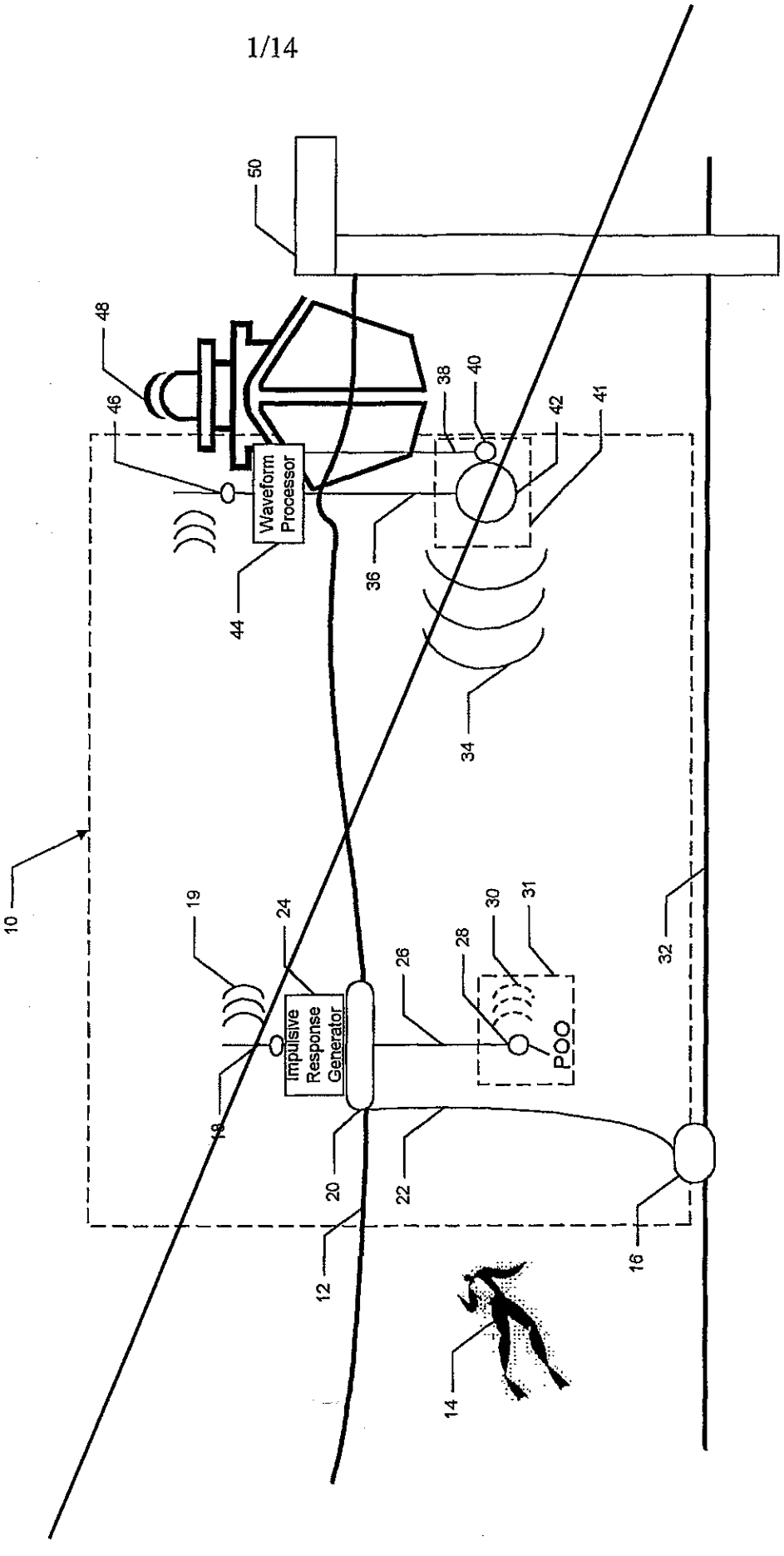

50
48
46
38
40
42
41
Waveform Processor
44
36
34
10
19
24
26
28
30
31
32
Impulsive Response Generator
POO
18
20
22
12
16
14

FIG. 1

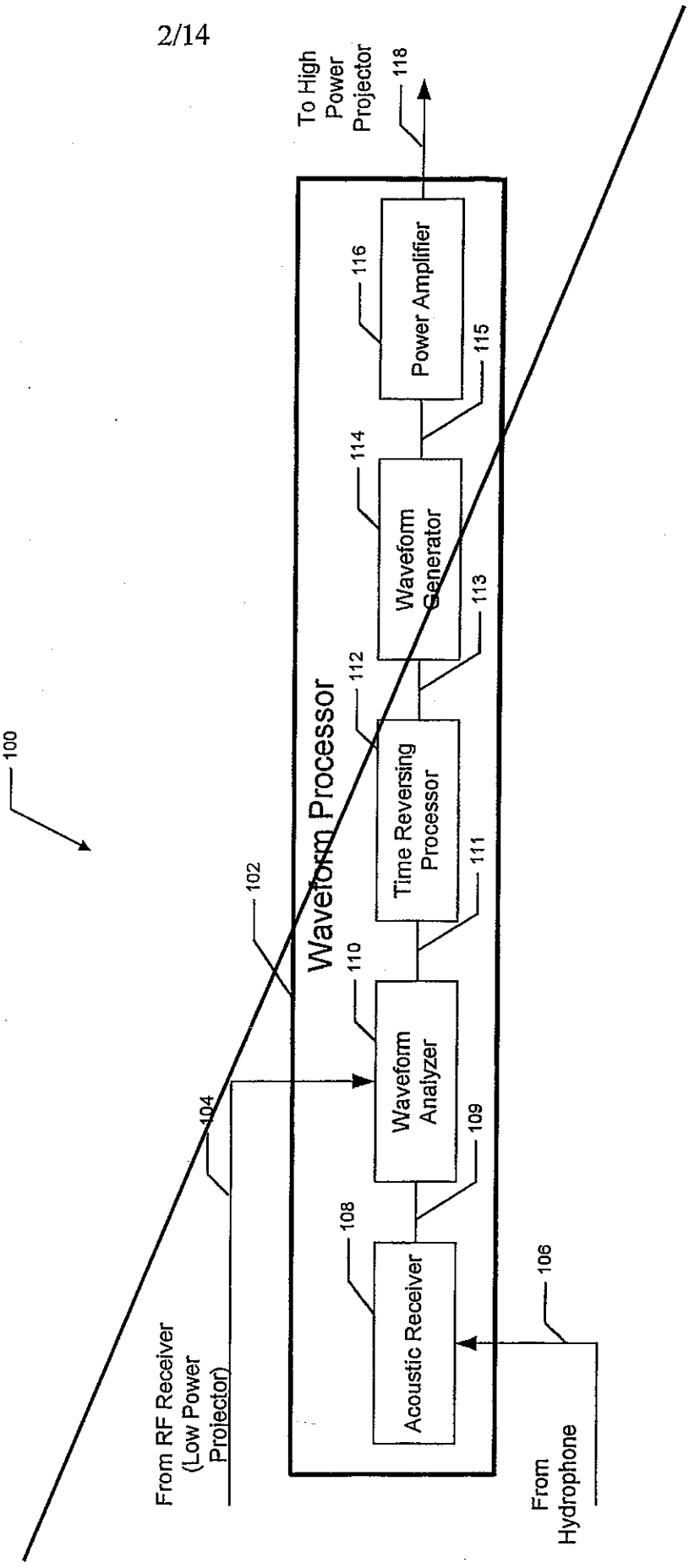

100
Waveform Processor
102
To High Power Projector
118
Power Amplifier
116
115
Waveform Generator
114
113
Time Reversing Processor
112
111
Waveform Analyzer
110
109
Acoustic Receiver
108
106
104
From RF Receiver (Low Power Projector)
From Hydrophone

FIG. 1A

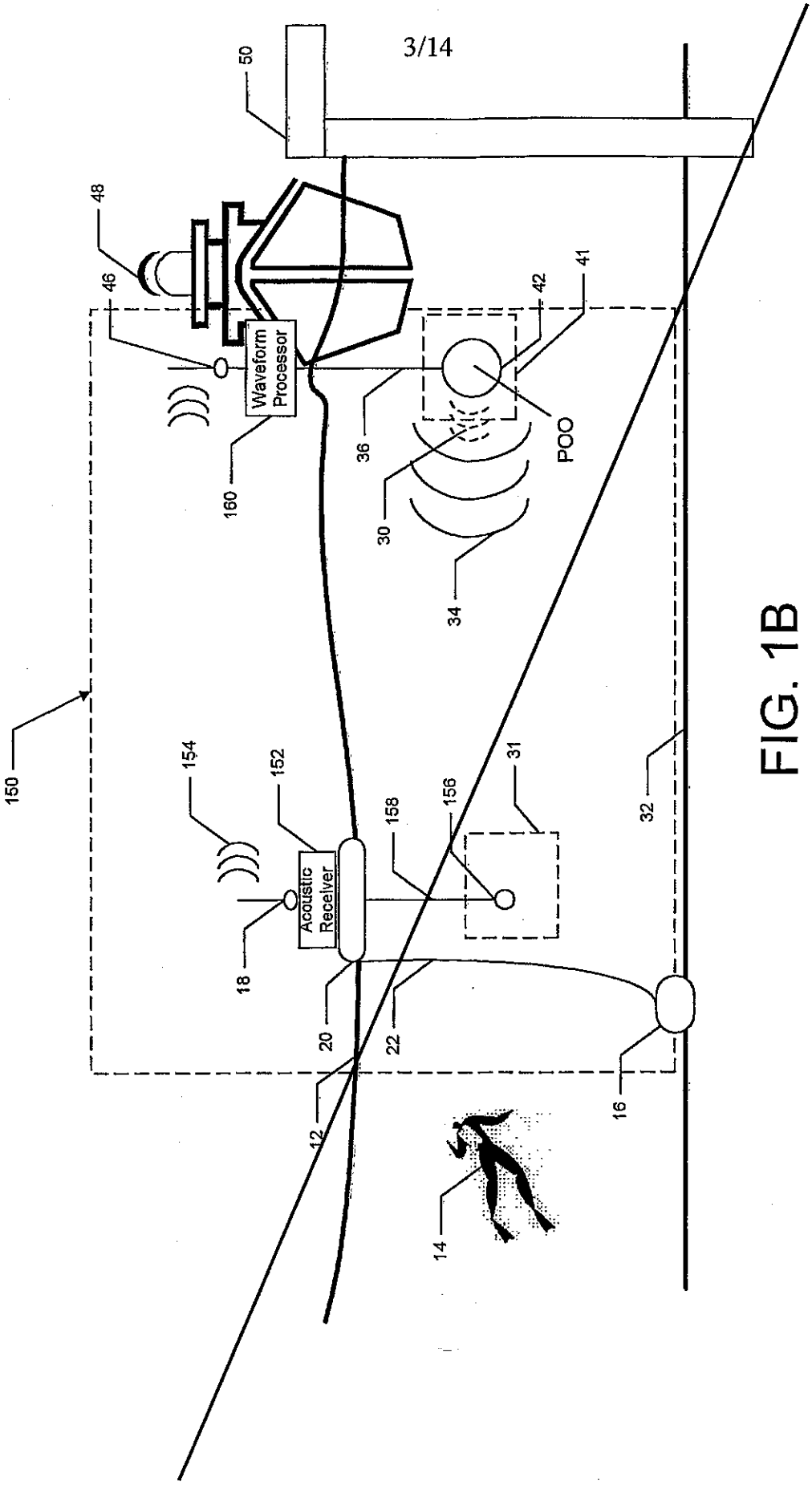

50
48
46
Waveform Processor
160
36
30
34
42
41
POO
150
154
152
Acoustic Receiver
18
158
156
31
32
20
22
12
16
14

