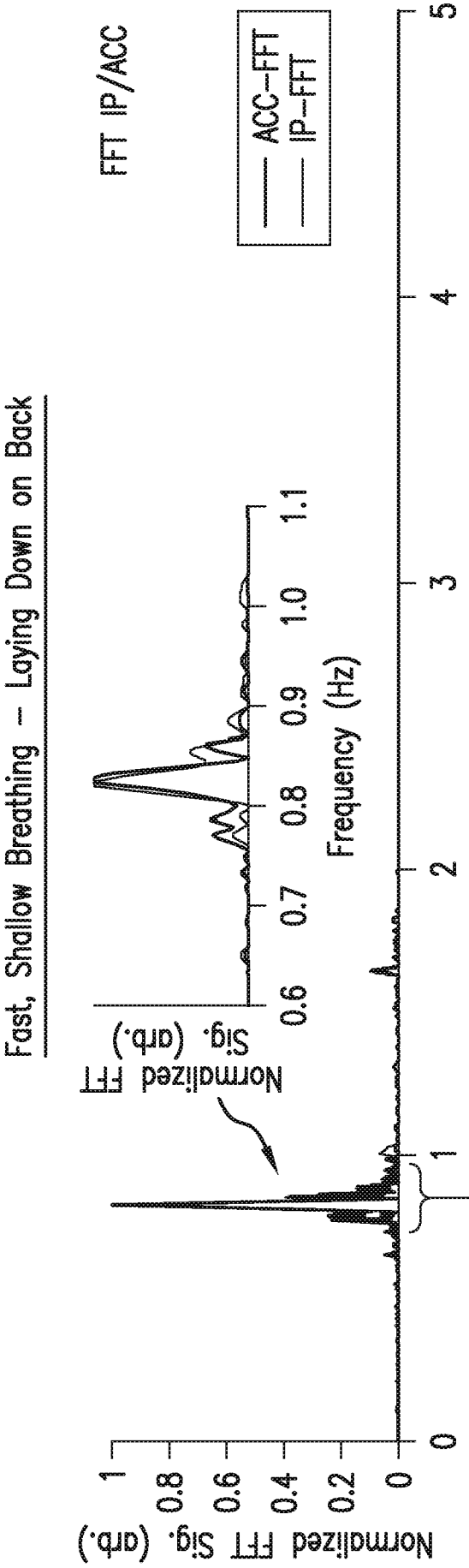

Fast, Shallow Breathing – Laying Down on Back
FFT IP/ACC
ACC–FFT
IP–FFT
Normalized FFT Sig. (arb.)
Frequency (Hz)
actual RR determined by
et–CO2 (48–50 breaths/min.)
Normalized FFT Sig. (arb.)
Frequency (Hz)

