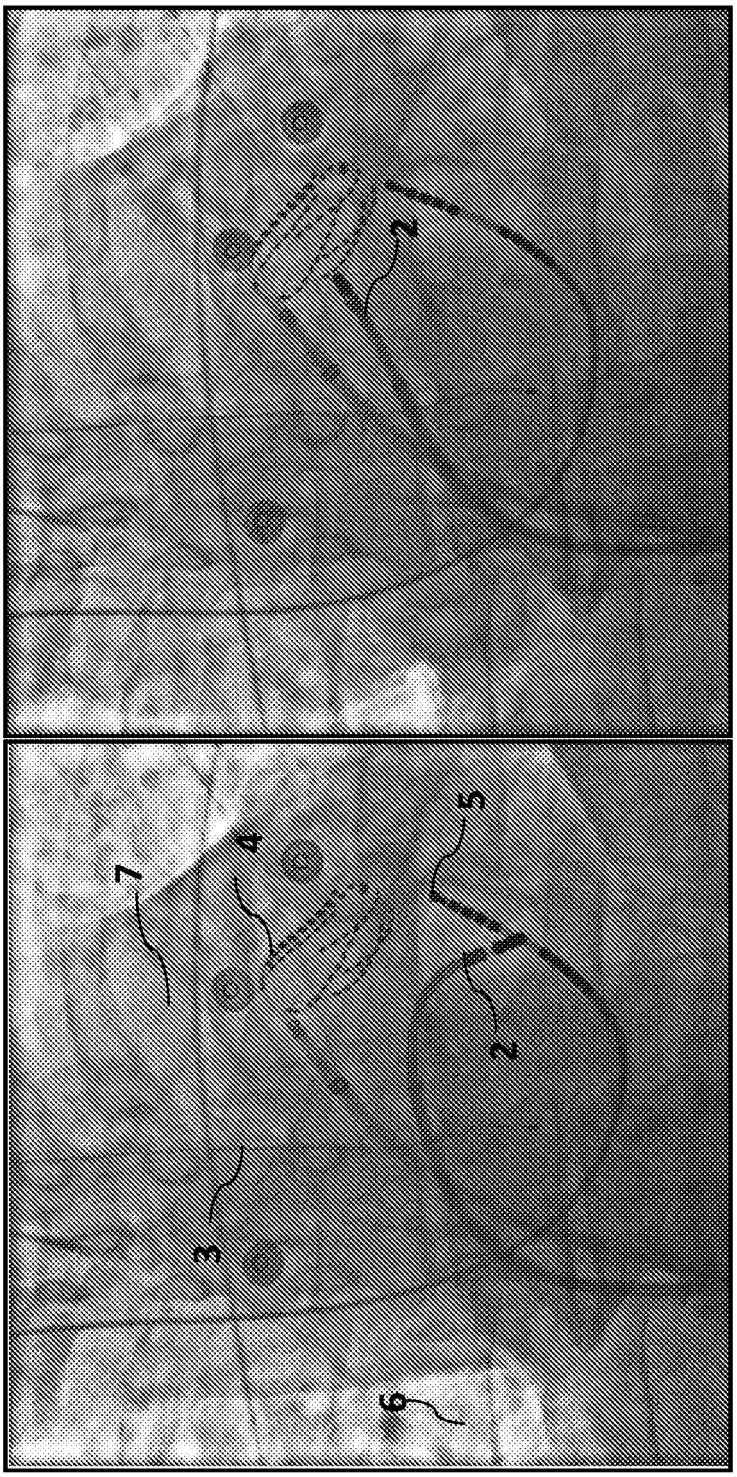


FIG. 1B

FIG. 1A

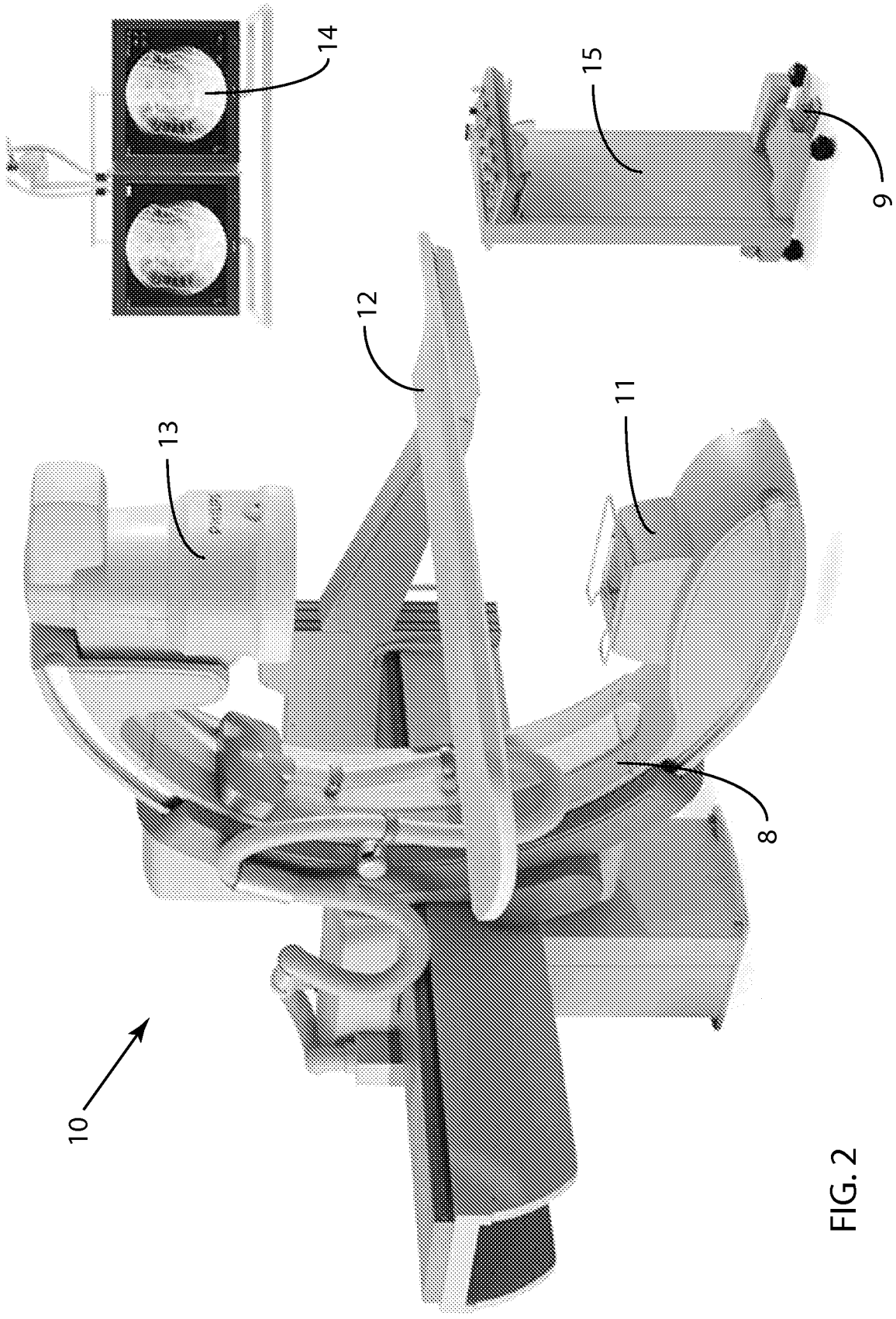


FIG. 2

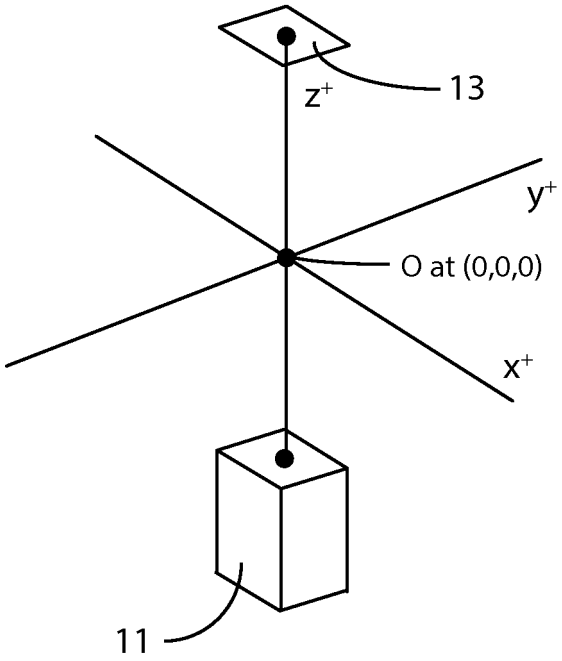


FIG. 3A

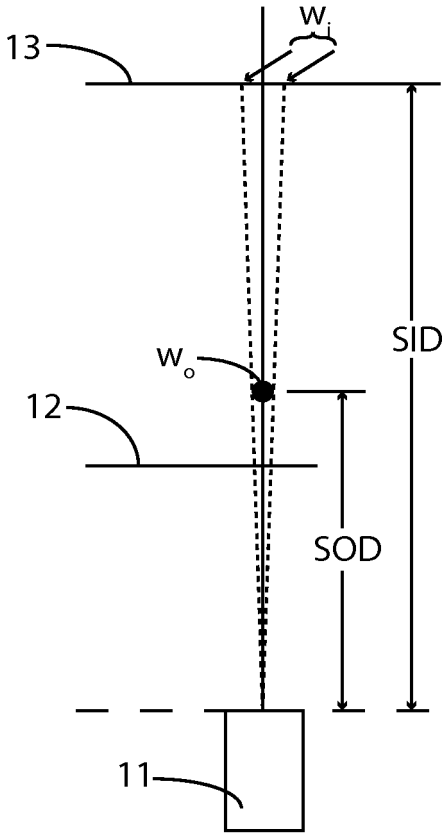


FIG. 3B

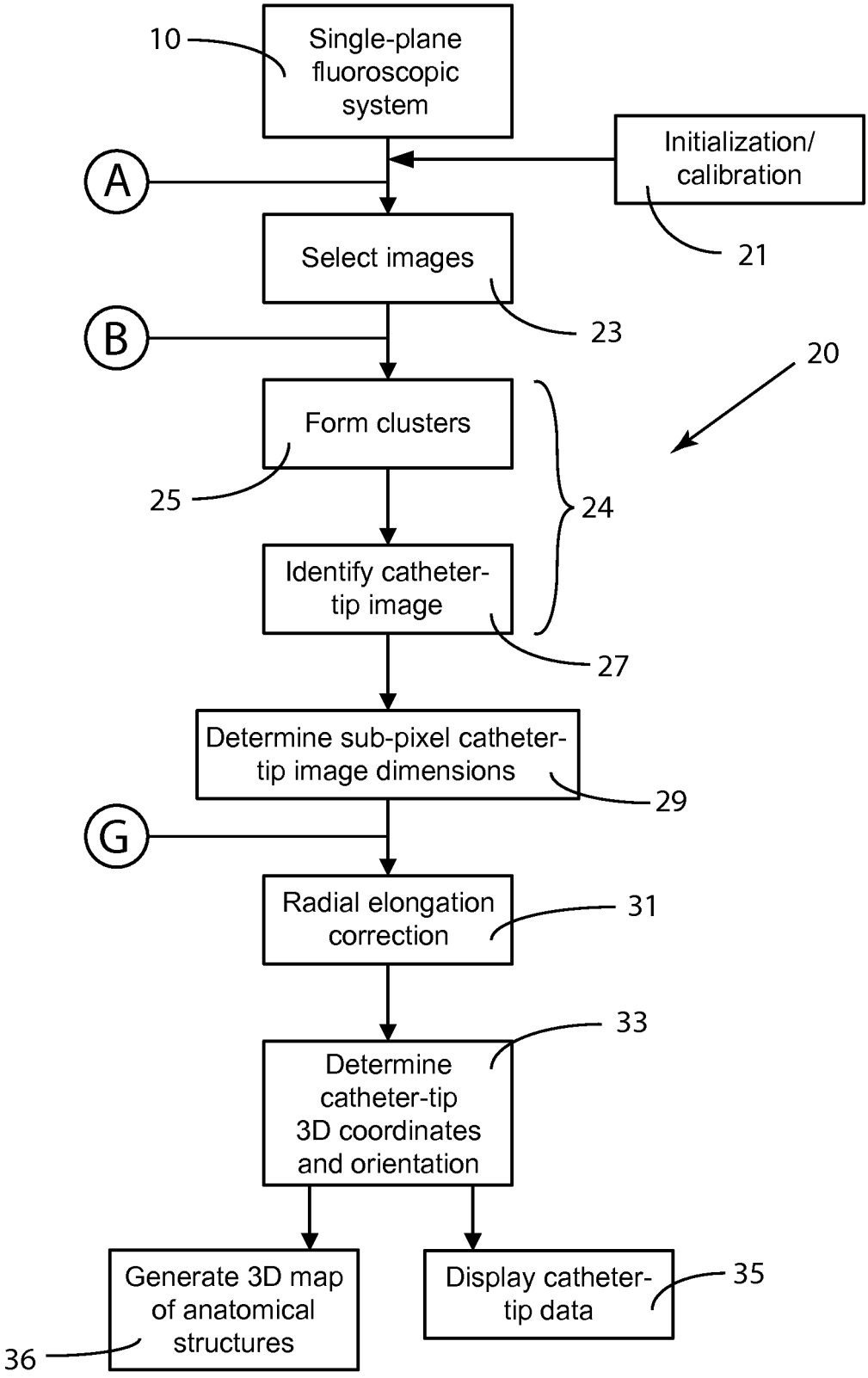

10
Single-plane fluoroscopic system
Initialization/ calibration
21
A
Select images
23
B
20
Form clusters
25
24
Identify catheter-tip image
27
Determine sub-pixel catheter-tip image dimensions
29
G
Radial elongation correction
31
33
Determine catheter-tip 3D coordinates and orientation
Generate 3D map of anatomical structures
36
Display catheter-tip data
35

FIG. 4

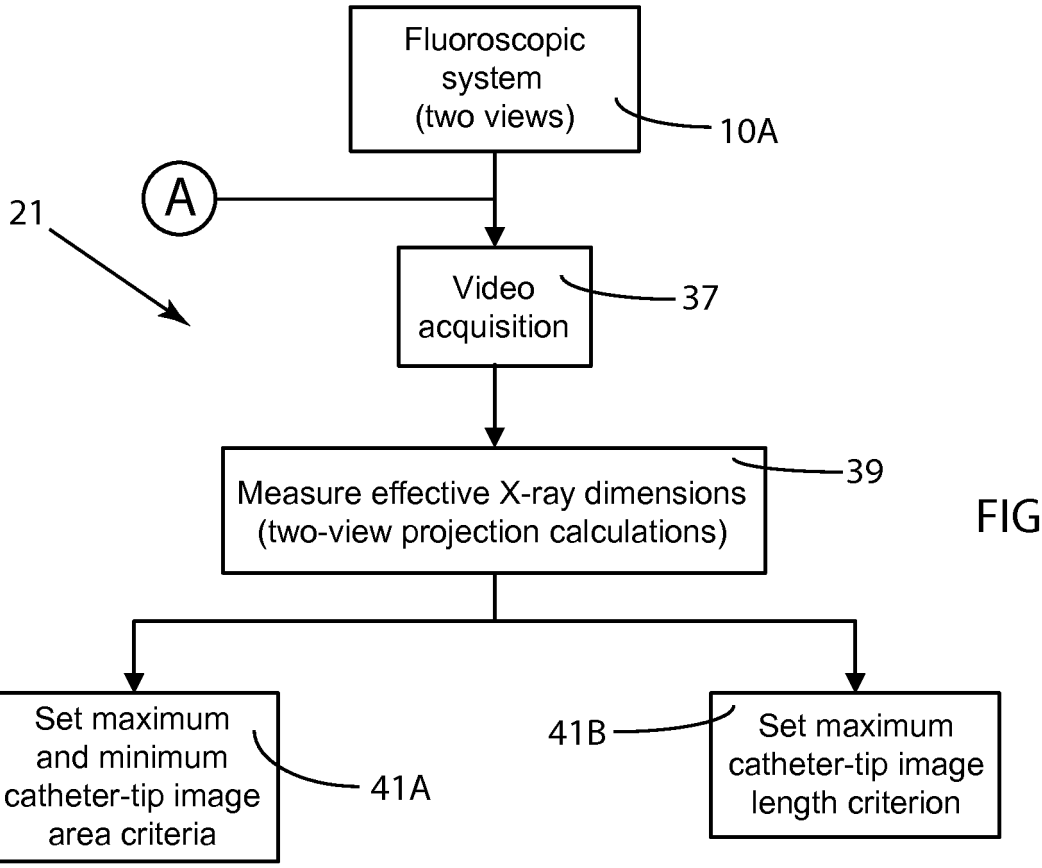

Fluoroscopic system (two views)
10A
A
21
Video acquisition
37
Measure effective X-ray dimensions (two-view projection calculations)
39
Set maximum and minimum catheter-tip image area criteria
41A
41B