FIG. 1B

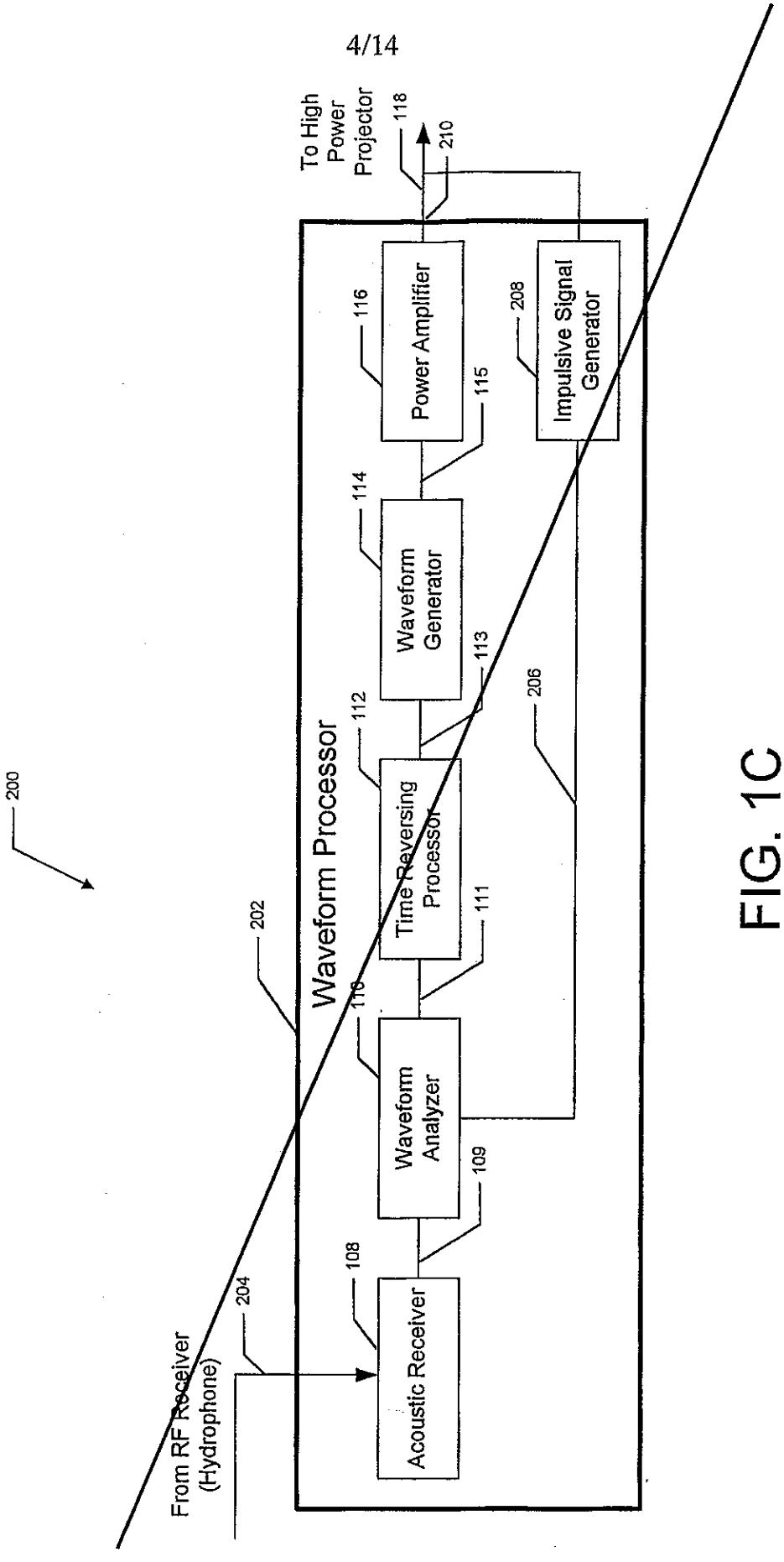

200
202
Waveform Processor
To High Power Projector
118
210
Power Amplifier
116
115
Impulsive Signal Generator
208
Waveform Generator
114
113
Time Reversing Processor
112
111
206
Waveform Analyzer
110
109
Acoustic Receiver
108
From RF Receiver (Hydrophone)
204

FIG. 1C

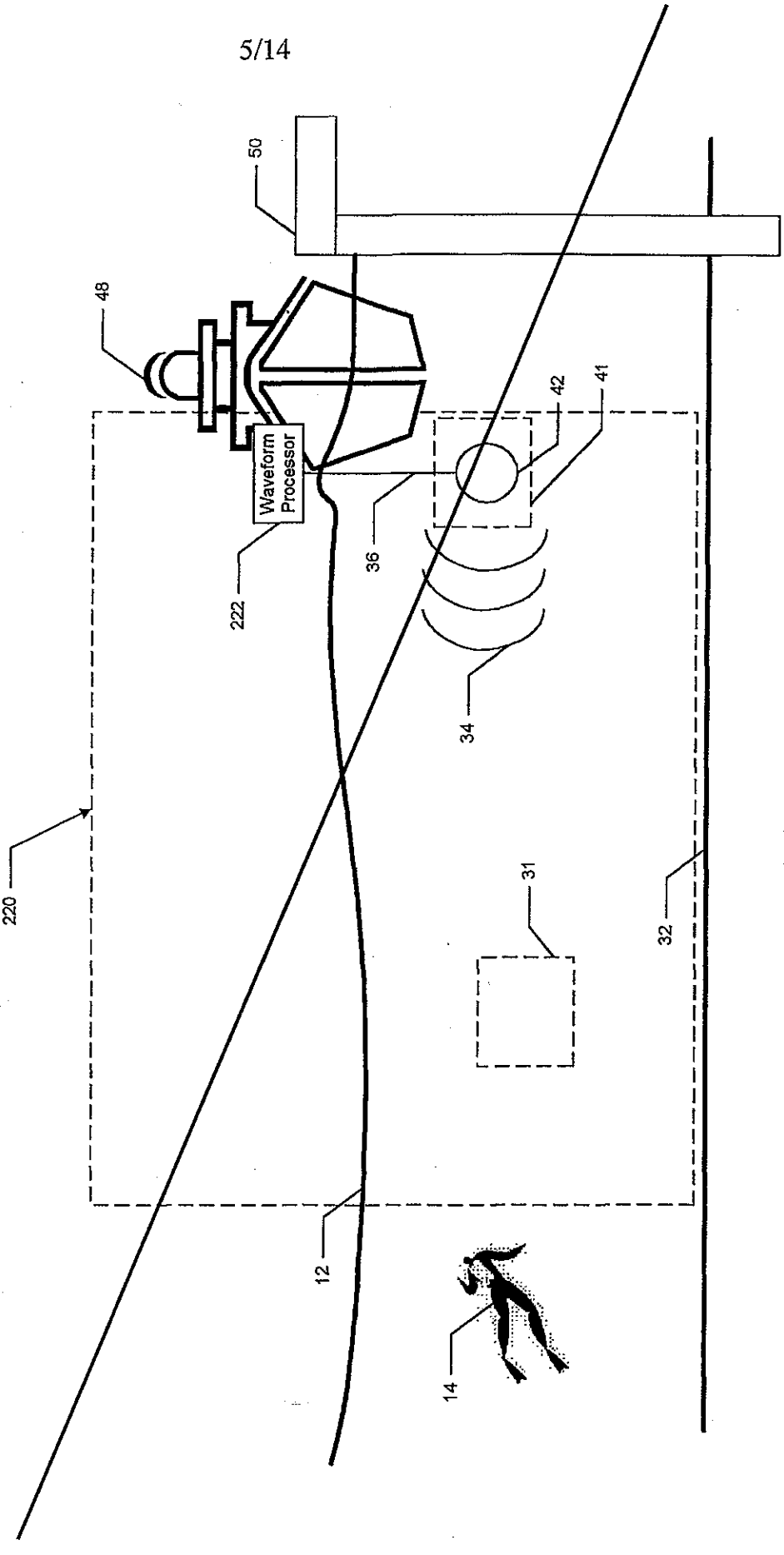


FIG. 1D

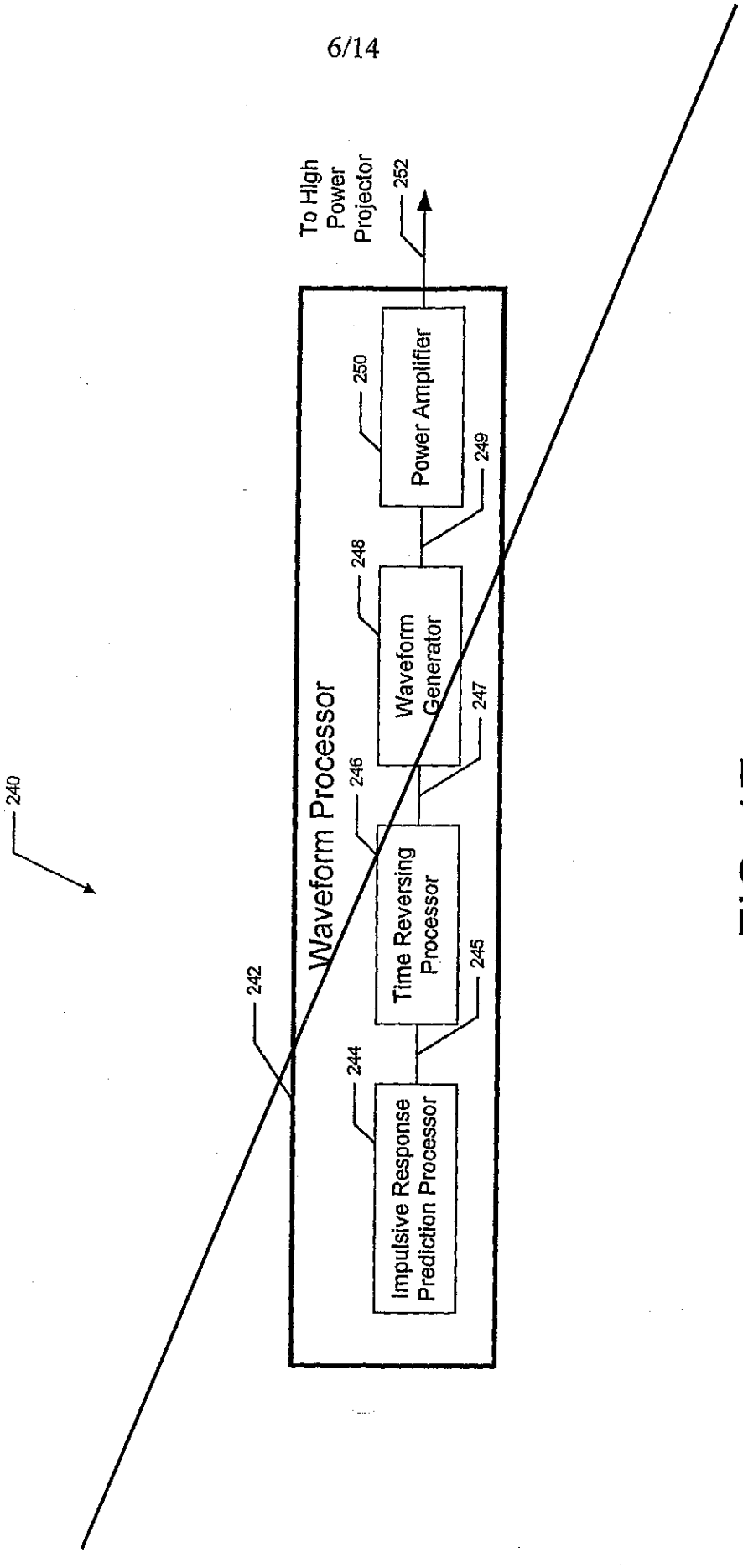

240
242
Waveform Processor
Impulsive Response Prediction Processor
244
Time Reversing Processor
245
246
Waveform Generator
247
248
Power Amplifier
249
250
To High Power Projector
252