FIG.23C

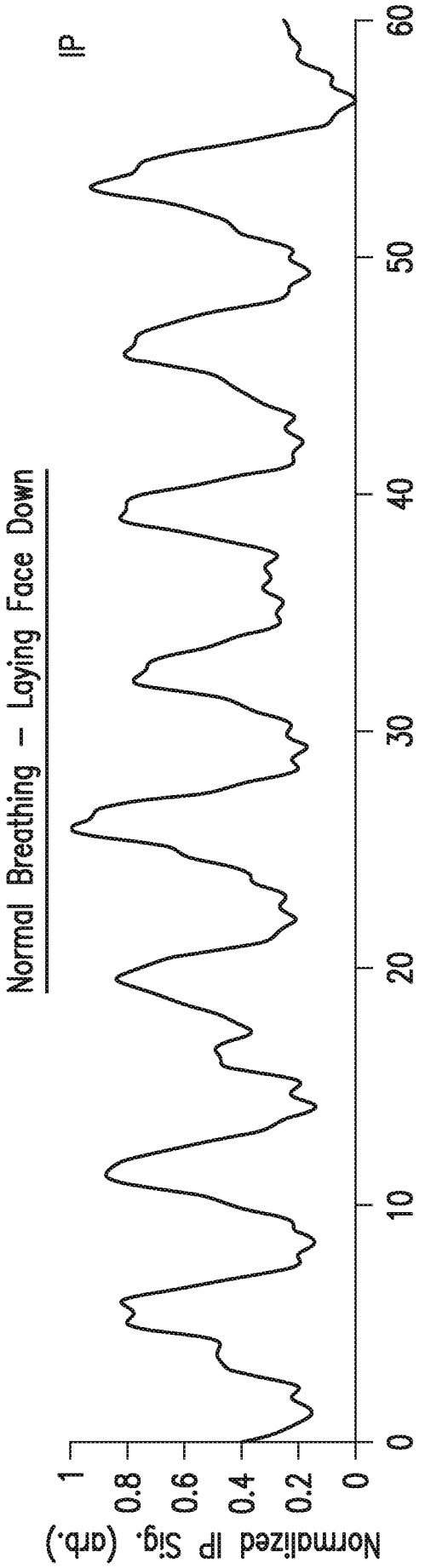


FIG.24A

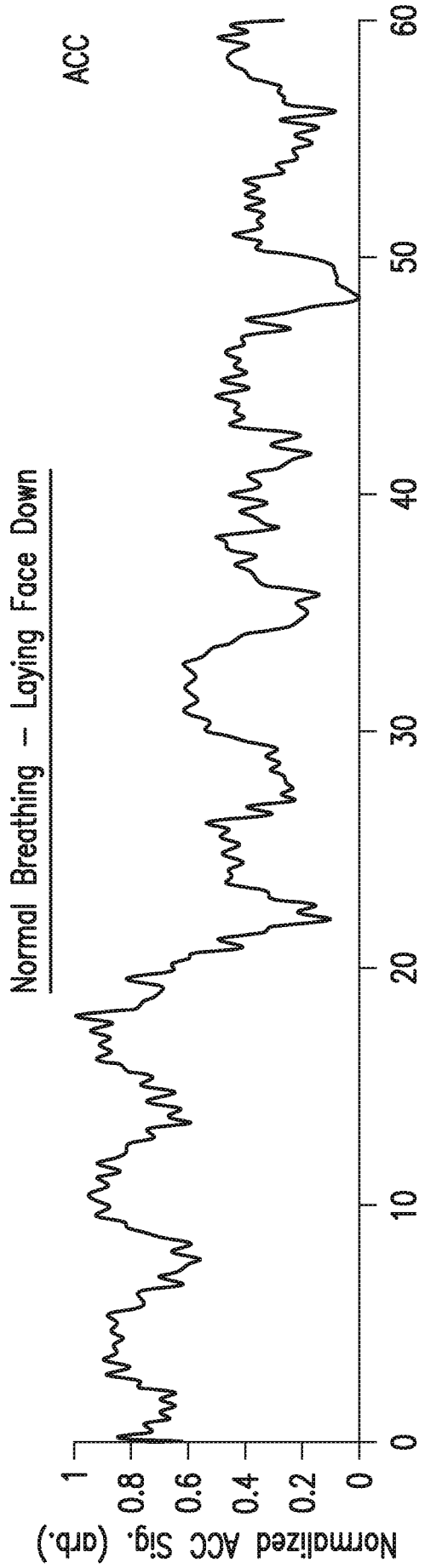


FIG.24B

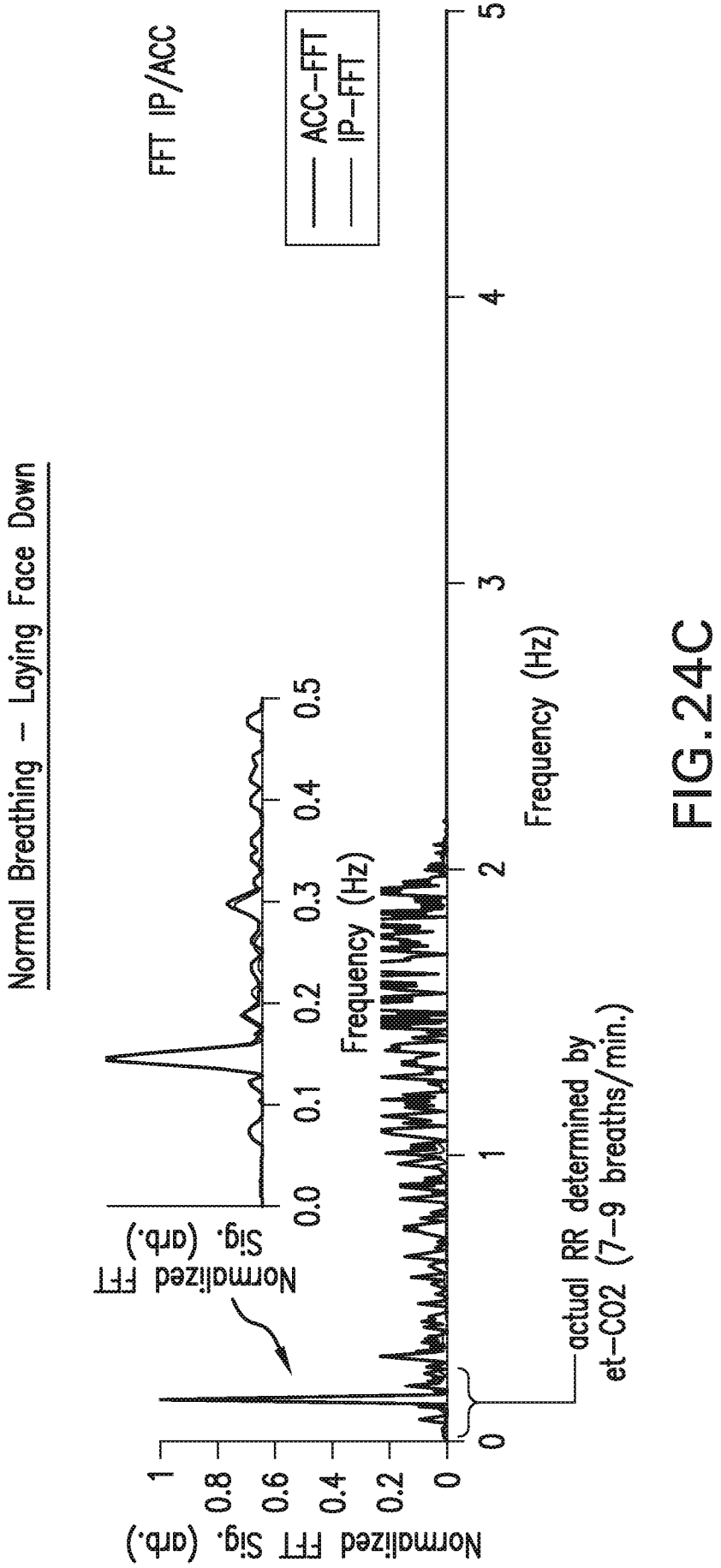

Normal Breathing – Laying Face Down
FFT IP/ACC
ACC–FFT
IP–FFT
Normalized FFT Sig. (arb.)
Frequency (Hz)
Normalized FFT Sig. (arb.)
actual RR determined by et–CO2 (7–9 breaths/min.)
Frequency (Hz)