Set maximum catheter-tip image length criterion

FIG. 5

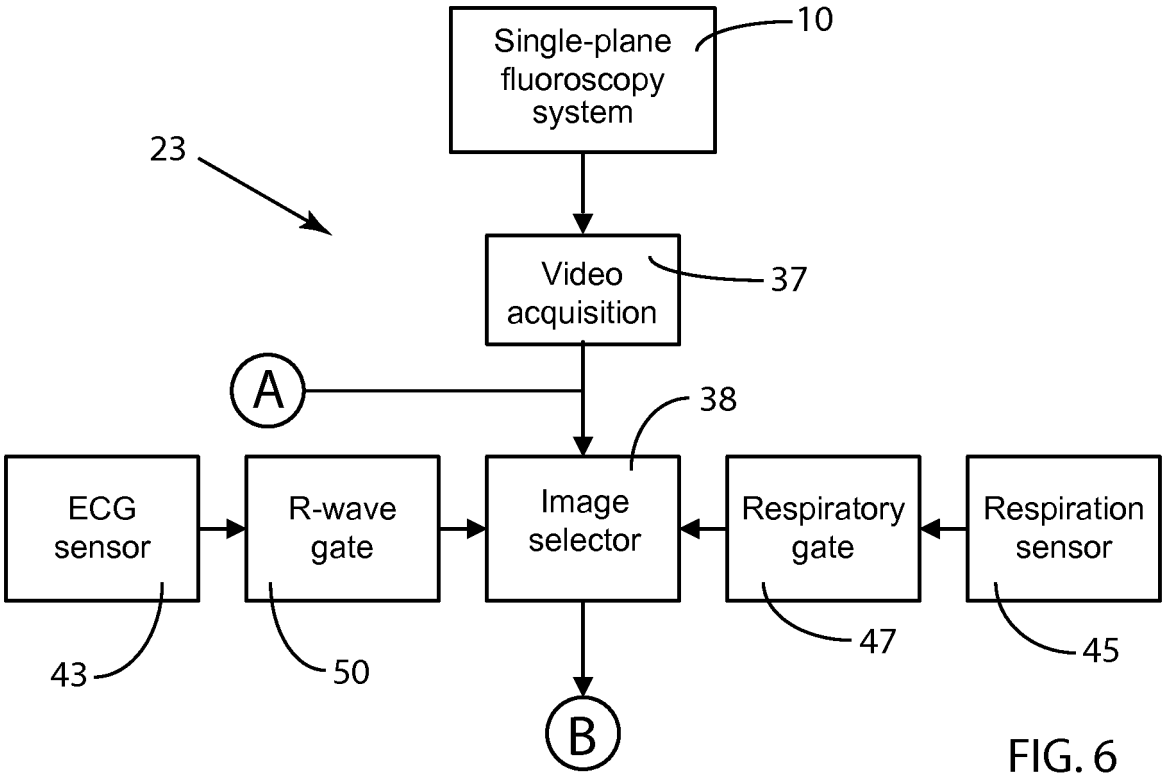

Single-plane fluoroscopy system
10
23
Video acquisition
37
A
38
ECG sensor
R-wave gate
Image selector
Respiratory gate
Respiration sensor
43
50
47
45
B

FIG. 6

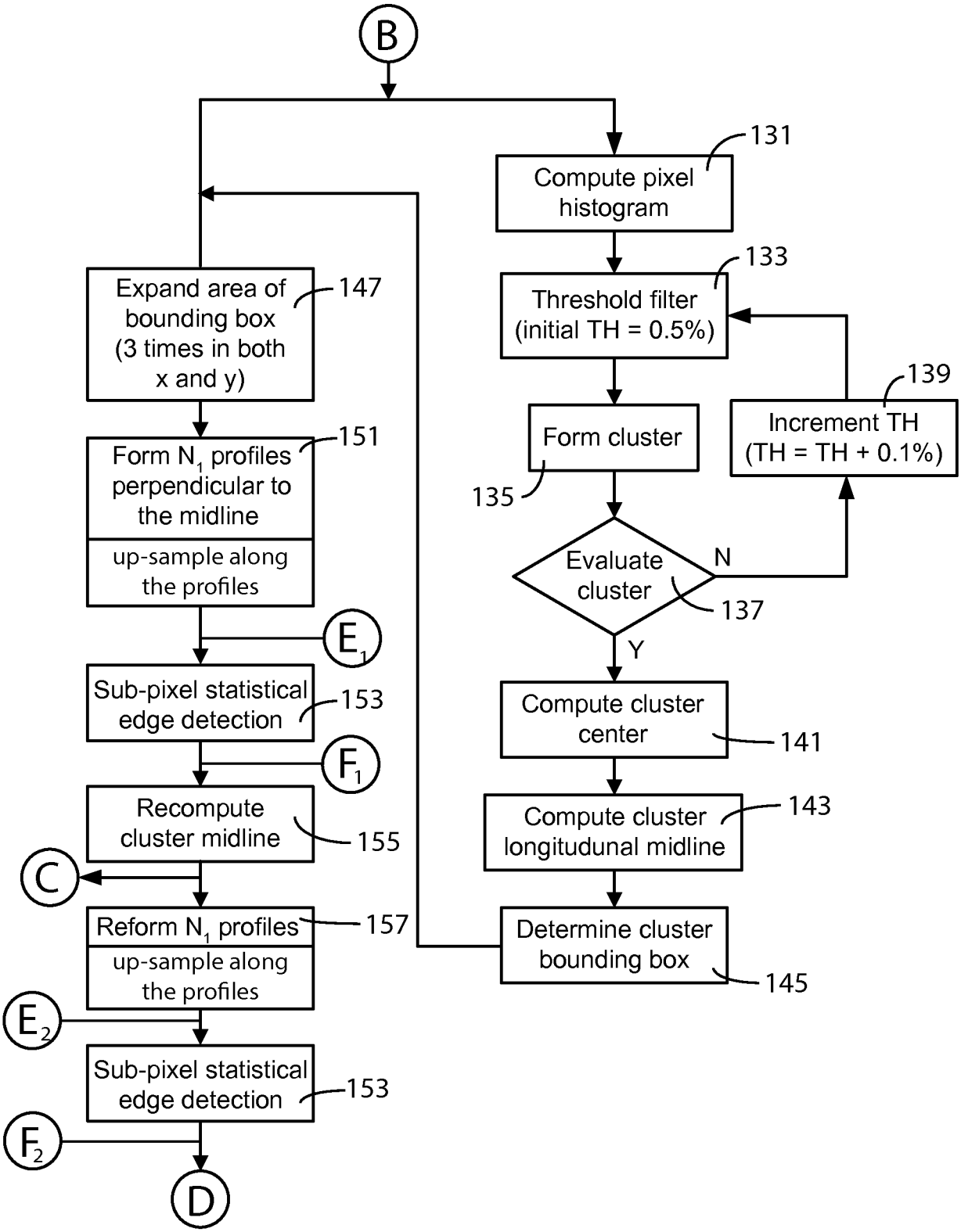

B
Compute pixel histogram
131
Threshold filter (initial TH = 0.5%)
133
Form cluster
135
Evaluate cluster
137
N
Y
Increment TH (TH = TH + 0.1%)
139
Compute cluster center
141
Compute cluster longitudunal midline
143
Determine cluster bounding box
145
Expand area of bounding box (3 times in both x and y)
147
Form N1 profiles perpendicular to the midline
up-sample along the profiles
151
E1
Sub-pixel statistical edge detection
153
F1
Recompute cluster midline
155
C
Reform N1 profiles
up-sample along the profiles
157
E2
Sub-pixel statistical edge detection
153
F2
D