FIG. 1E

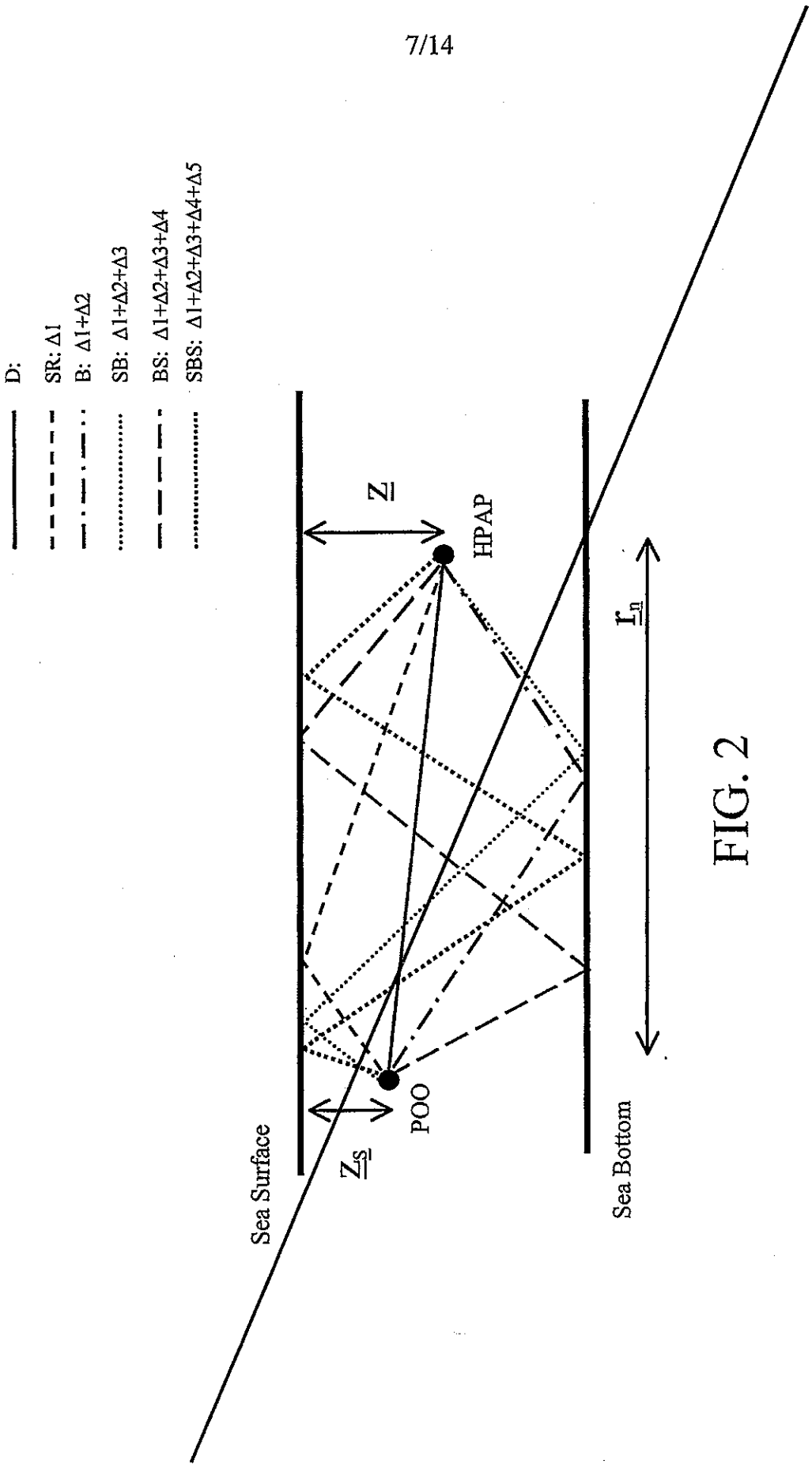

D:
SR: Δ1
B: Δ1+Δ2
SB: Δ1+Δ2+Δ3
BS: Δ1+Δ2+Δ3+Δ4
SBS: Δ1+Δ2+Δ3+Δ4+Δ5
Z
HPAP
r_n
Z_s
POO
Sea Surface
Sea Bottom

FIG. 2

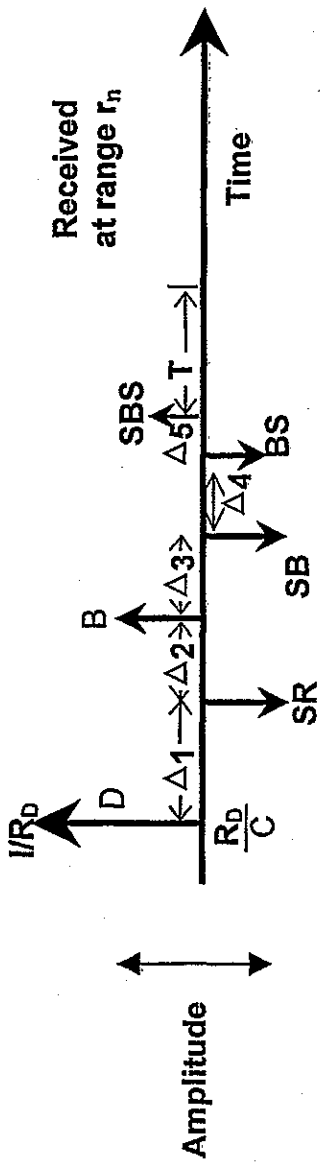

Received
at range r_n
Time
Amplitude
I/R_D
D
$\frac{R_D}{C}$
$\Delta 1$
$\Delta 2$
$\Delta 3$
$\Delta 4$
$\Delta 5$
T
SR
SB
BS
SBS
B

FIG. 3

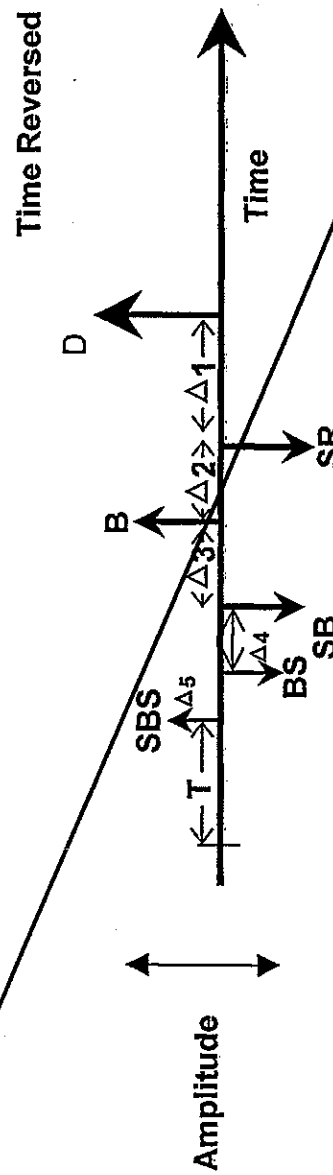

Time Reversed
Time
Amplitude
D
$\Delta 1$
$\Delta 2$
$\Delta 3$
$\Delta 4$
$\Delta 5$
T
SR
SB
BS
SBS
B