FIG. 24C

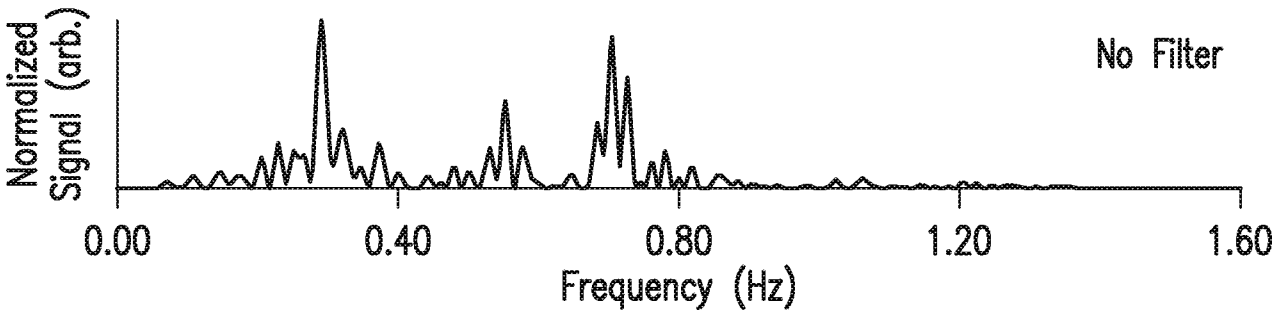


FIG.25A

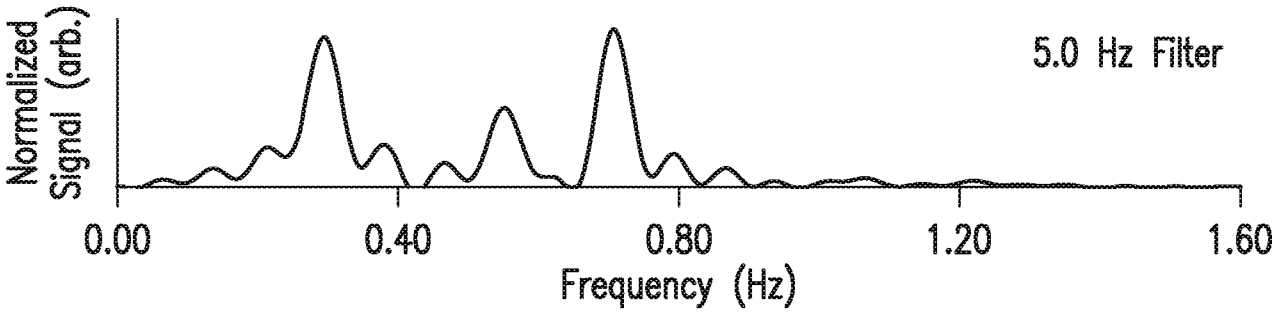


FIG.25B

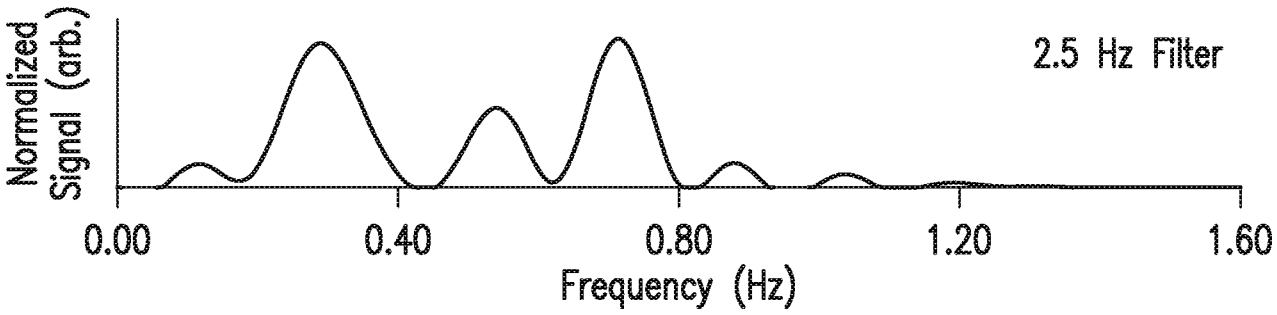


FIG.25C