FIG. 7

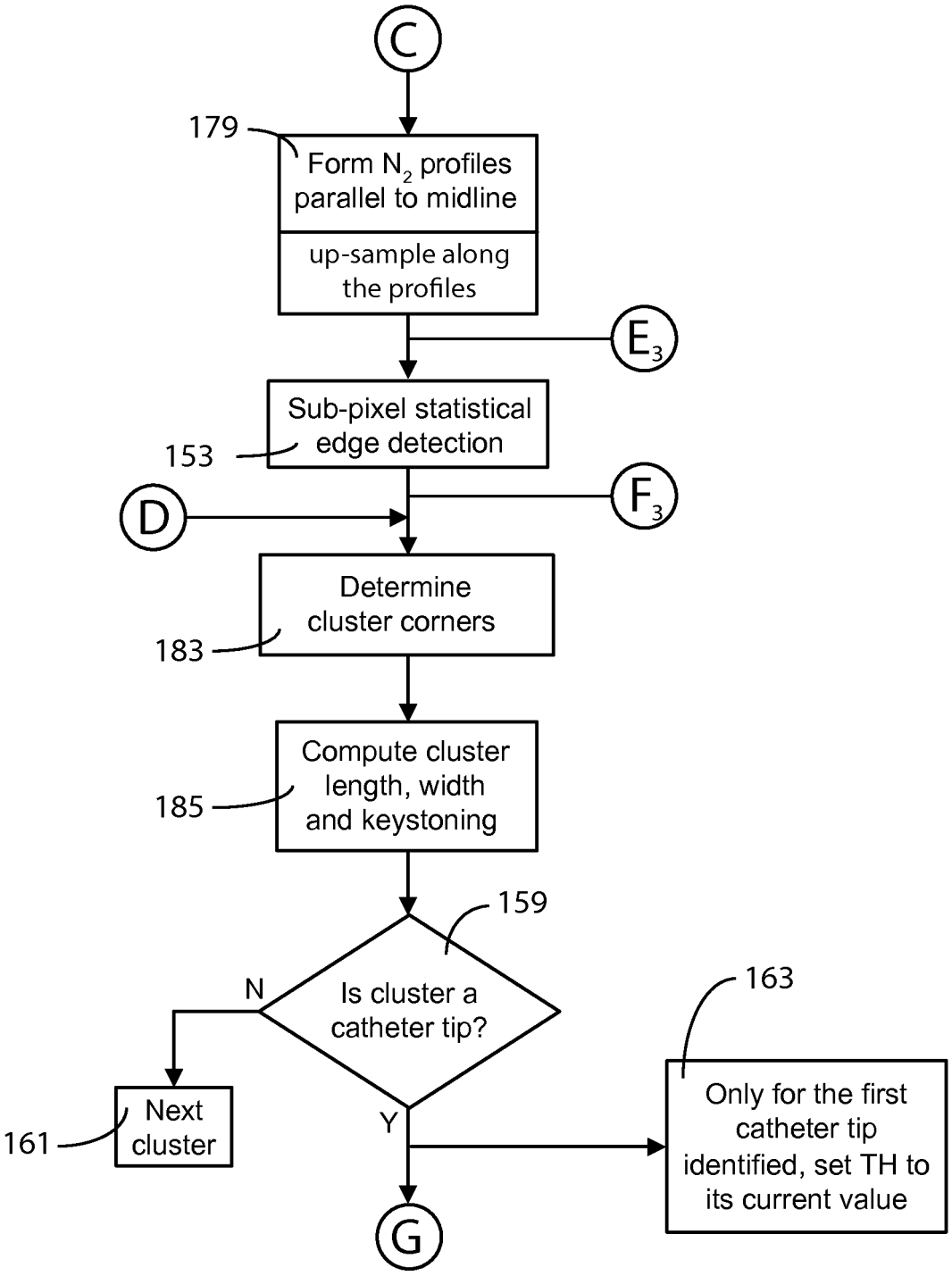

C
179
Form N_2 profiles parallel to midline
up-sample along the profiles
E_3
Sub-pixel statistical edge detection
153
D
F_3
Determine cluster corners
183
Compute cluster length, width and keystoning
185
159
Is cluster a catheter tip?
N
Y
Next cluster
161
163
Only for the first catheter tip identified, set TH to its current value
G

FIG. 8

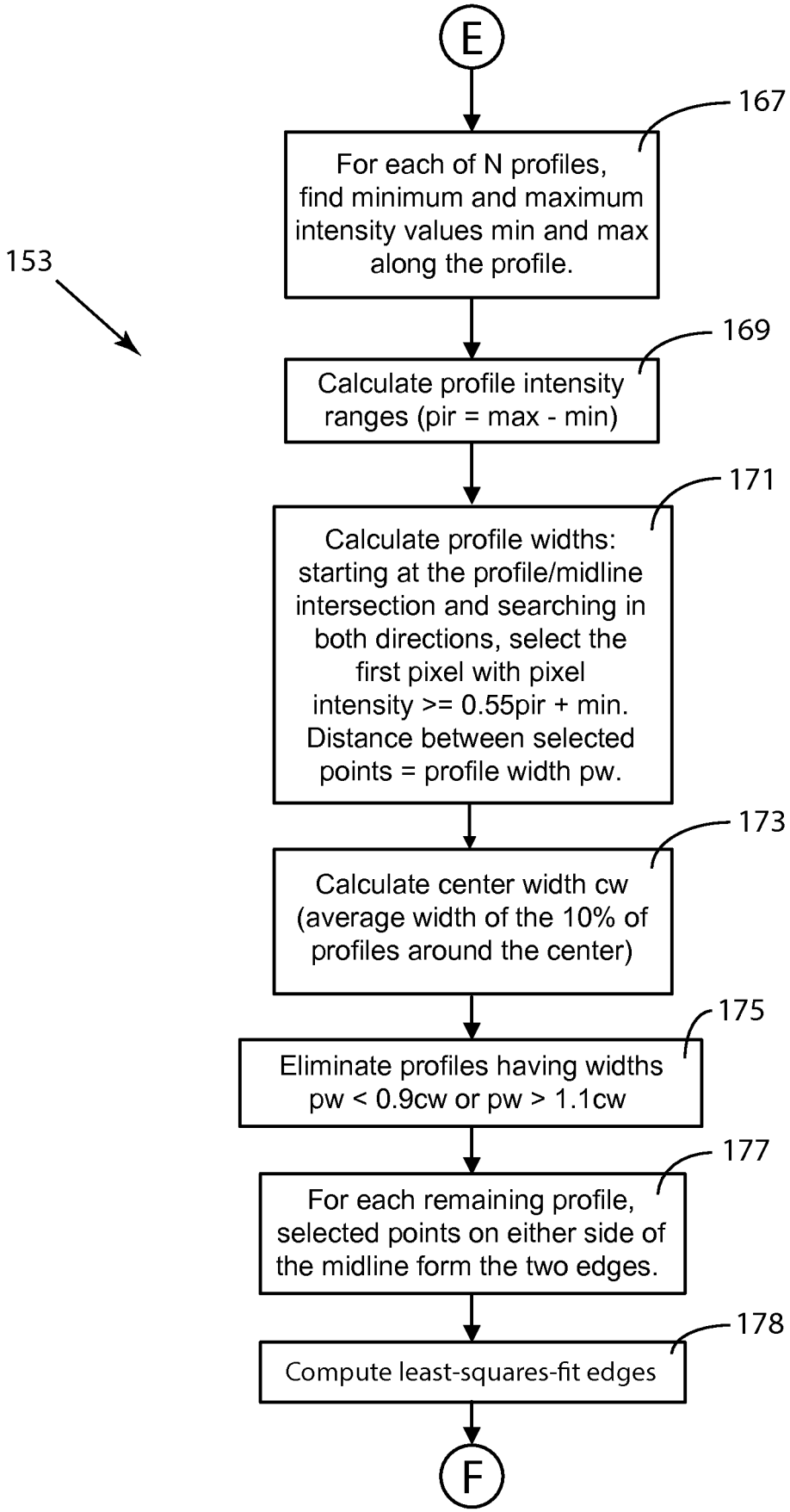

E
167
For each of N profiles, find minimum and maximum intensity values min and max along the profile.
153
169
Calculate profile intensity ranges (pir = max - min)
171
Calculate profile widths: starting at the profile/midline intersection and searching in both directions, select the first pixel with pixel intensity >= 0.55pir + min. Distance between selected points = profile width pw.
173
Calculate center width cw (average width of the 10% of profiles around the center)
175
Eliminate profiles having widths pw < 0.9cw or pw > 1.1cw
177
For each remaining profile, selected points on either side of the midline form the two edges.
178
Compute least-squares-fit edges
F