FIG. 3A

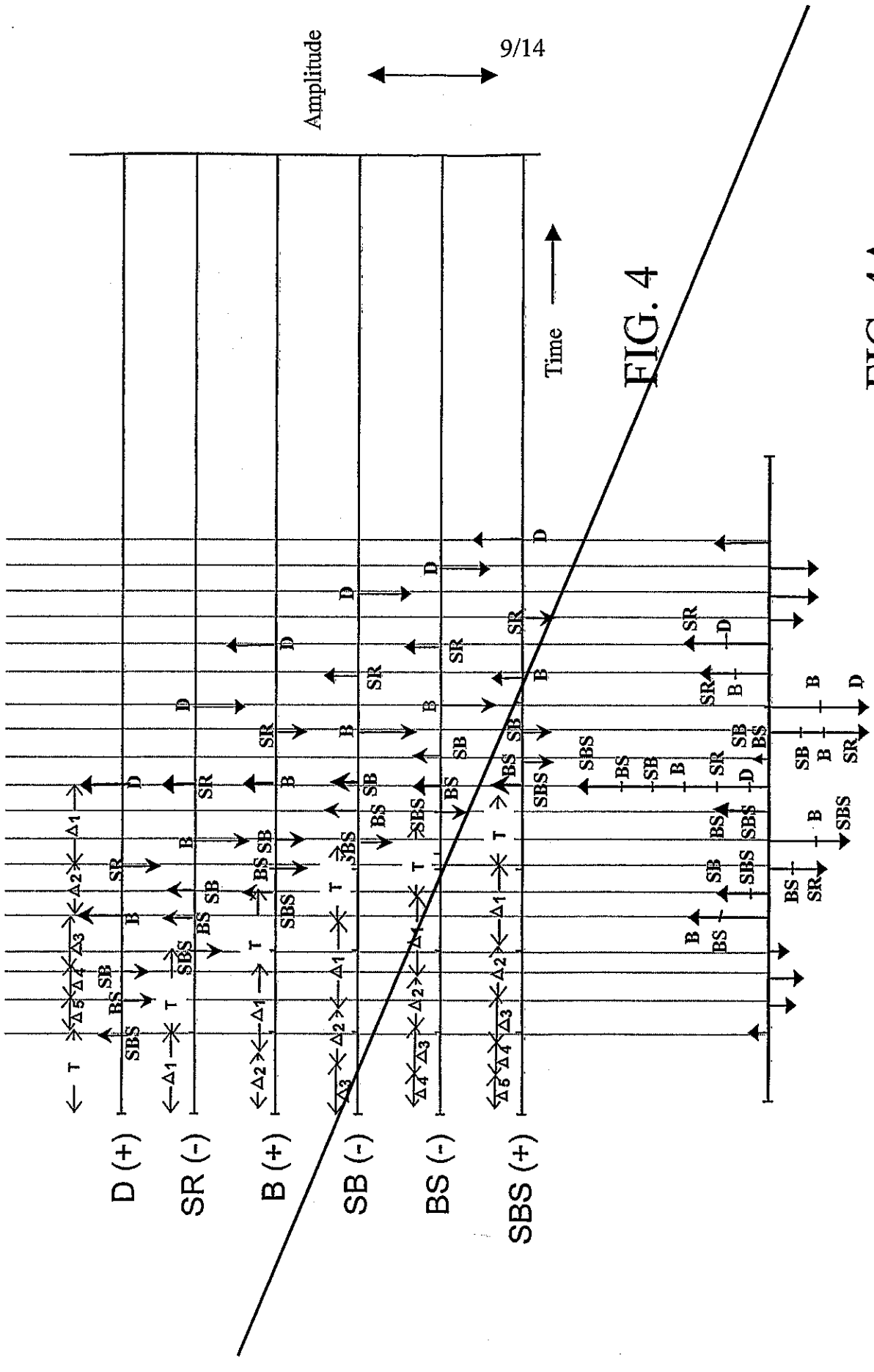


FIG. 4

FIG. 4A

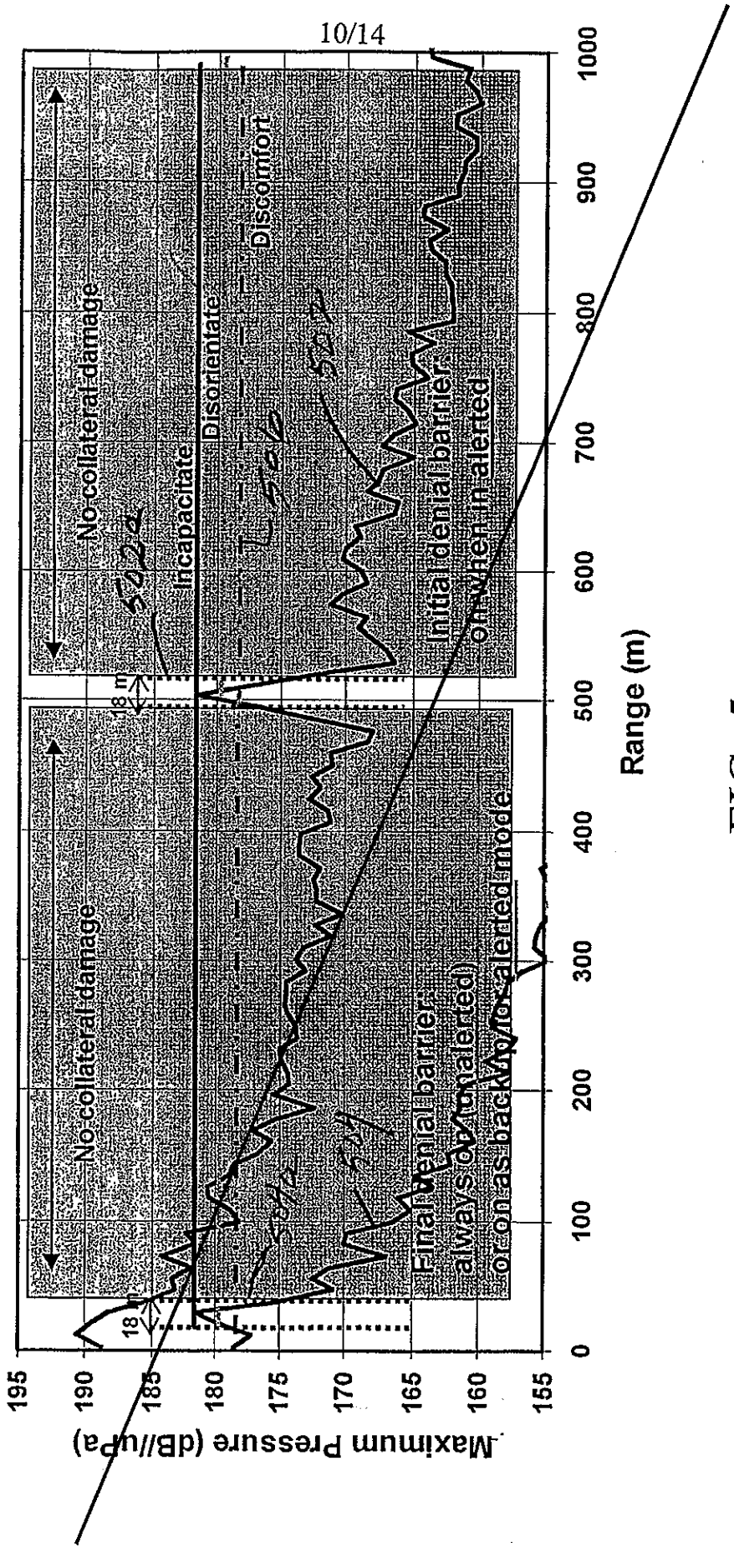

Maximum Pressure (dB//uPa)
195
190
185
180
175
170
165
160
155
Range (m)
0
100
200
300
400
500
600
700
800
900
1000
No collateral damage
Incapacitate
Disorientate
Discomfort
Initial denial barrier:
on when in alerted
Final denial barrier:
always on (unalerted)
or on as backup for alerted mode
18 m
18 m

FIG. 5

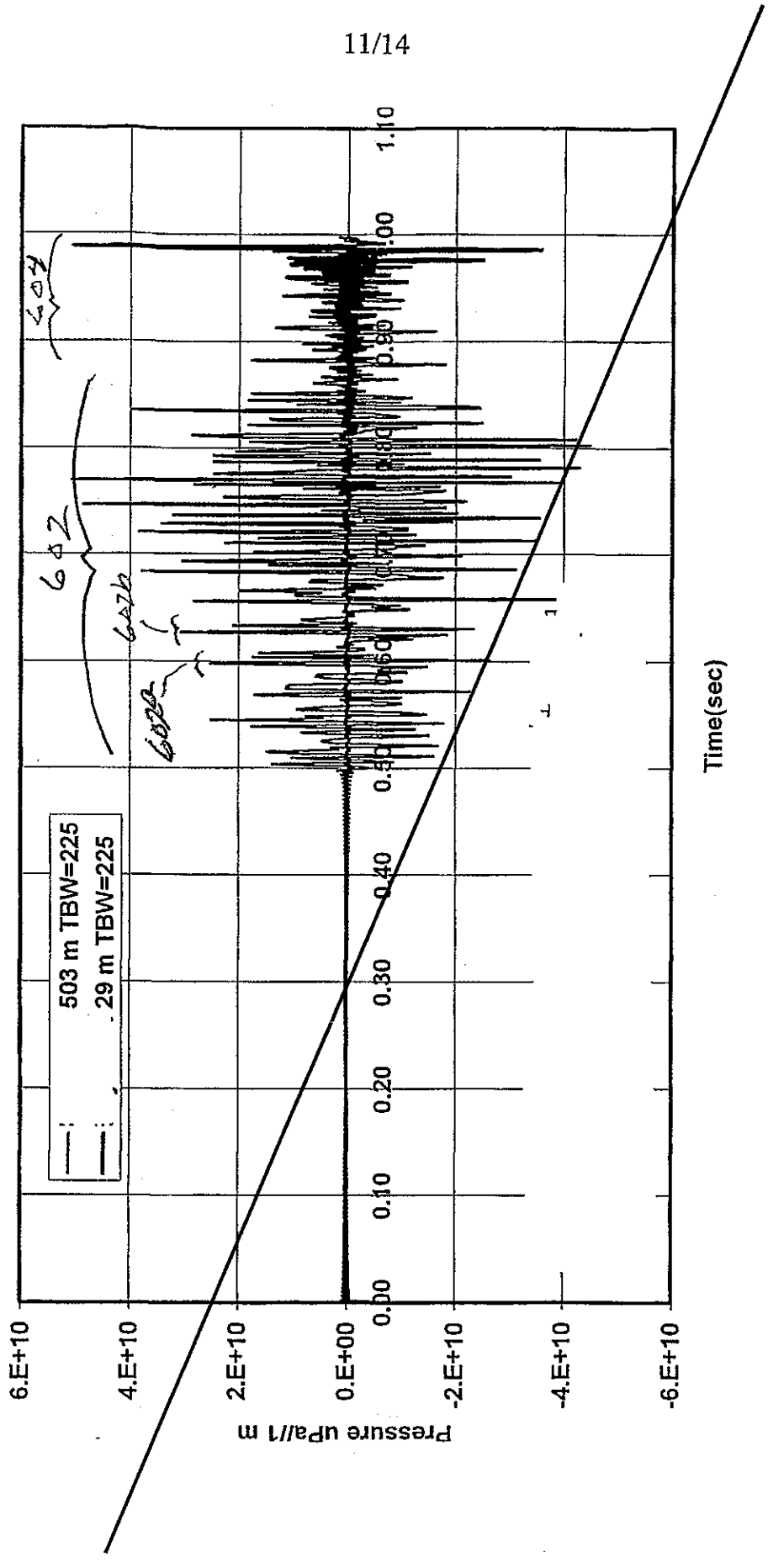

503 m TBW=225
29 m TBW=225
Pressure uPa//1 m
6.E+10
4.E+10
2.E+10
0.E+00
-2.E+10
-4.E+10
-6.E+10
0.00
0.10
0.20
0.30
0.40
0.80
1.00
1.10
Time(sec)

FIG. 6

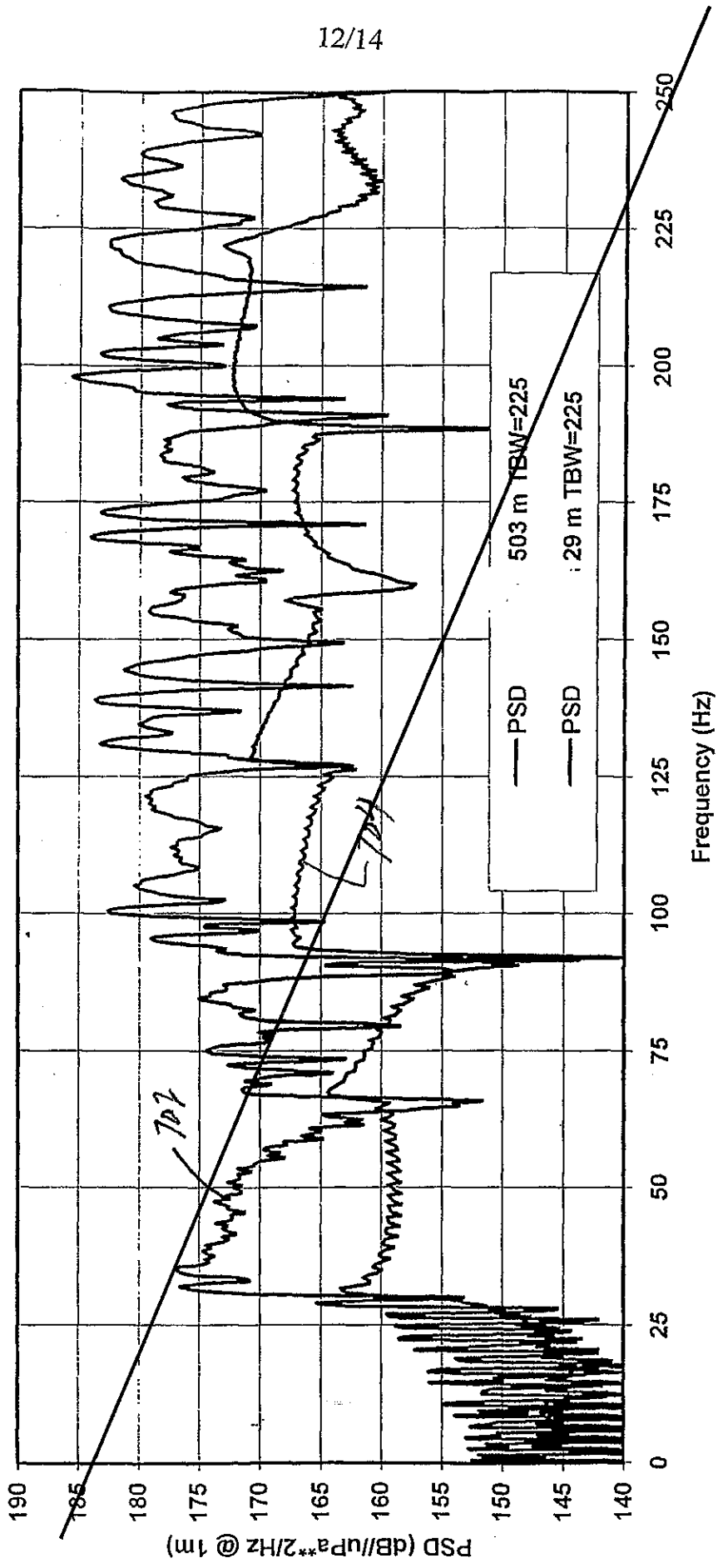

PSD (dB//uPa**2/Hz @ 1m)
190
185
180
175
170
165
160
155
150
145
140
0
25
50
75
100
125
150
175
200
225
250
Frequency (Hz)
PSD
503 m TBW=225
PSD
29 m TBW=225
Td2
Td1