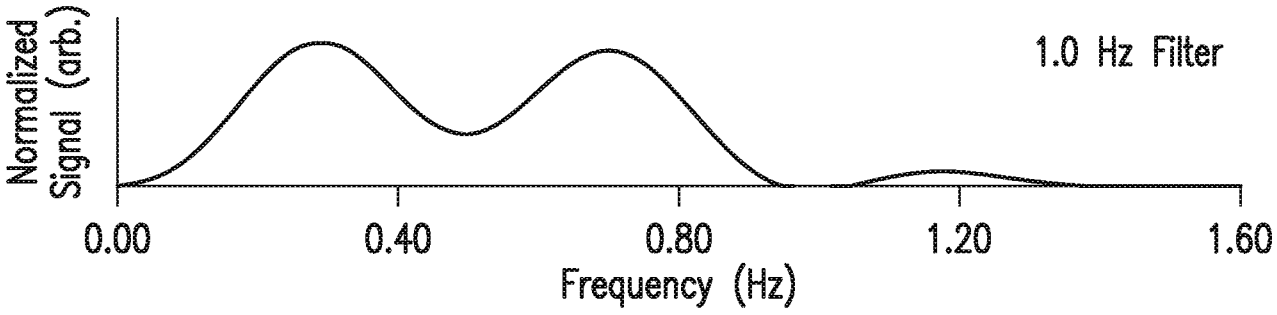


FIG.25D

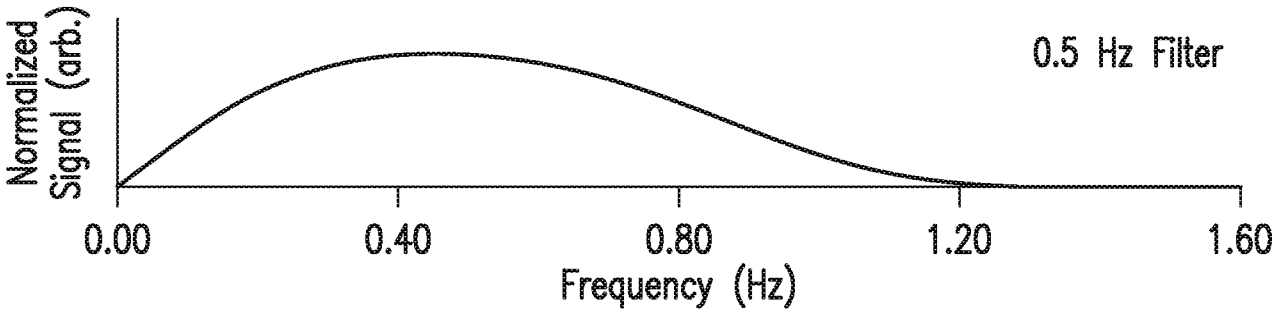


FIG.25E

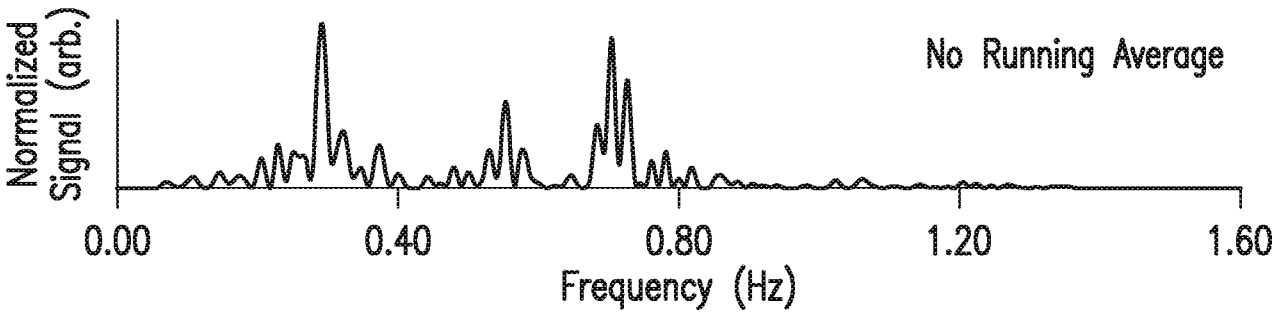


FIG.26A

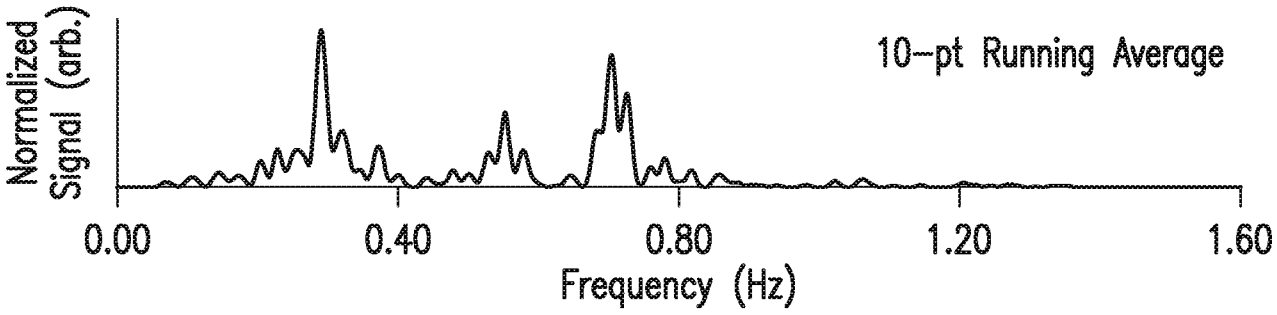