FIG. 9

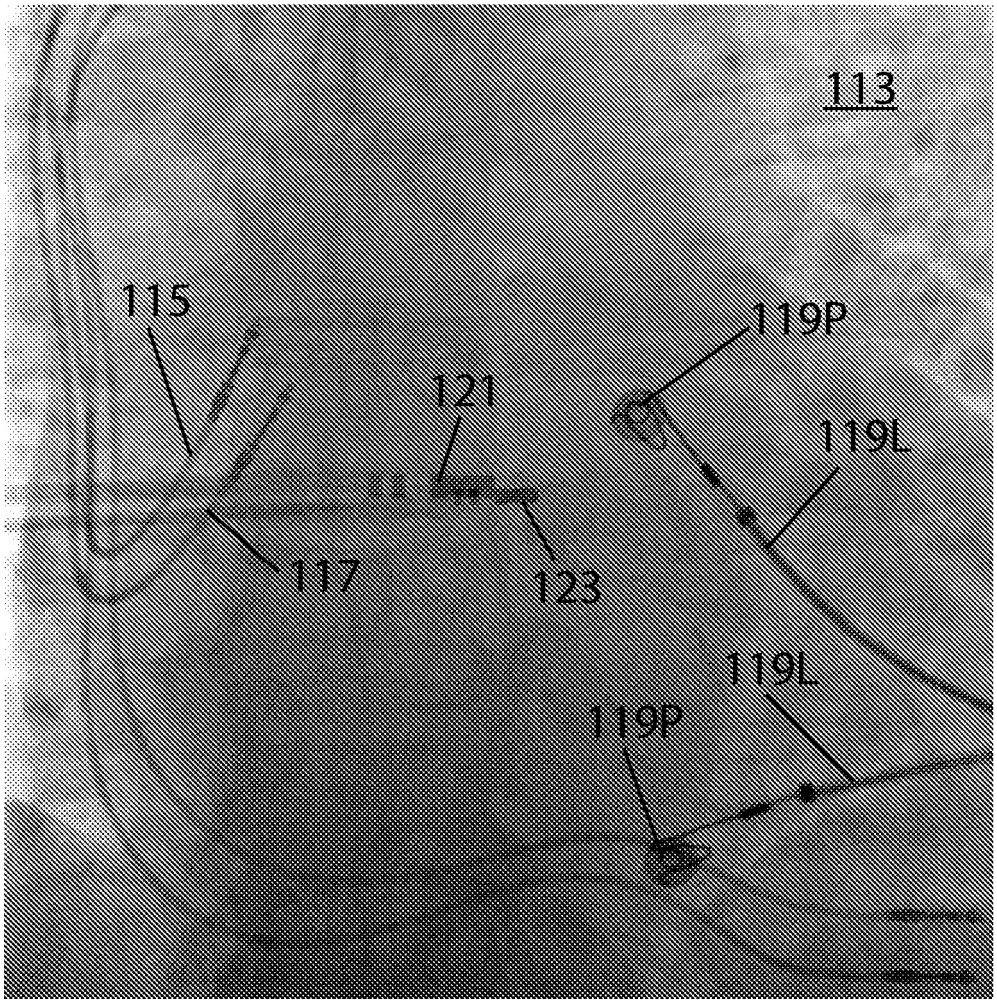


FIG. 10

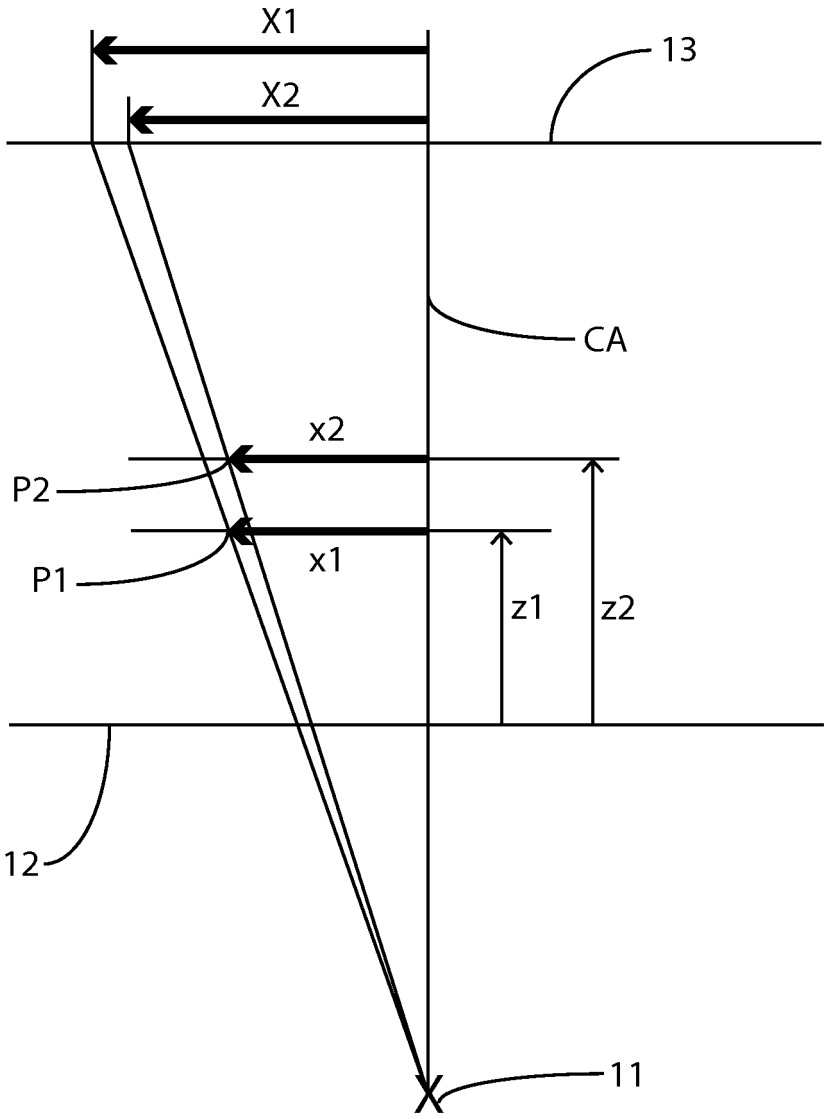


FIG. 11

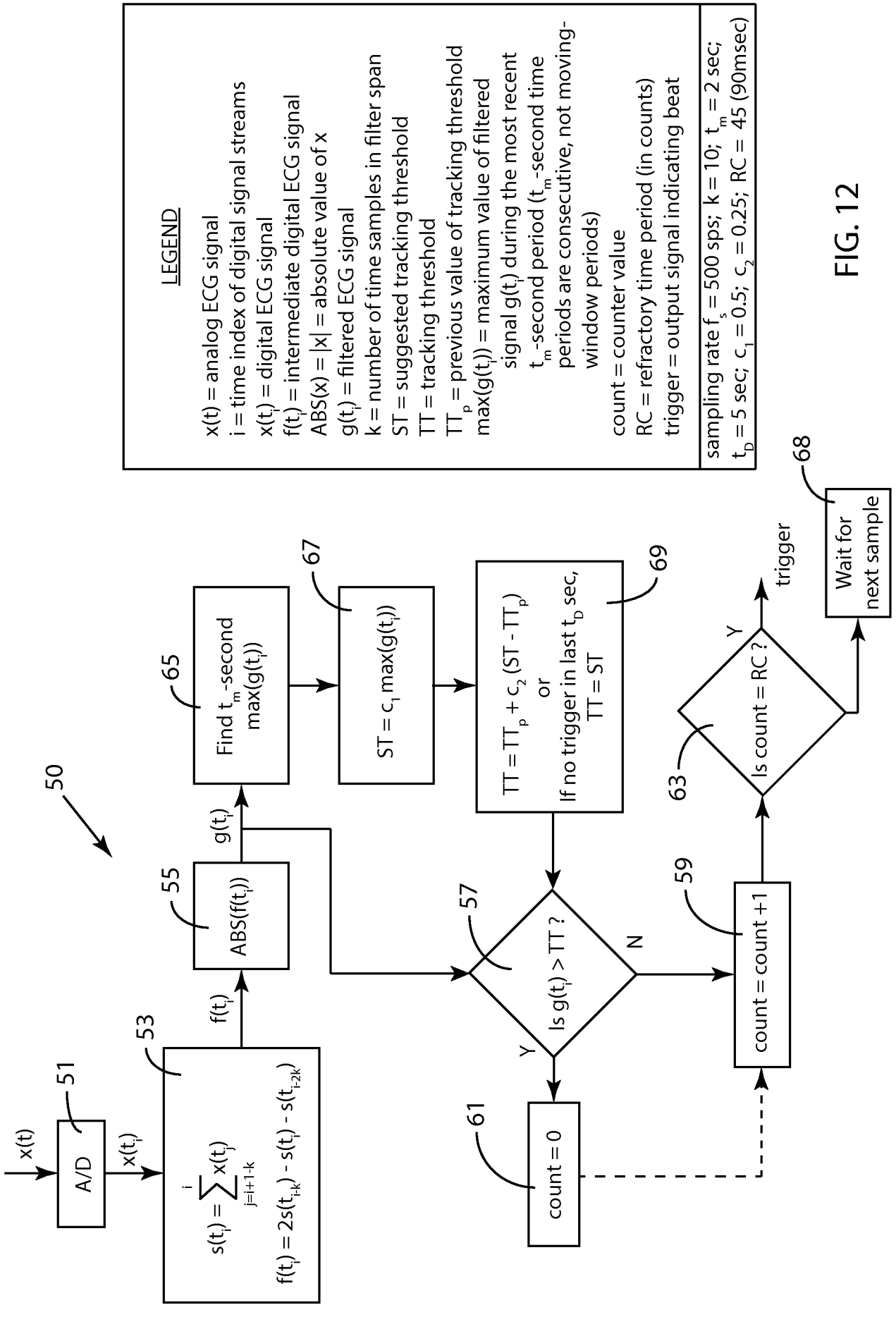

LEGEND
x(t) = analog ECG signal
i = time index of digital signal streams
x(t_i) = digital ECG signal
f(t_i) = intermediate digital ECG signal
ABS(x) = |x| = absolute value of x
g(t_i) = filtered ECG signal
k = number of time samples in filter span
ST = suggested tracking threshold
TT = tracking threshold
TT_p = previous value of tracking threshold
max(g(t_i)) = maximum value of filtered signal g(t_i) during the most recent t_m-second period (t_m-second time periods are consecutive, not moving-window periods)
count = counter value
RC = refractory time period (in counts)
trigger = output signal indicating beat
sampling rate f_s = 500 sps; k = 10; t_m = 2 sec; t_D = 5 sec; c_1 = 0.5; c_2 = 0.25; RC = 45 (90msec)
50
x(t)
A/D
51
x(t_i)
53
s(t_i) = Σ x(t_j), j=i+1-k
f(t_i) = 2s(t_i-k) - s(t_i) - s(t_i-2k)
f(t_i)
ABS(f(t_i))
55
g(t_i)
Find t_m-second max(g(t_i))
65
ST = c_1 max(g(t_i))
67
TT = TT_p + c_2 (ST - TT_p) or If no trigger in last t_D sec, TT = ST
69
Is g(t_i) > TT ?
57
Y
N
count = 0
61
count = count +1
59
Is count = RC ?
63
Y
trigger
Wait for next sample
68