FIG. 7

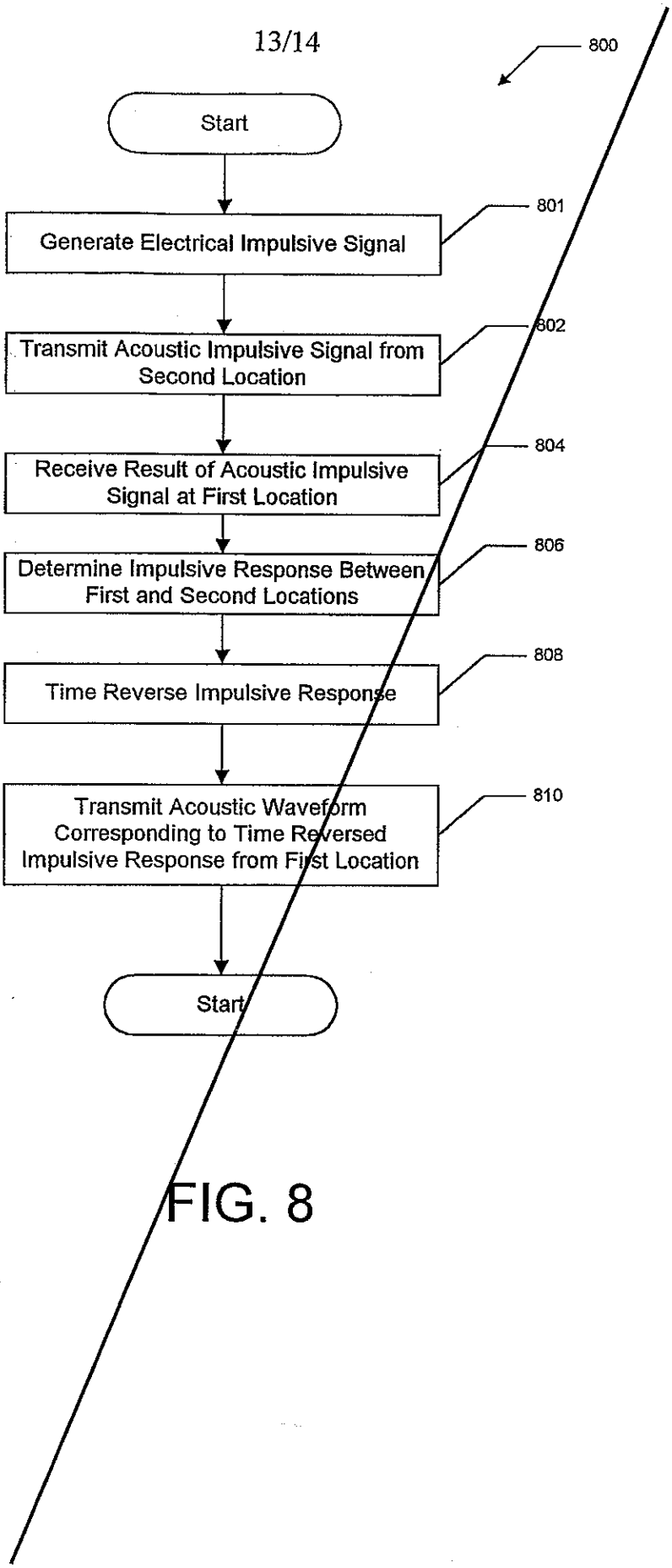

800
Start
801
Generate Electrical Impulsive Signal
802
Transmit Acoustic Impulsive Signal from Second Location
804
Receive Result of Acoustic Impulsive Signal at First Location
806
Determine Impulsive Response Between First and Second Locations
808
Time Reverse Impulsive Response
810
Transmit Acoustic Waveform Corresponding to Time Reversed Impulsive Response from First Location
Start

FIG. 8

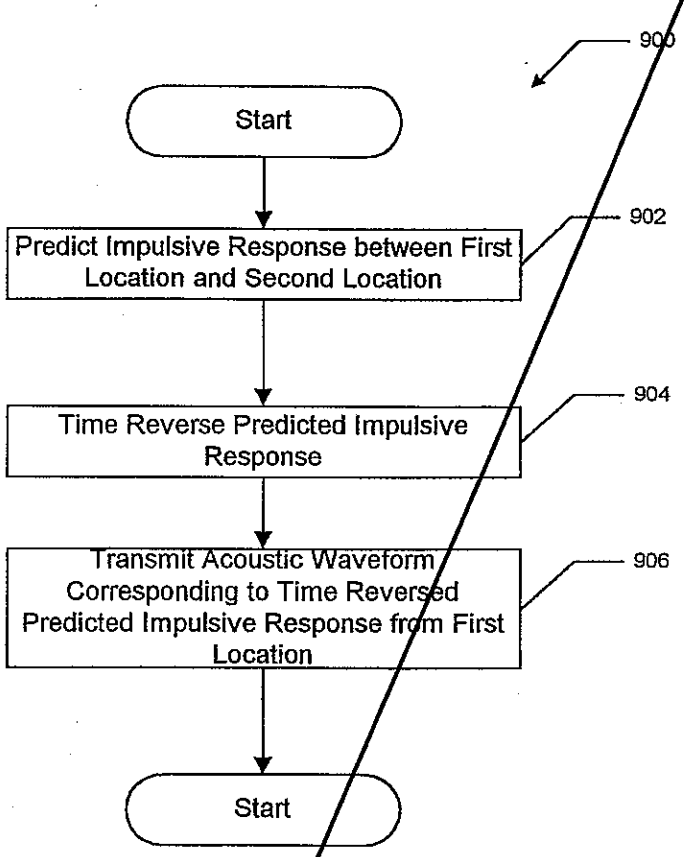

900
Start
902
Predict Impulsive Response between First Location and Second Location
904
Time Reverse Predicted Impulsive Response
906
Transmit Acoustic Waveform Corresponding to Time Reversed Predicted Impulsive Response from First Location
Start

FIG. 9

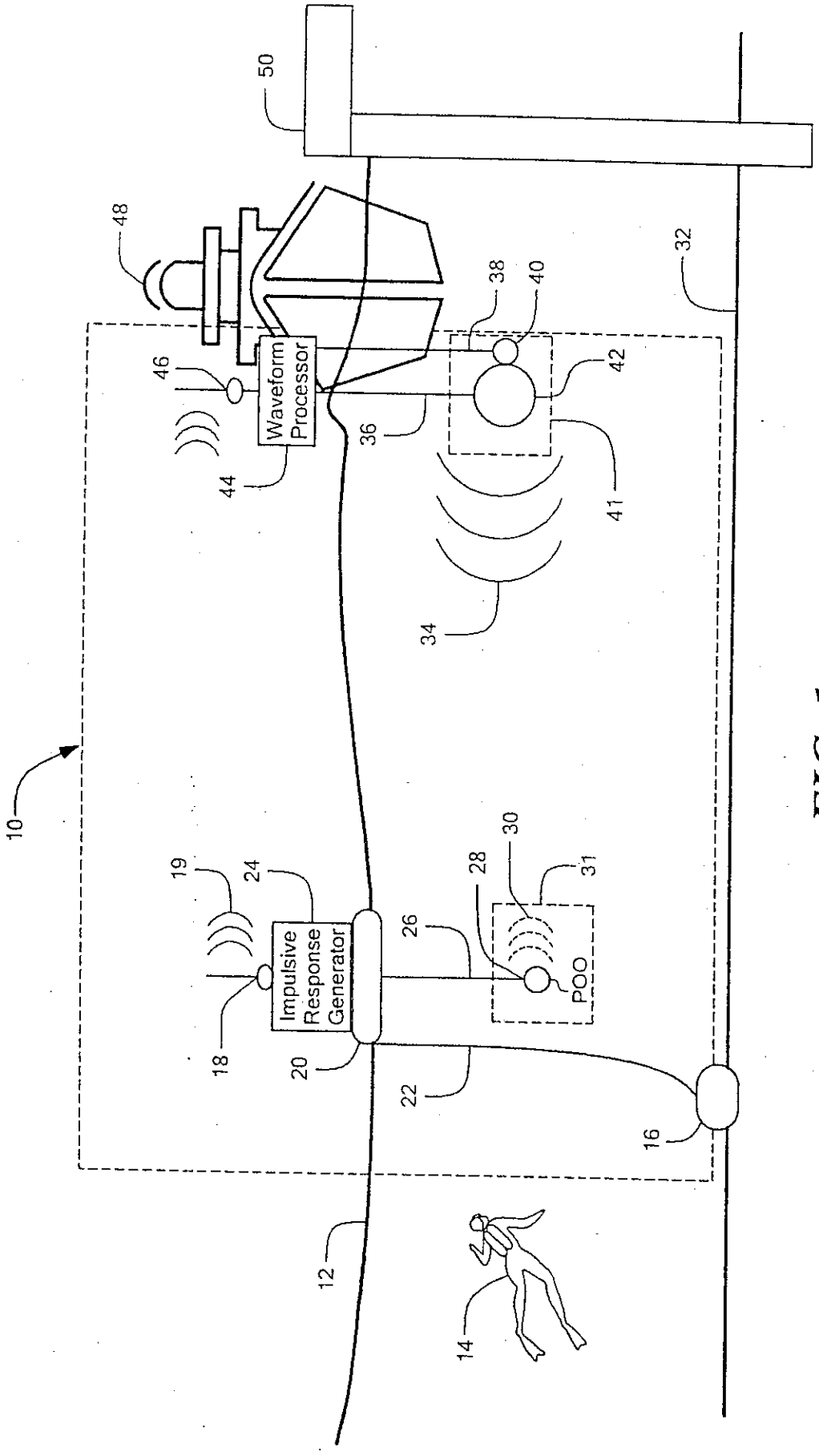

50
48
32
38
40
46
Waveform Processor
42
36
44
41
34
10
19
24
28
30
31
26
Impulsive Response Generator
POO
18
20
22
16
12
14

FIG. 1

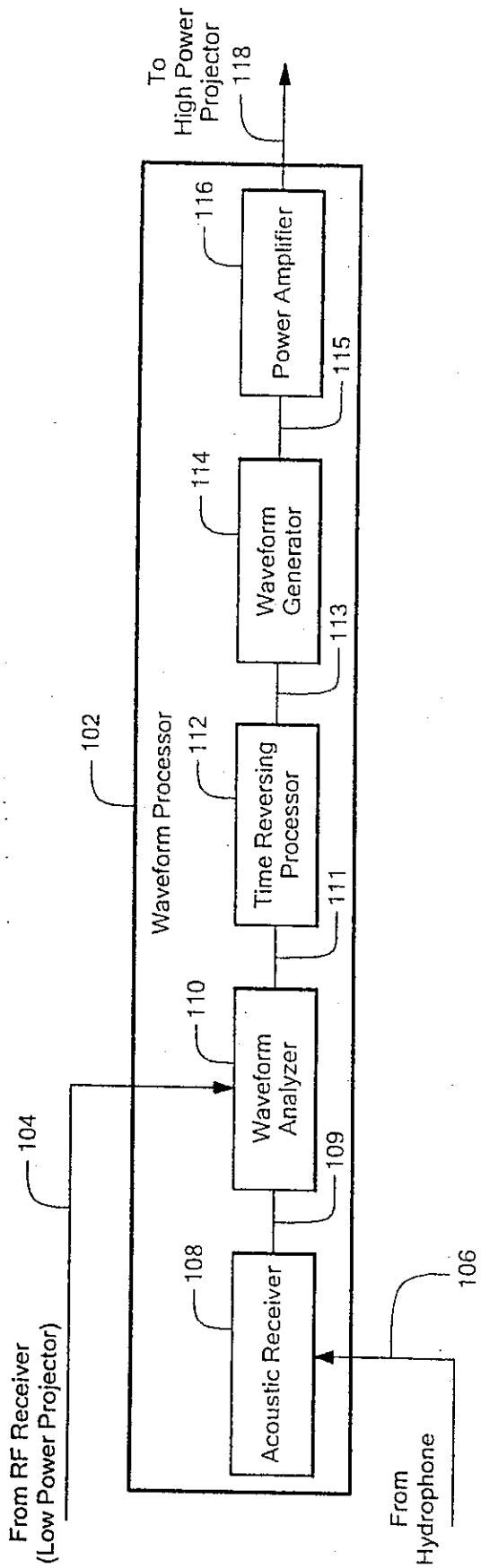

100
102
Waveform Processor
104
From RF Receiver
(Low Power Projector)
106
From
Hydrophone
108
Acoustic Receiver
109
110
Waveform
Analyzer
111
112
Time Reversing
Processor
113
114
Waveform
Generator
115
116
Power Amplifier
118
To
High Power
Projector