FIG.26B

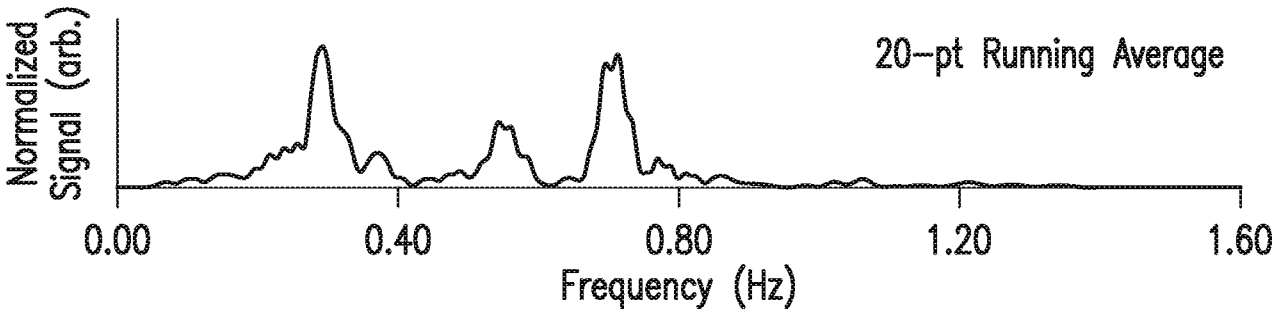


FIG.26C

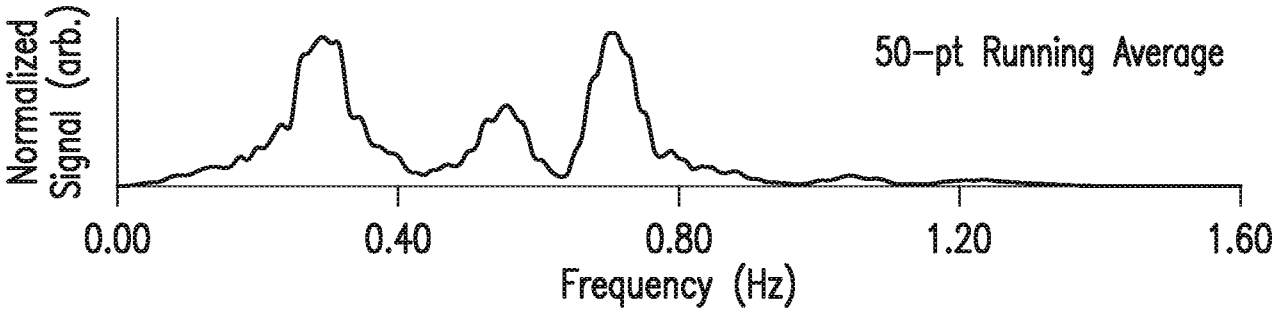


FIG.26D

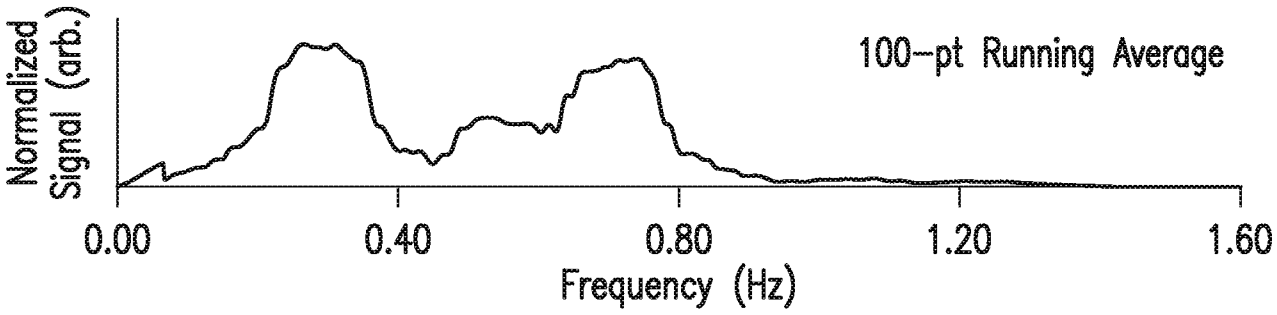