FIG. 12

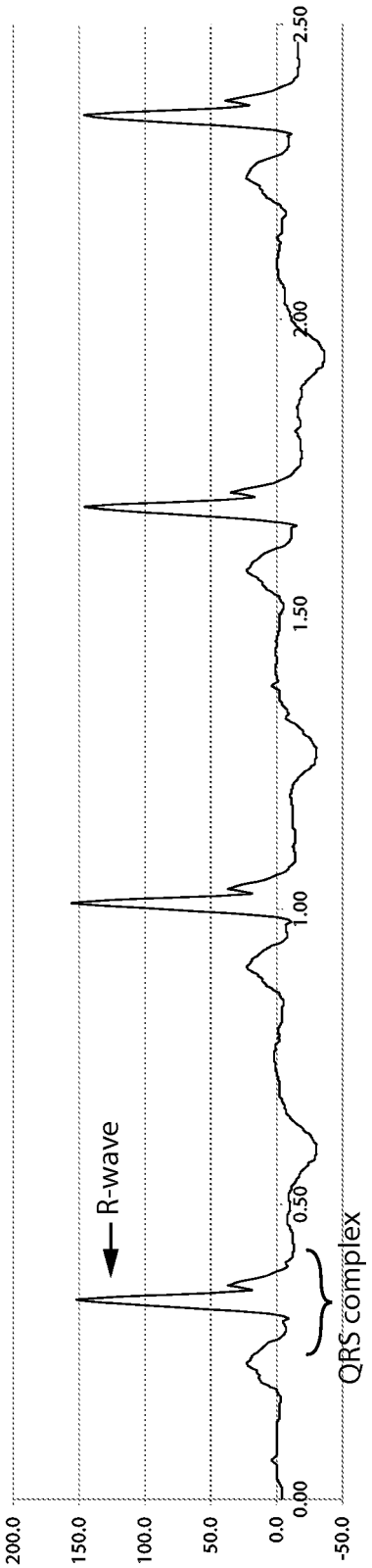


FIG. 13A

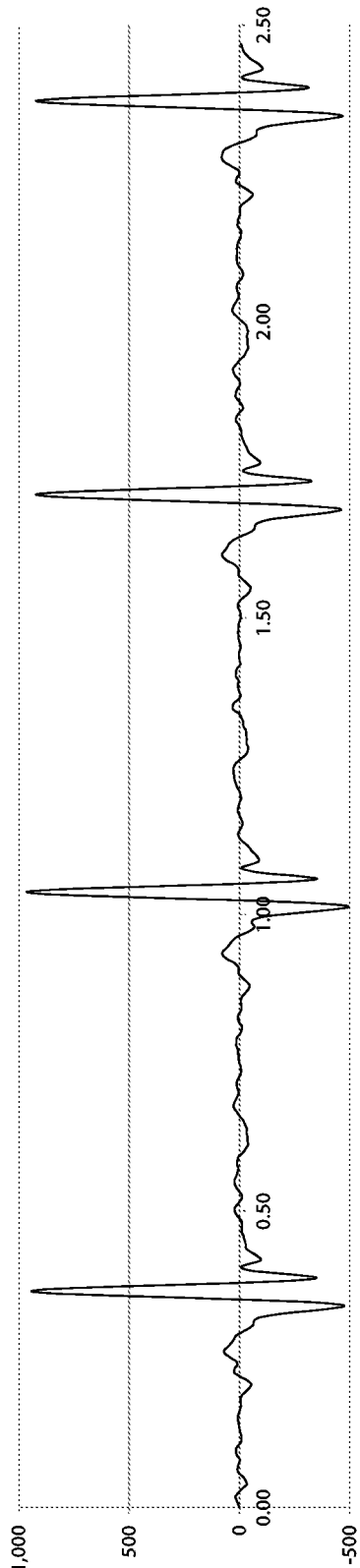


FIG. 13B

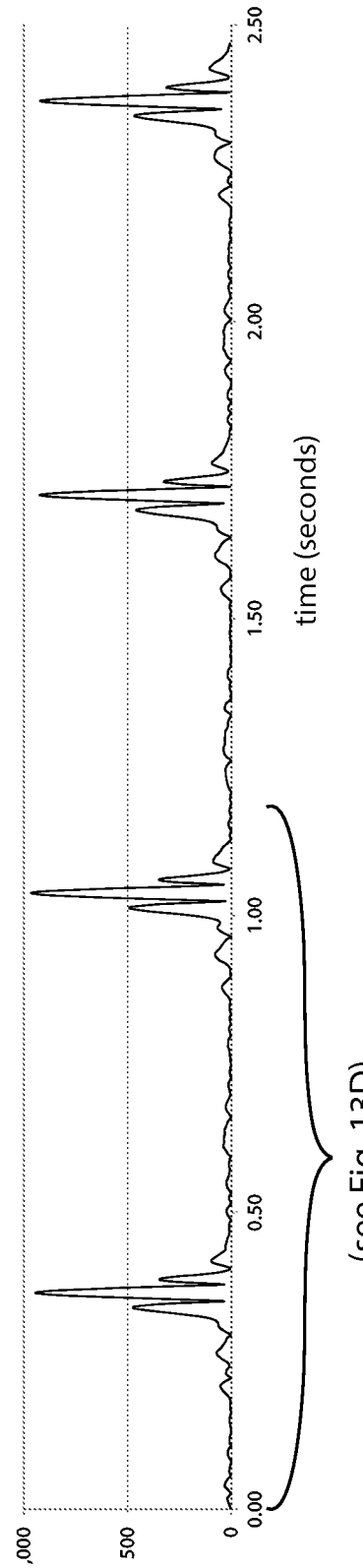


FIG. 13C

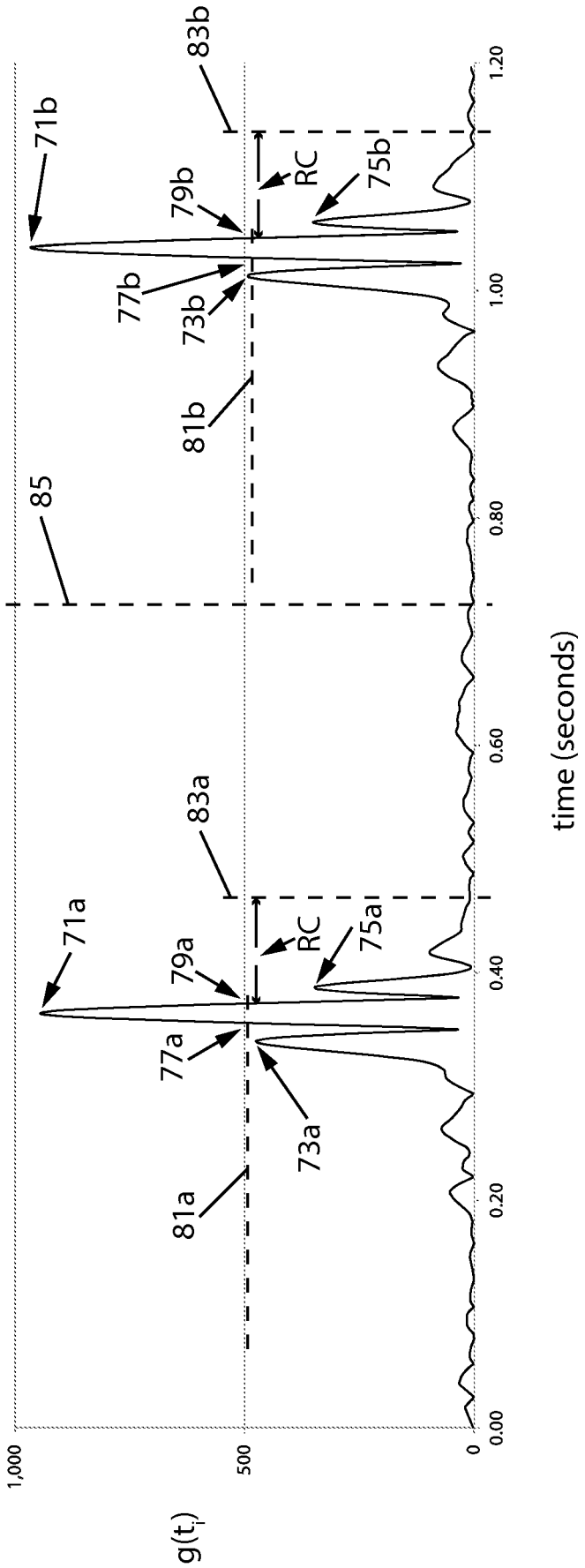

83b
71b
RC
75b
79b
77b
73b
81b
85
83a
71a
RC
75a
79a
77a
73a
81a
1,000
500
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
time (seconds)
g(t_i)