FIG. 1A

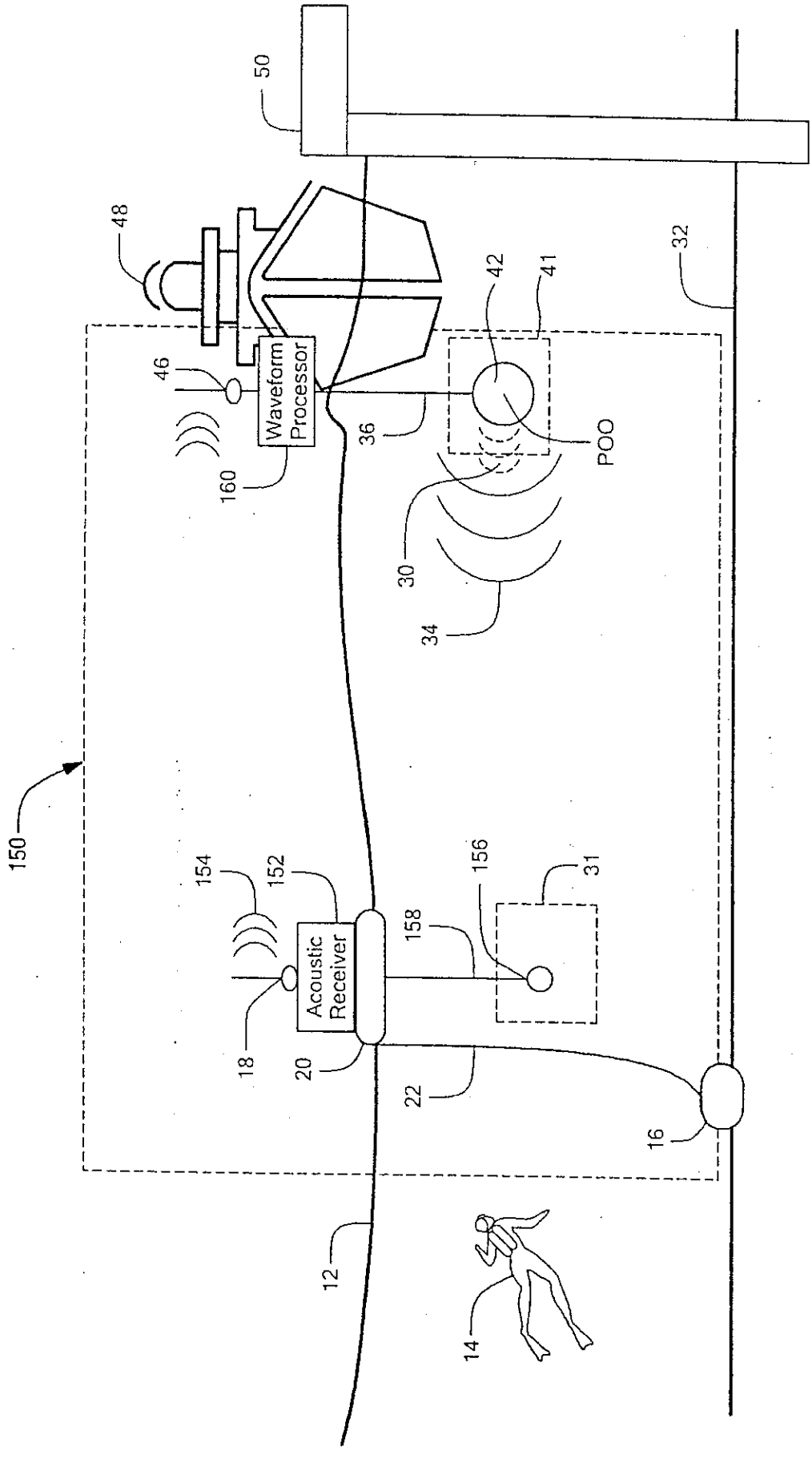

50
48
32
42
41
46
Waveform Processor
36
POO
160
30
34
150
154
152
156
31
158
Acoustic Receiver
18
20
22
16
12
14

FIG. 1B

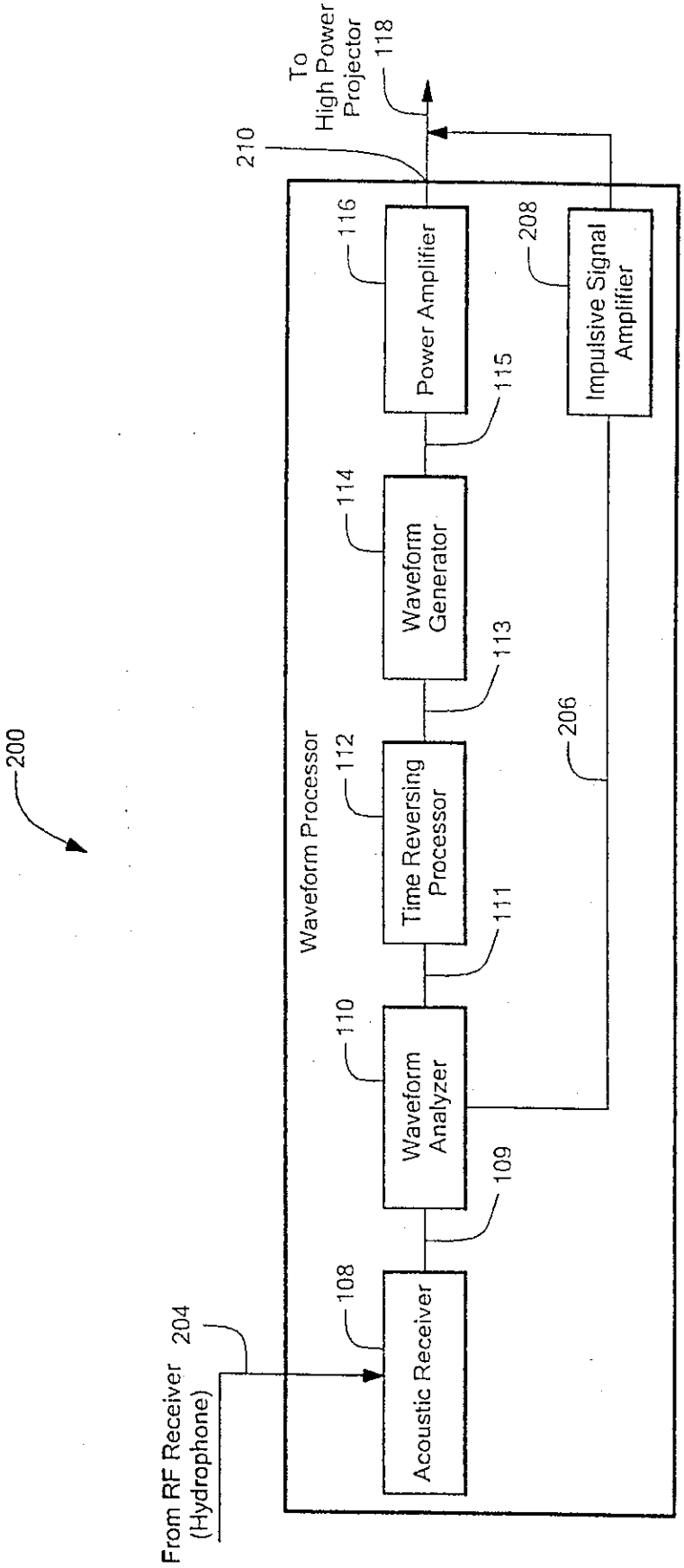

200
210
To High Power Projector
118
Waveform Processor
116
Power Amplifier
208
Impulsive Signal Amplifier
115
114
Waveform Generator
113
112
Time Reversing Processor
206
111
110
Waveform Analyzer
109
108
Acoustic Receiver
204
From RF Receiver (Hydrophone)