FIG.26E

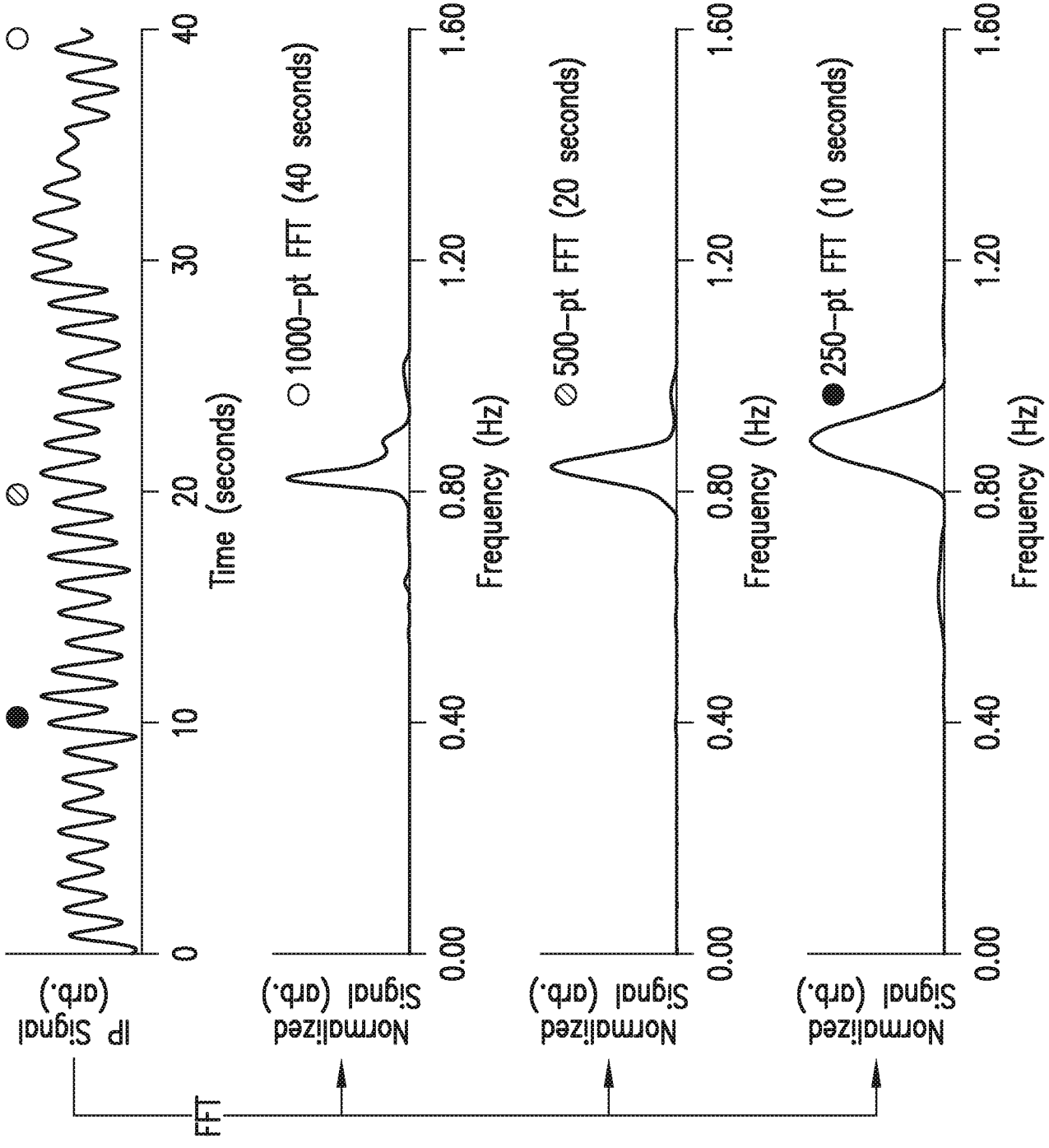


FIG.27A

FIG.27B

FIG.27C

FIG.27D

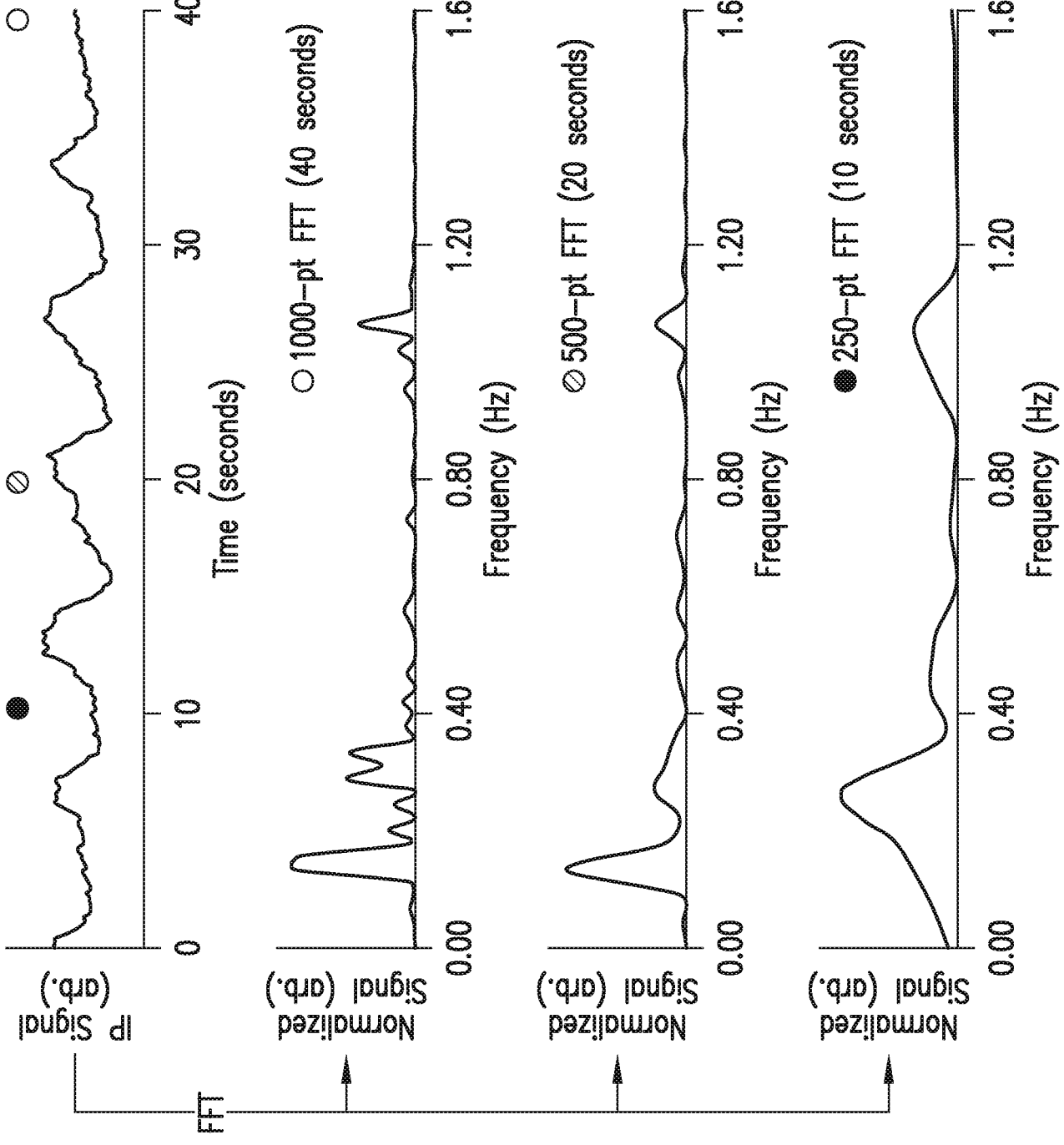


FIG.28A

FIG.28B

FIG.28C

FIG.28D