FIG. 13D

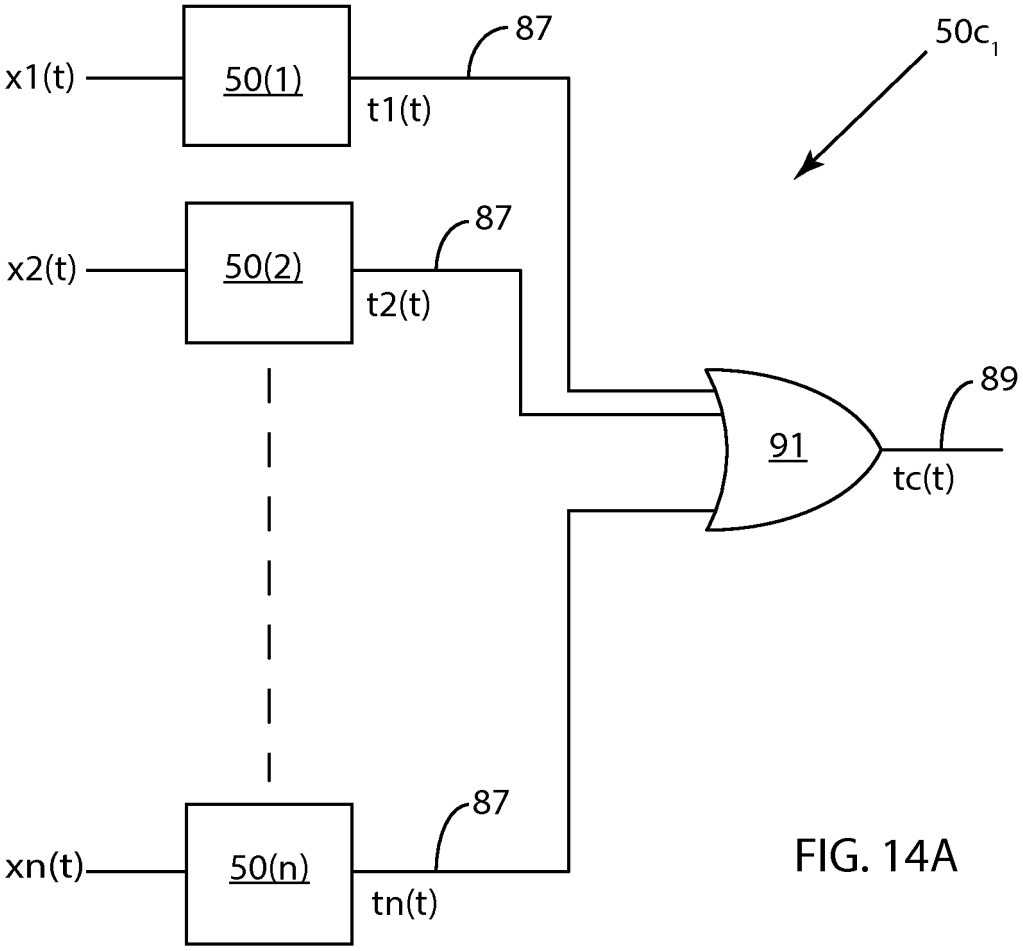


FIG. 14A

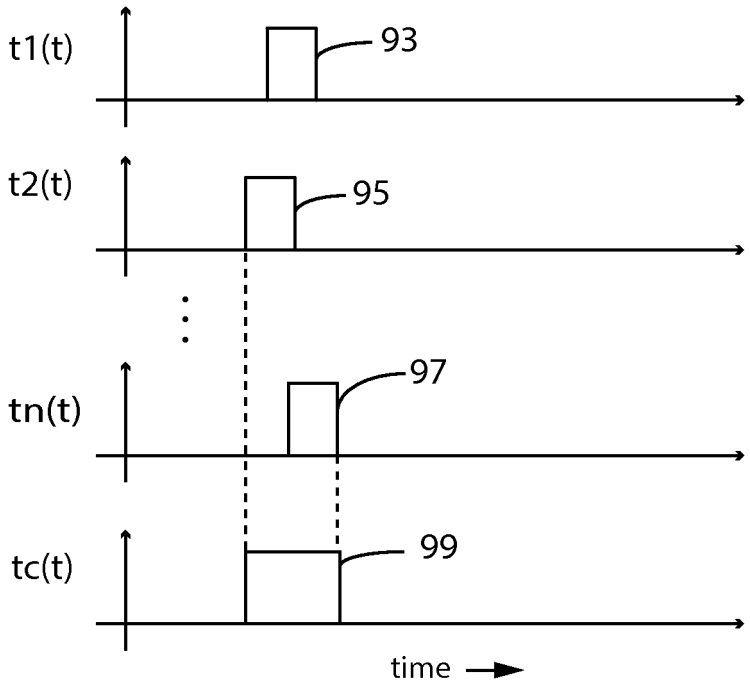


FIG. 14B

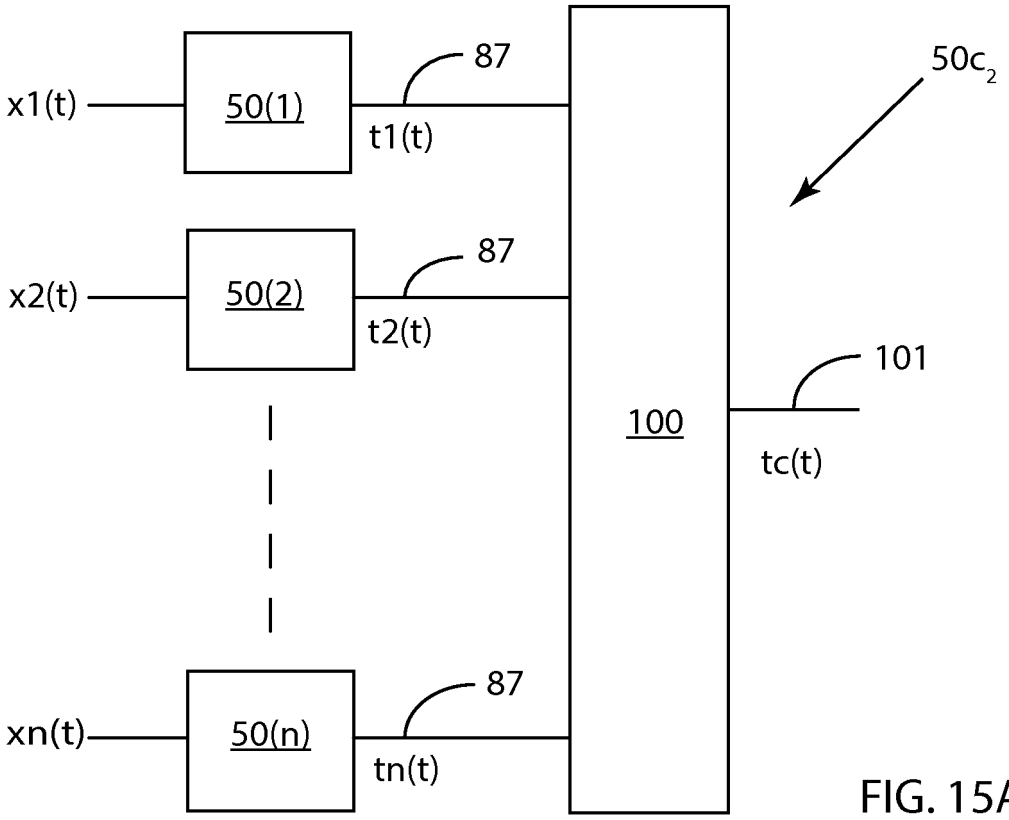


FIG. 15A

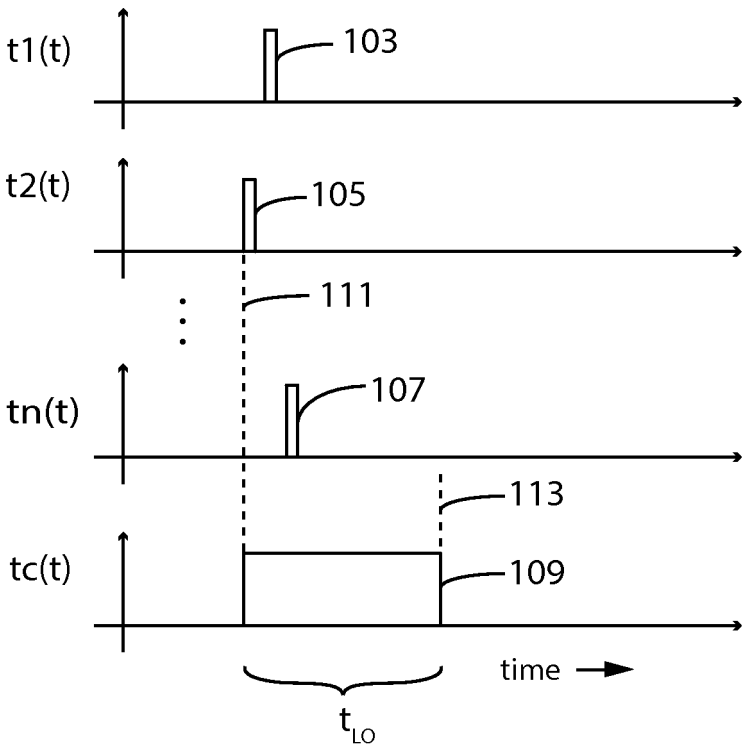


FIG. 15B

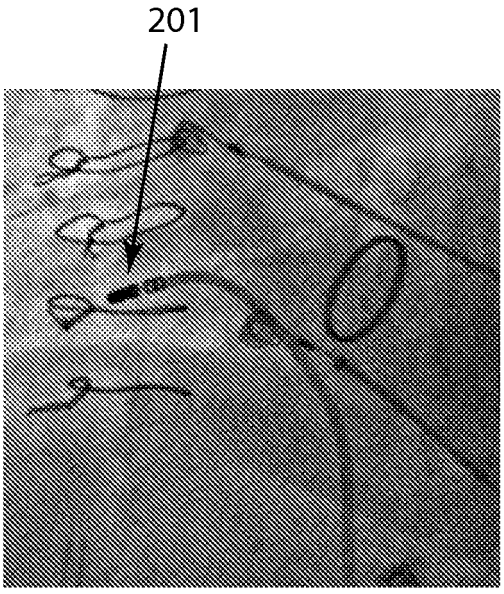


FIG. 16A

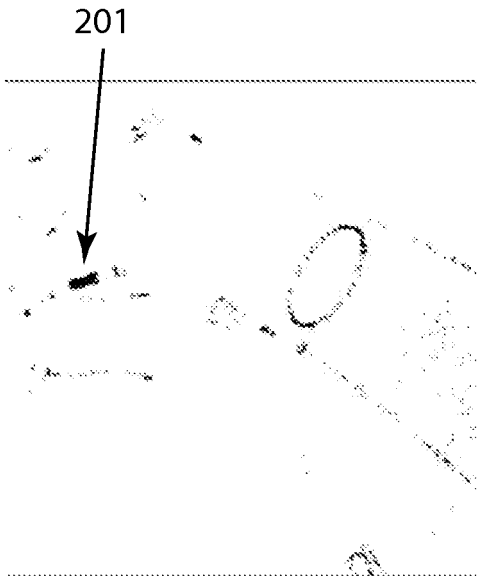


FIG. 16B

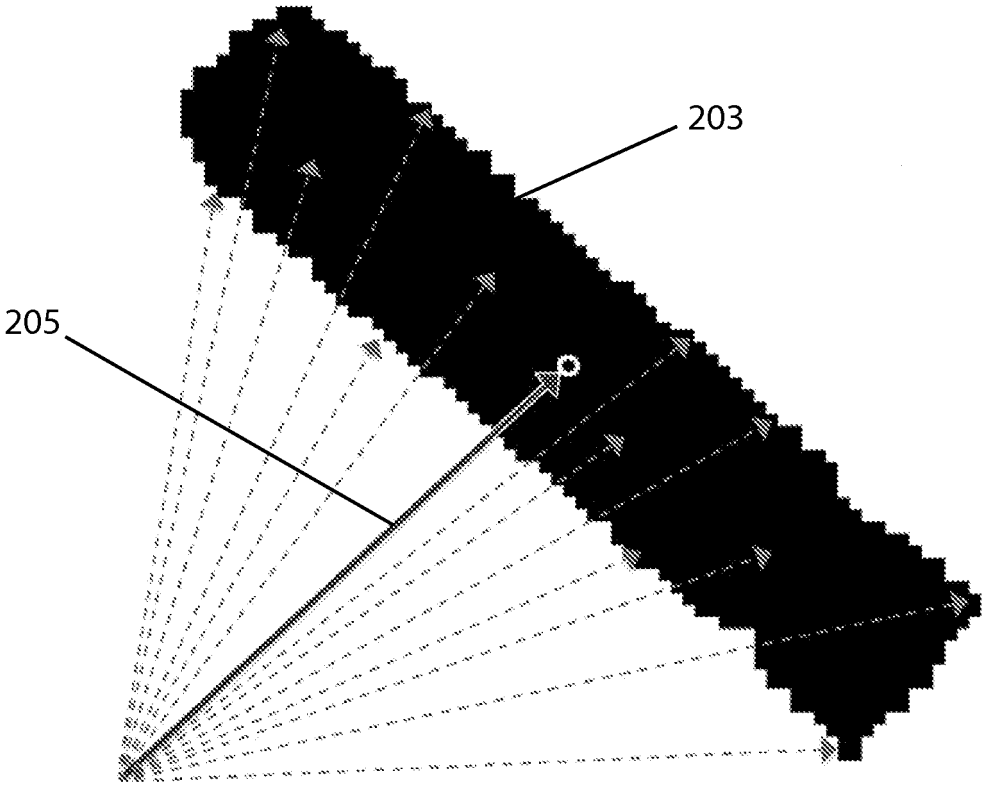


FIG. 17

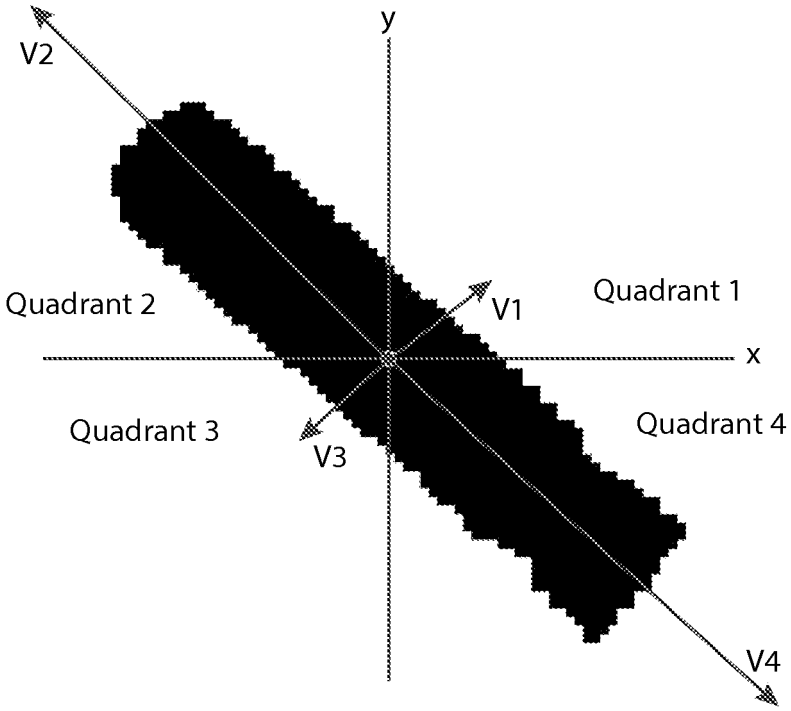


FIG. 18

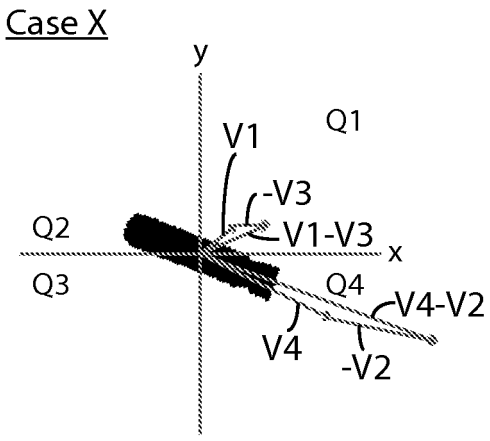


FIG. 19A