FIG. 1C

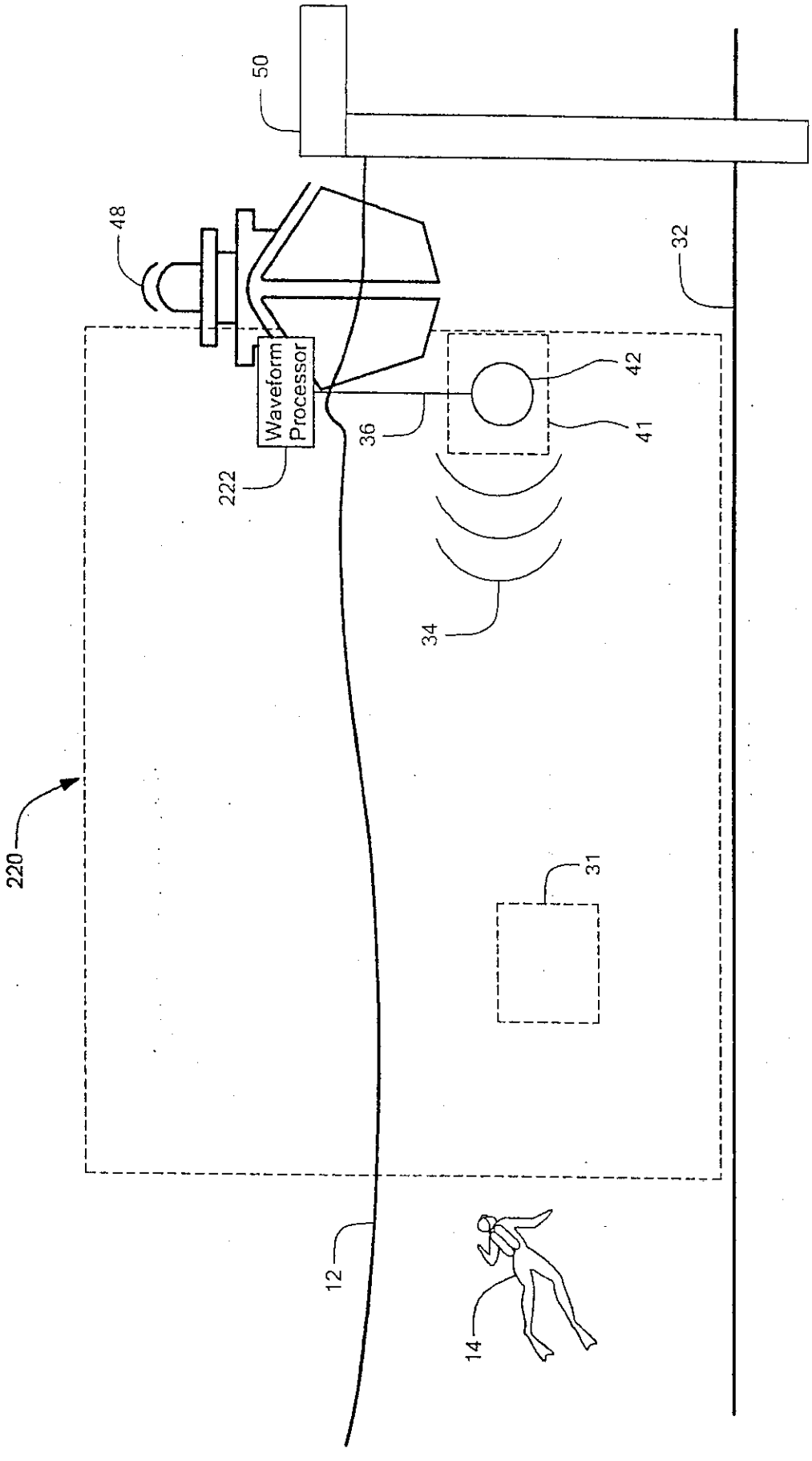


FIG. 1D

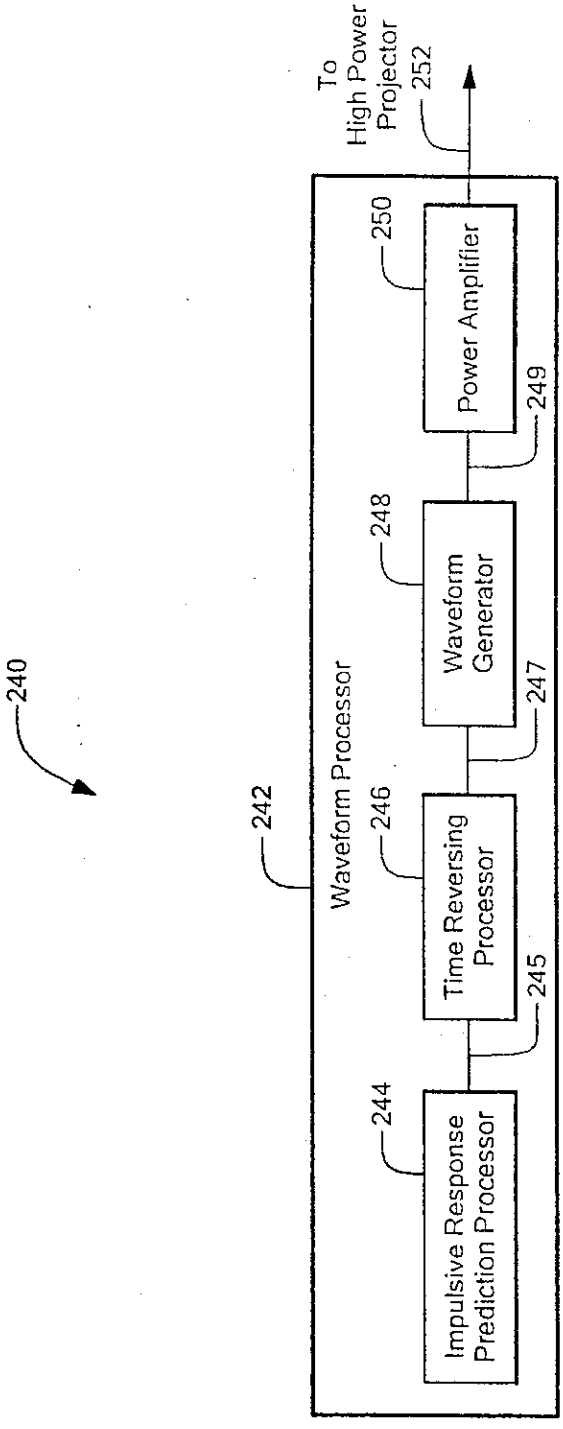

240
242
Waveform Processor
244
Impulsive Response Prediction Processor
245
246
Time Reversing Processor
247
248
Waveform Generator
249
250
Power Amplifier
252
To High Power Projector

FIG. 1E

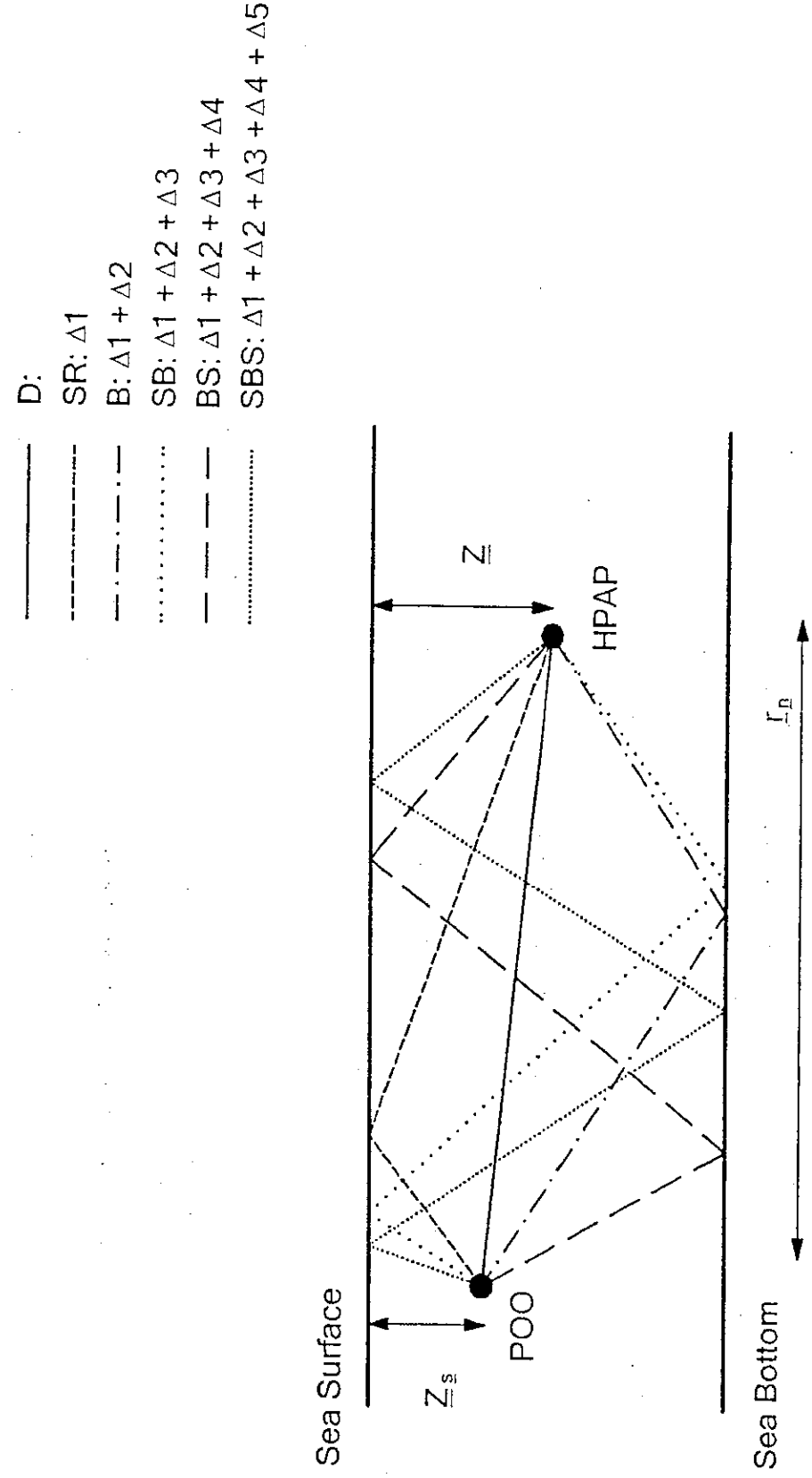

D:
SR: Δ1
B: Δ1 + Δ2
SB: Δ1 + Δ2 + Δ3
BS: Δ1 + Δ2 + Δ3 + Δ4
SBS: Δ1 + Δ2 + Δ3 + Δ4 + Δ5
Z
HPAP
r_n
Sea Surface
Z_s
POO
Sea Bottom

FIG. 2

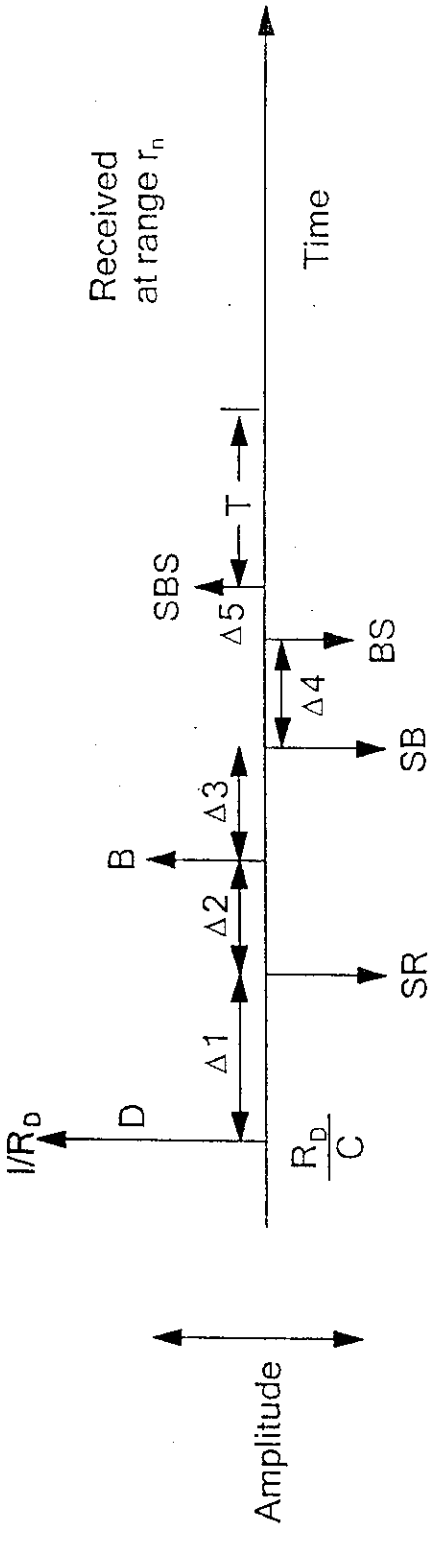

Received
at range r_n
Time
SBS
T
Δ5
BS
Δ4
SB
B
Δ3
Δ2
SR
Δ1
D
$1/R_D$
$\frac{R_D}{C}$
Amplitude