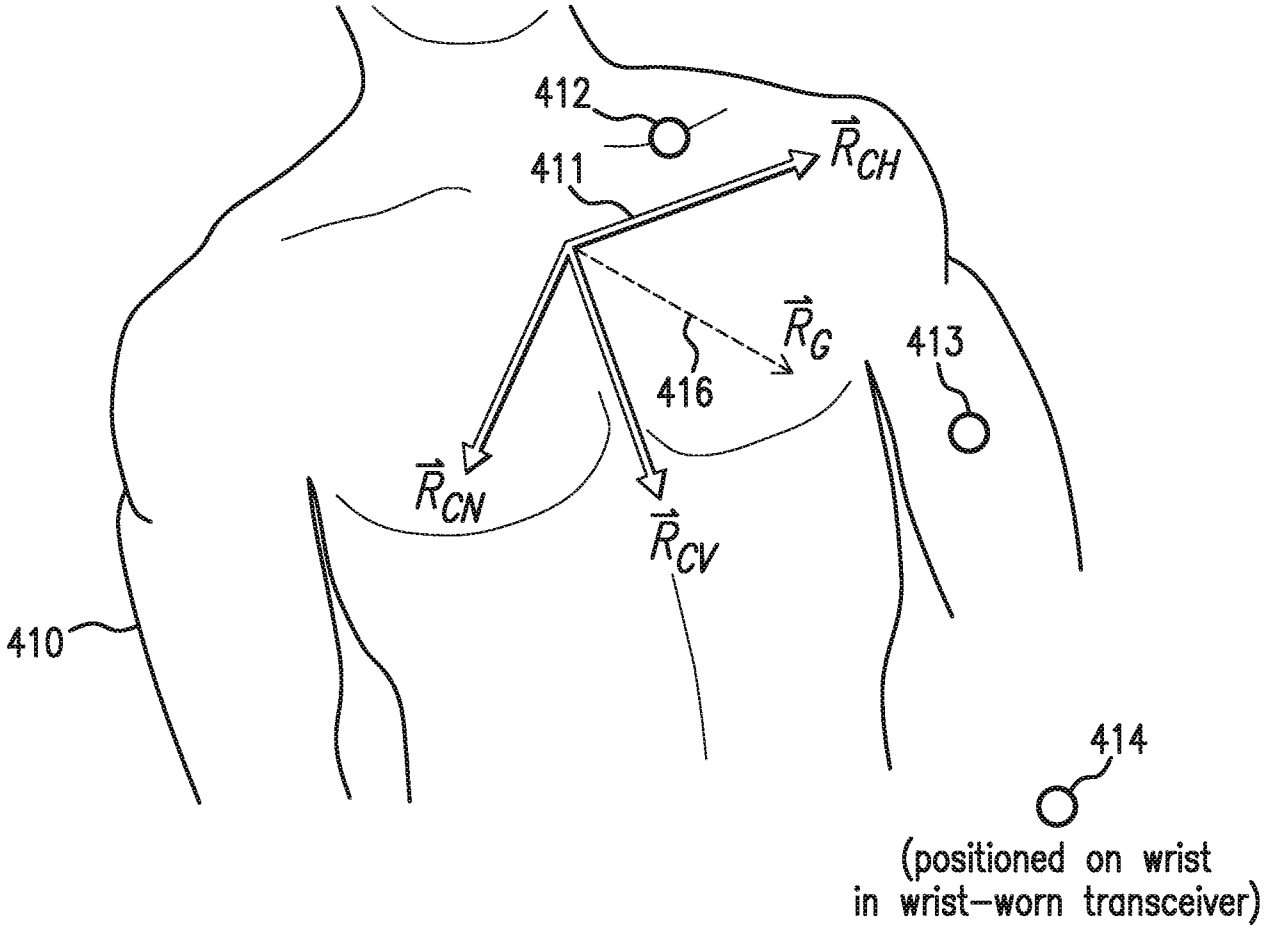

412
411
$\vec{R}_{CH}$
$\vec{R}_G$
416
413
$\vec{R}_{CN}$
$\vec{R}_{CV}$
410
414
(positioned on wrist
in wrist-worn transceiver)