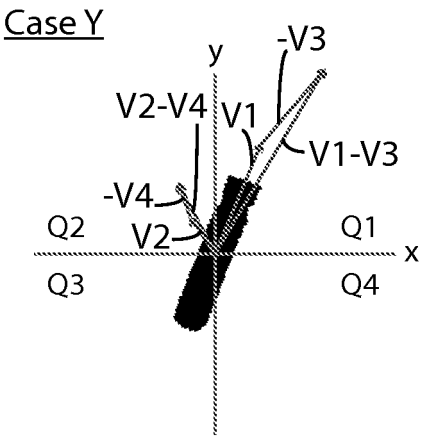


FIG. 19B

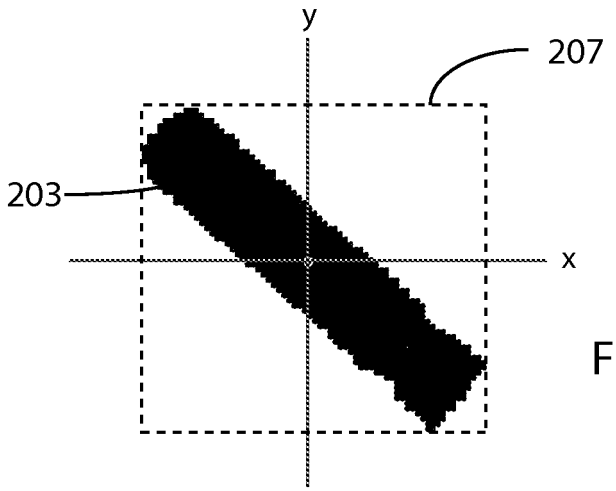


FIG. 20

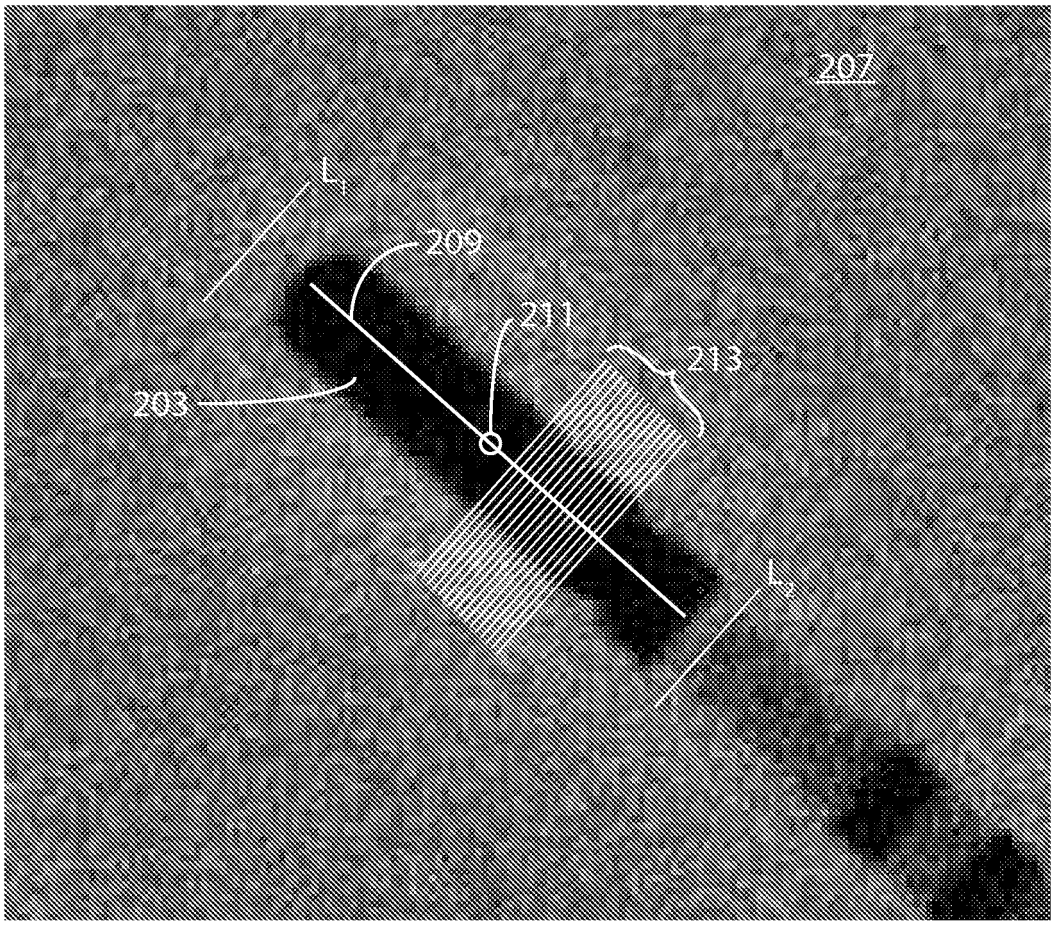


FIG. 21

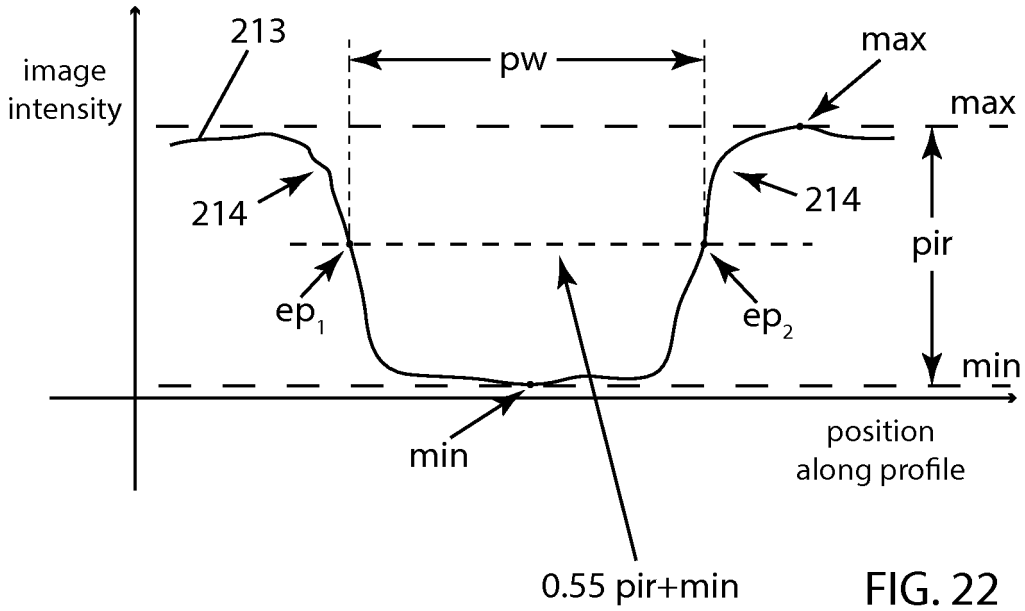


FIG. 22

	x_1	x	x_2
y_1	Q_{11}		Q_{21}
y		P	
y_2	Q_{12}		Q_{22}

$$P = \frac{(x_2 - x)(y_2 - y)}{(x_2 - x_1)(y_2 - y_1)} Q_{11} + \frac{(x - x_1)(y_2 - y)}{(x_2 - x_1)(y_2 - y_1)} Q_{21} + \frac{(x_2 - x)(y - y_1)}{(x_2 - x_1)(y_2 - y_1)} Q_{12} + \frac{(x - x_1)(y - y_1)}{(x_2 - x_1)(y_2 - y_1)} Q_{22}$$