FIG.29

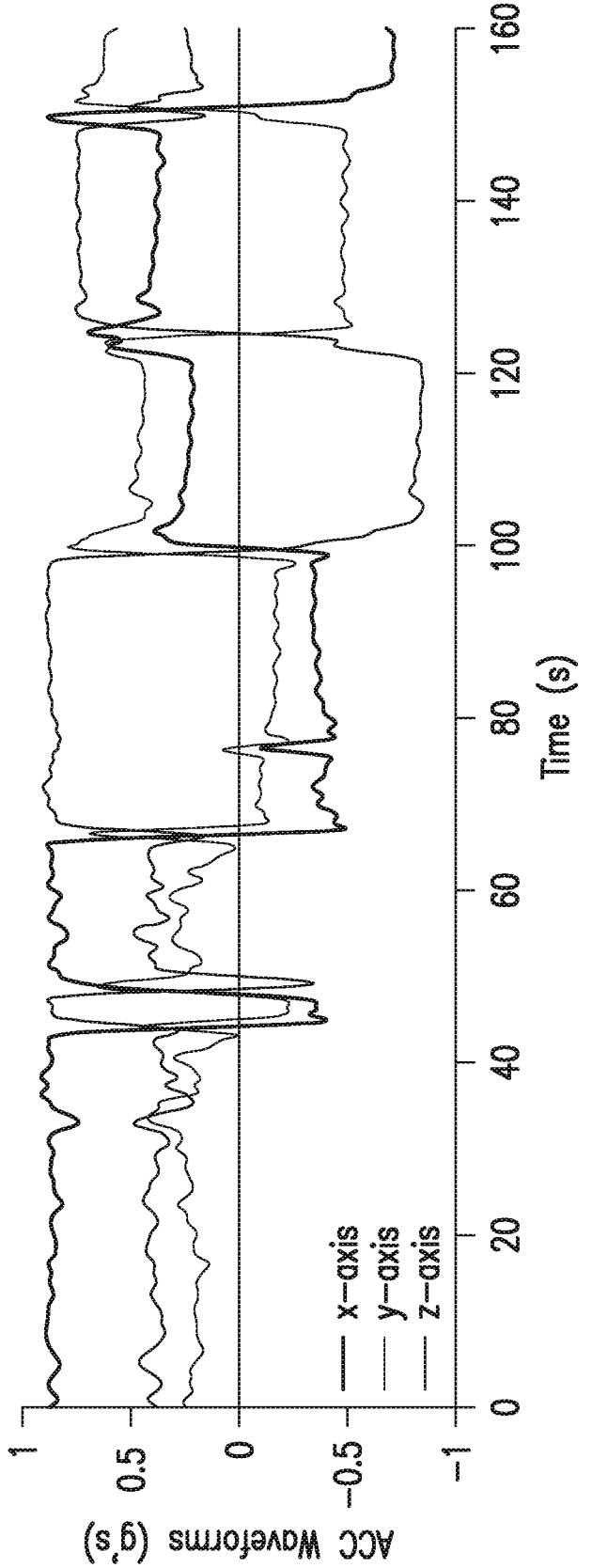


FIG.30A

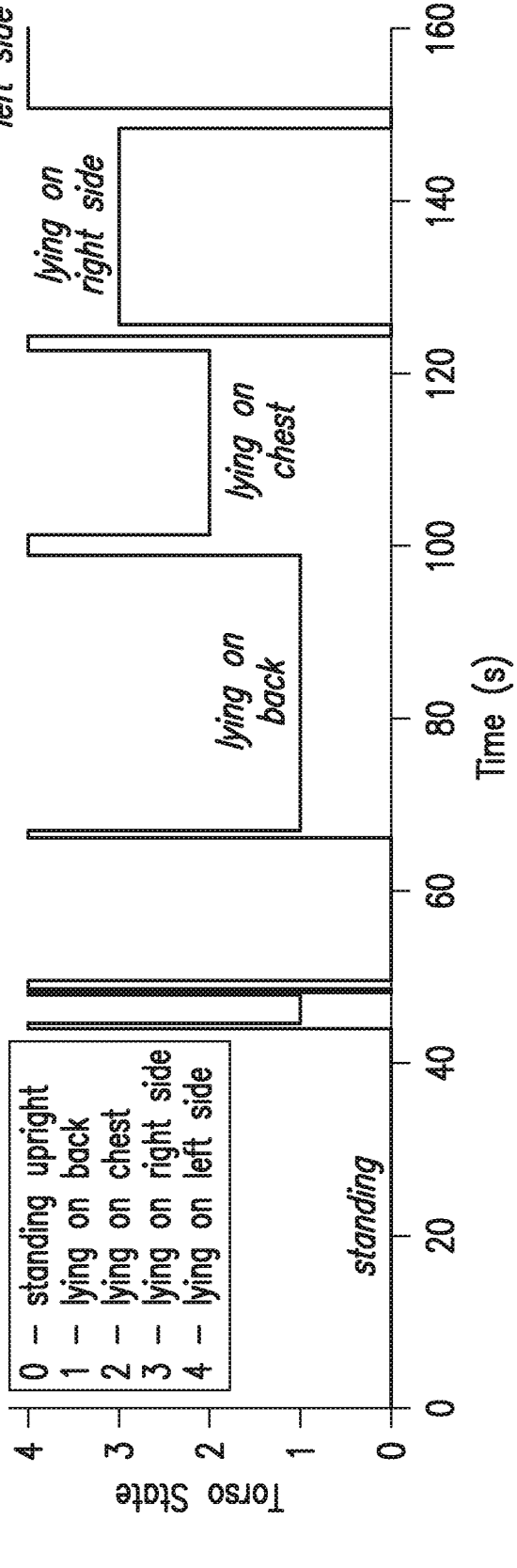


FIG.30B