FIG. 23

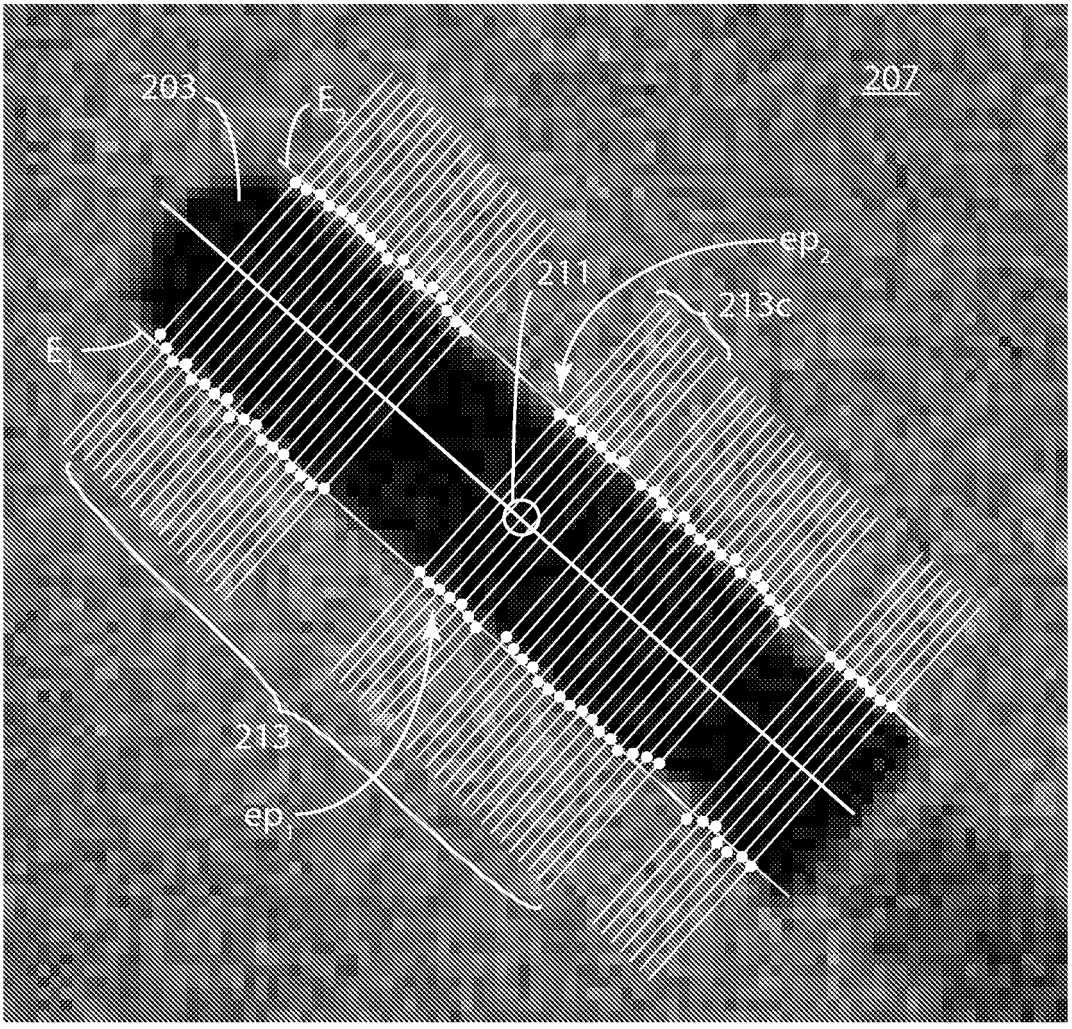


FIG. 24

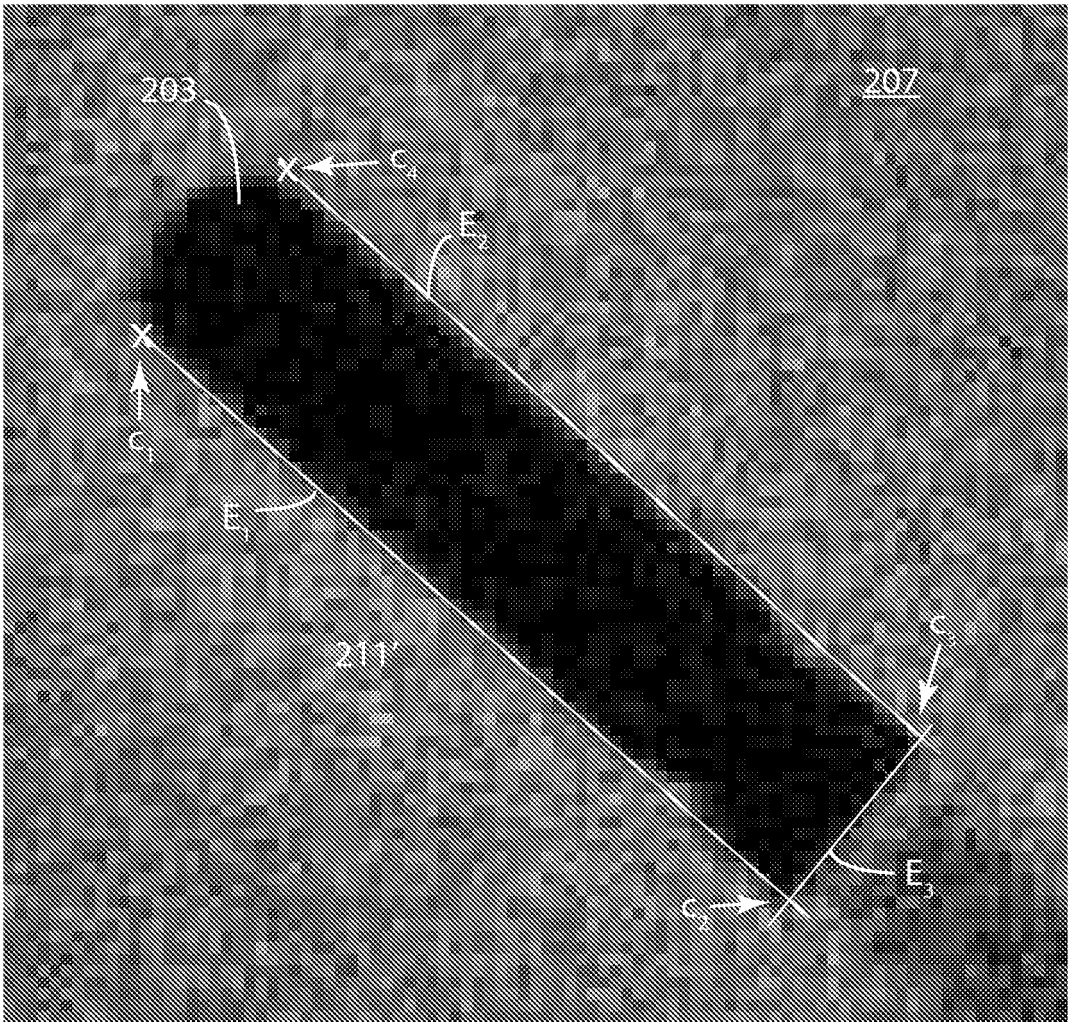


FIG. 25

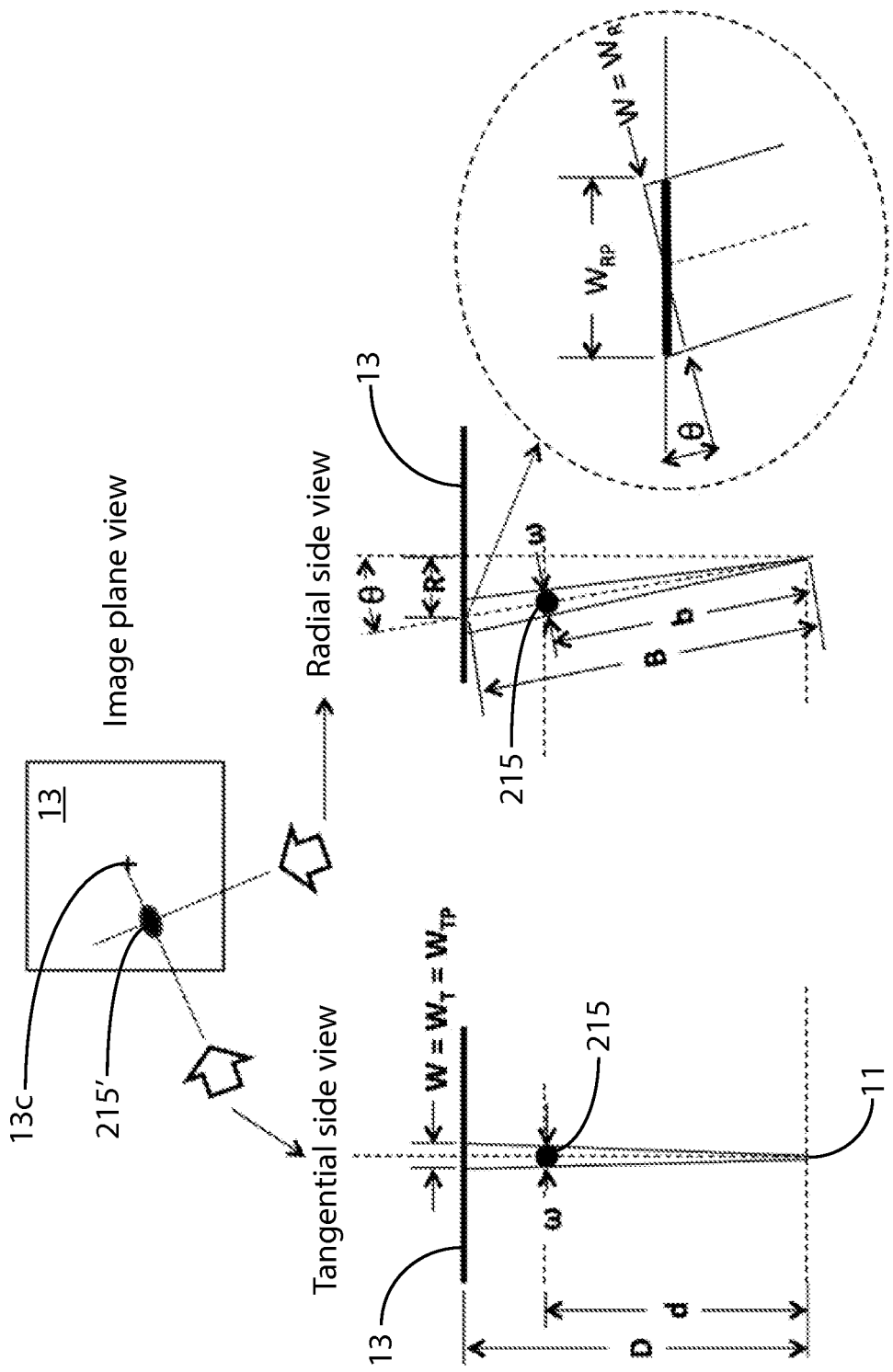

Image plane view
13
13c
215'
Radial side view
13
θ
R
ω
215
b
B
W = W_R
W_RP
θ
Tangential side view
W = W_T = W_TP
215
ω
13
D
d
11

FIG. 26A

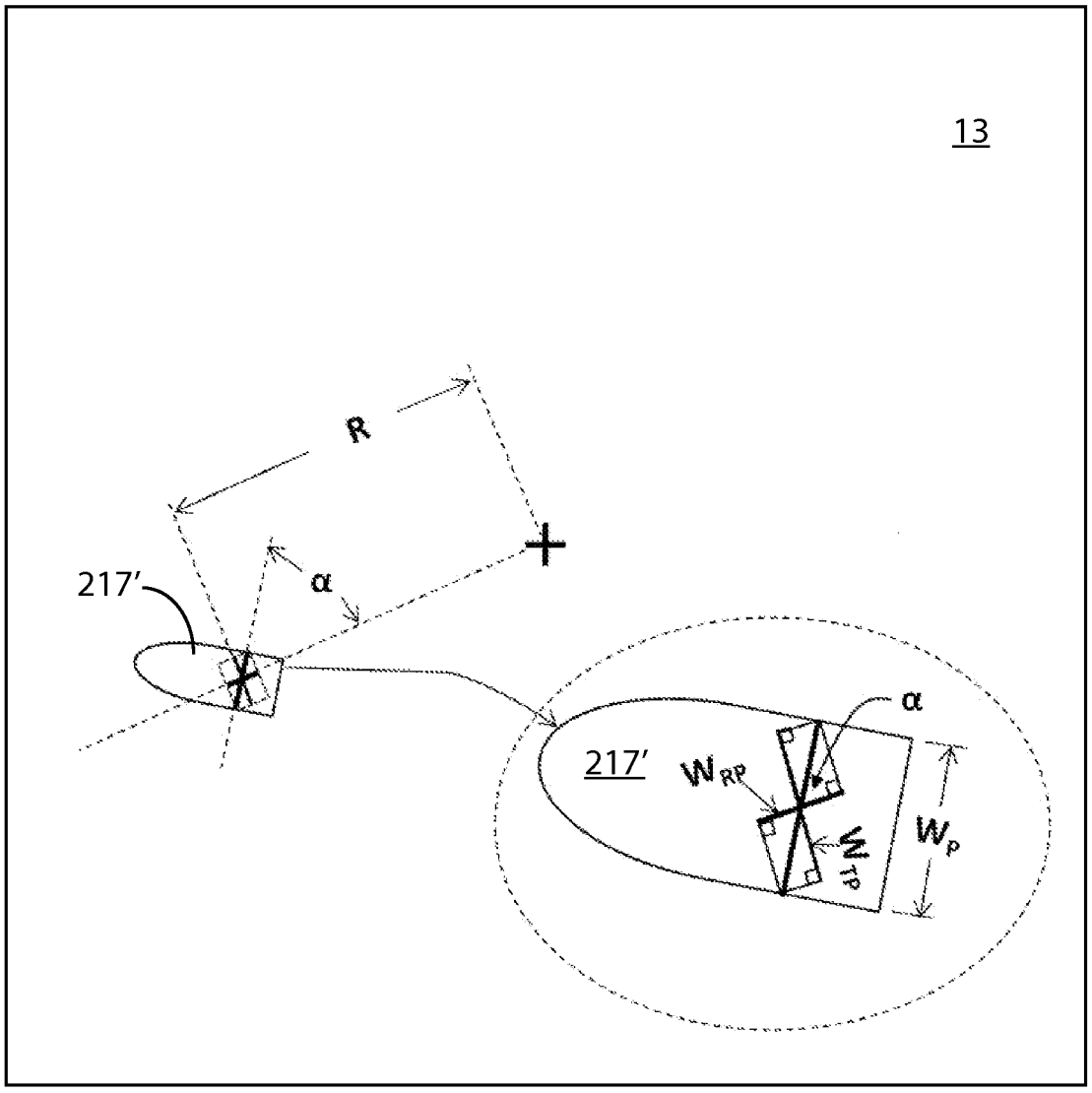


FIG. 26B

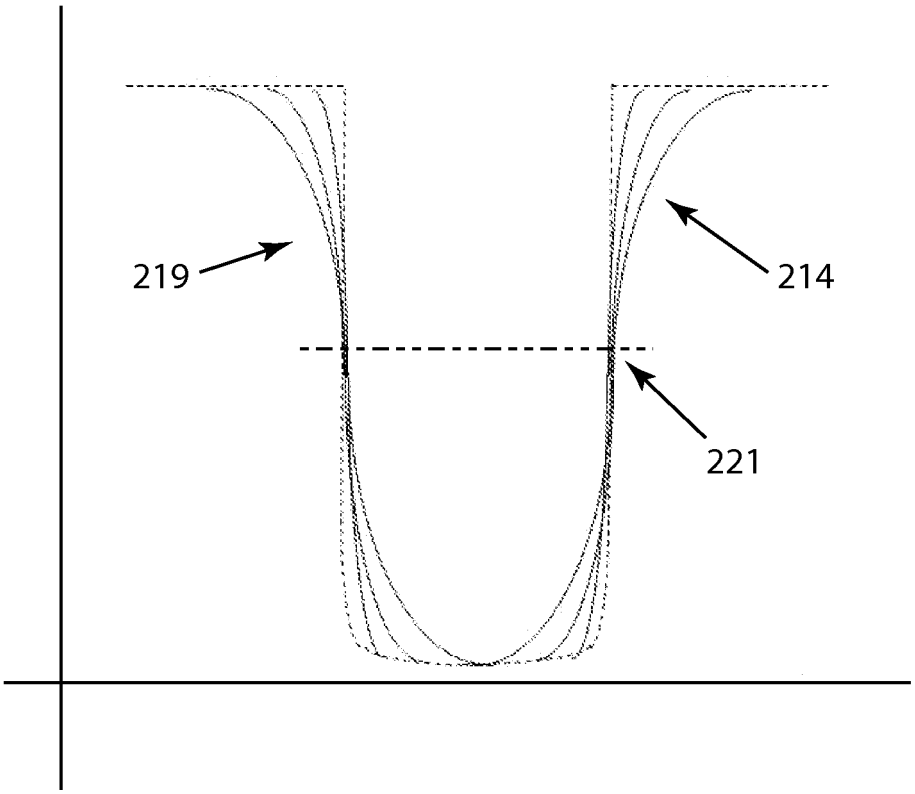


FIG. 27