FIG. 3

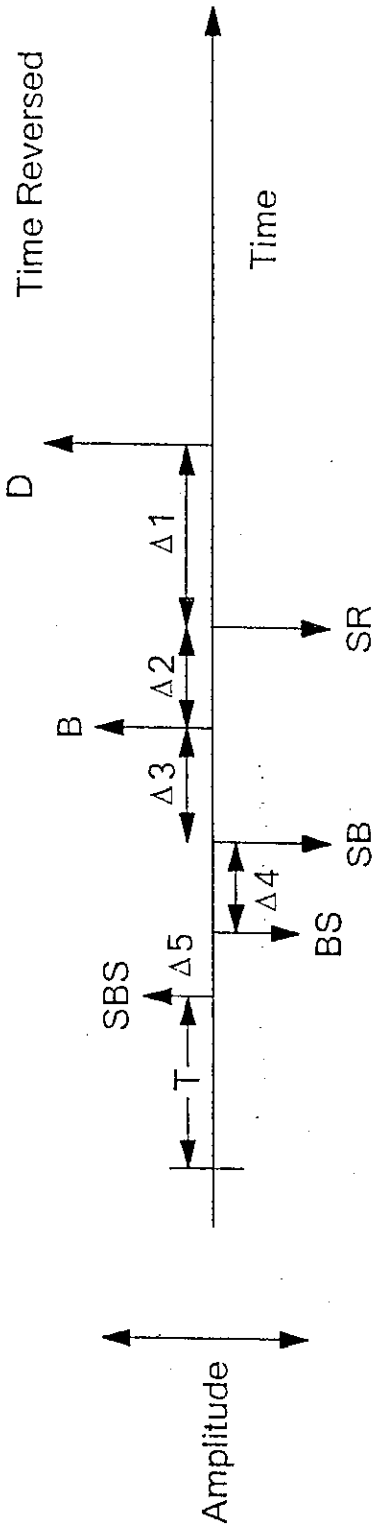

Time Reversed
Time
D
Δ1
Δ2
SR
B
Δ3
SB
Δ4
BS
Δ5
SBS
T
Amplitude

FIG. 3A

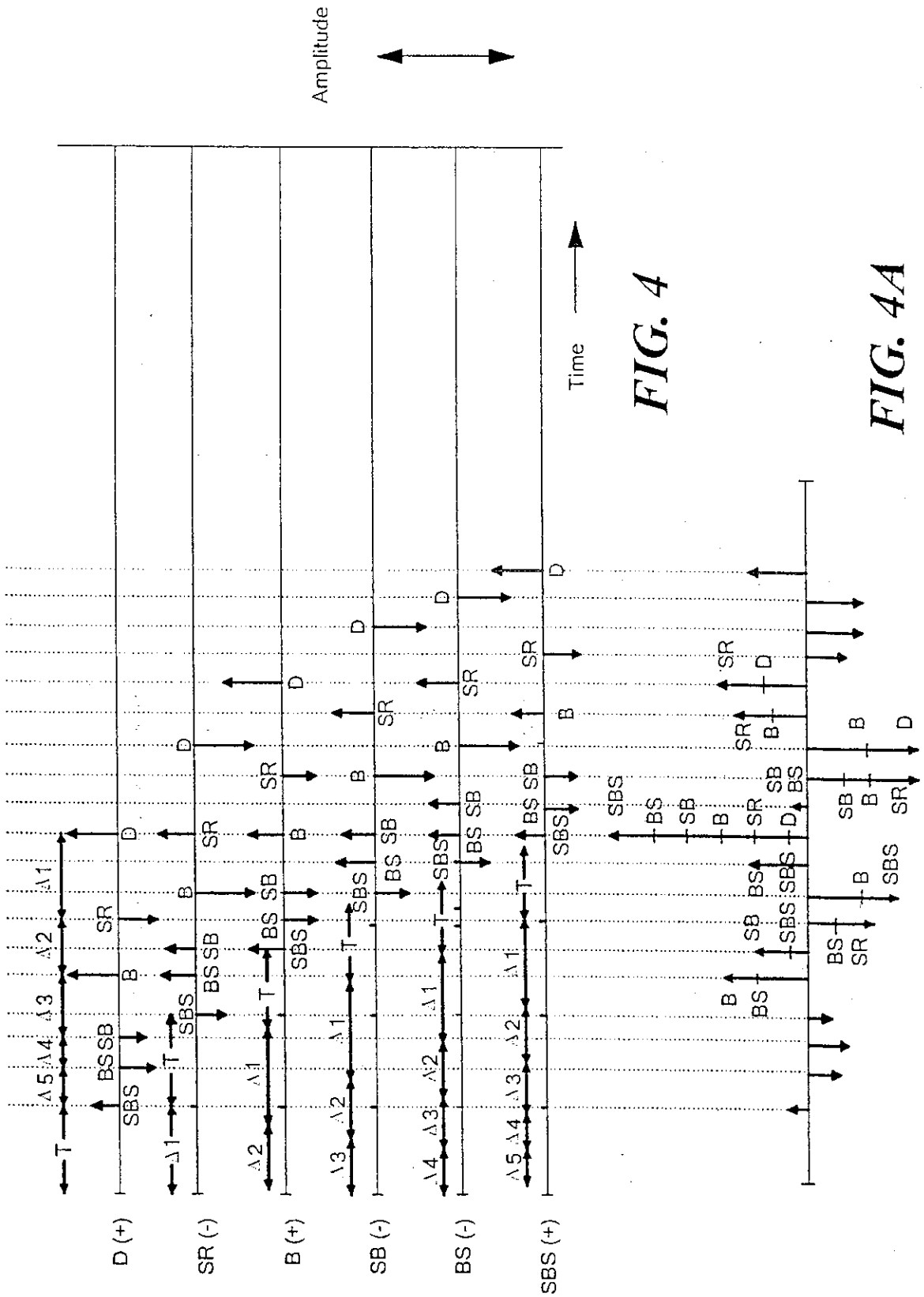


FIG. 4

FIG. 4A

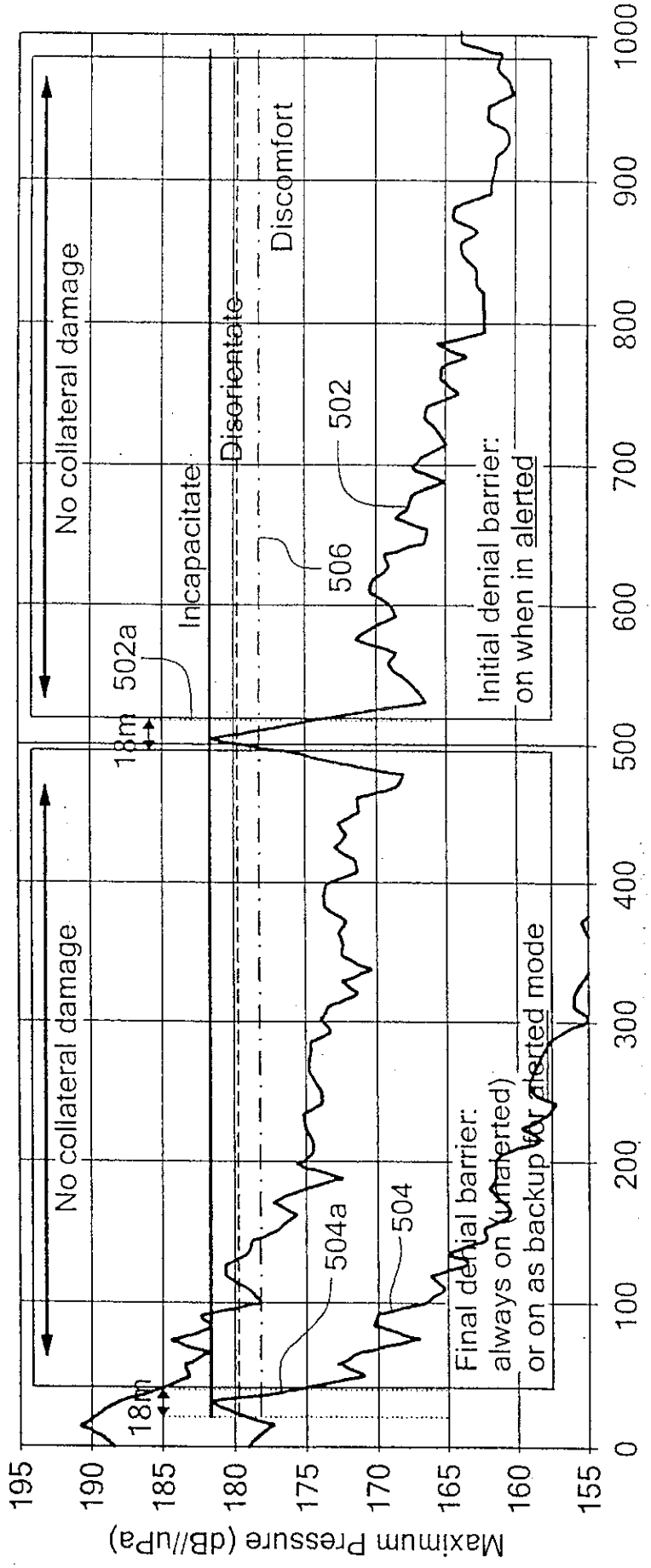

Maximum Pressure (dB//uPa)
195
190
185
180
175
170
165
160
155
0
100
200
300
400
500
600
700
800
900
1000
Range (m)
No collateral damage
No collateral damage
18m
18m
502a
Incapacitate
Disorientate
Discomfort
502
506
504a
504
Initial denial barrier:
on when in alerted
Final denial barrier:
always on (unalerted)
or on as backup for alerted mode

FIG. 5

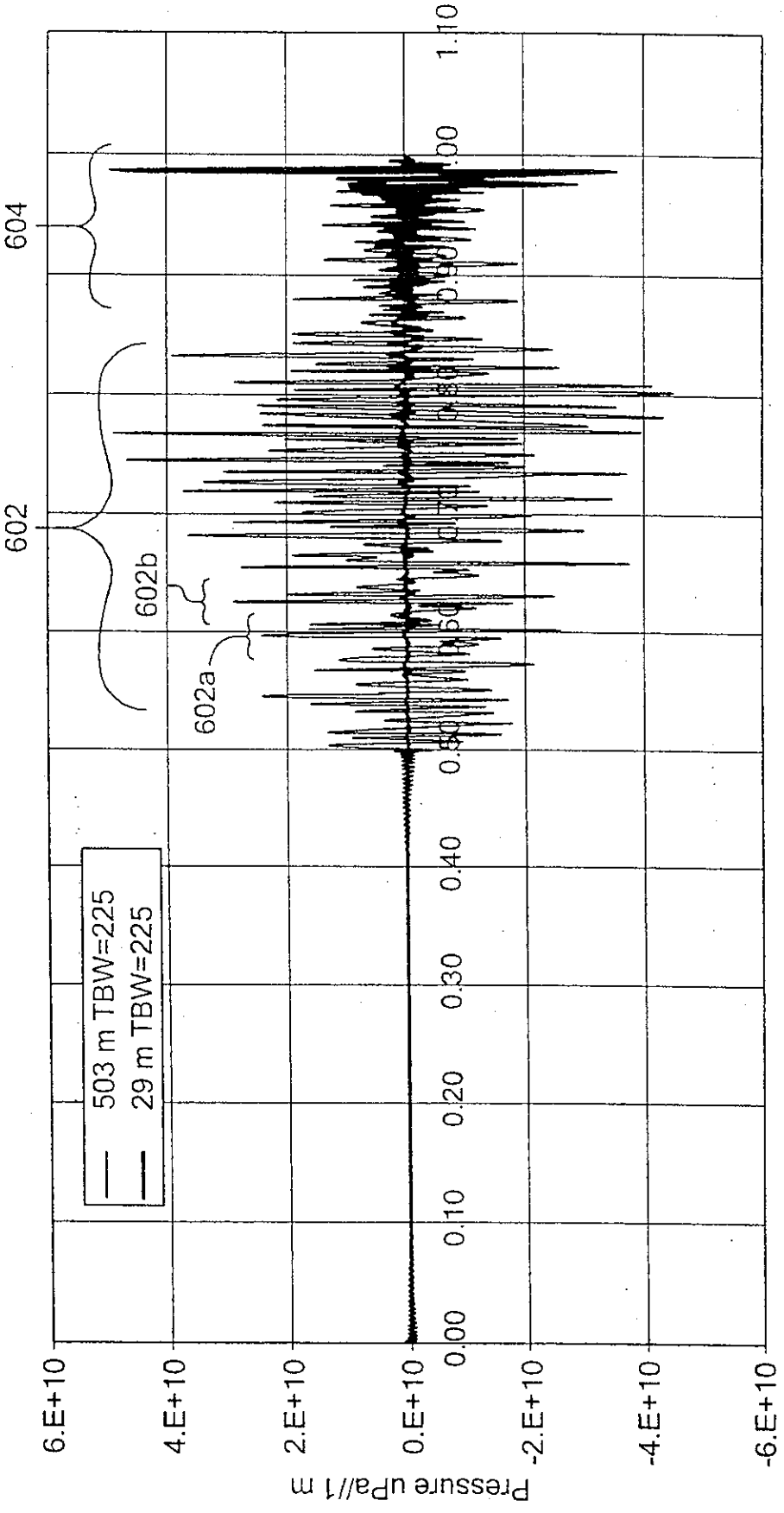

503 m TBW=225
29 m TBW=225
602
602a
602b
604
6.E+10
4.E+10
2.E+10
0.E+10
-2.E+10
-4.E+10
-6.E+10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.80
1.00
1.10
Time (sec)
Pressure uPa// 1 m

FIG. 6

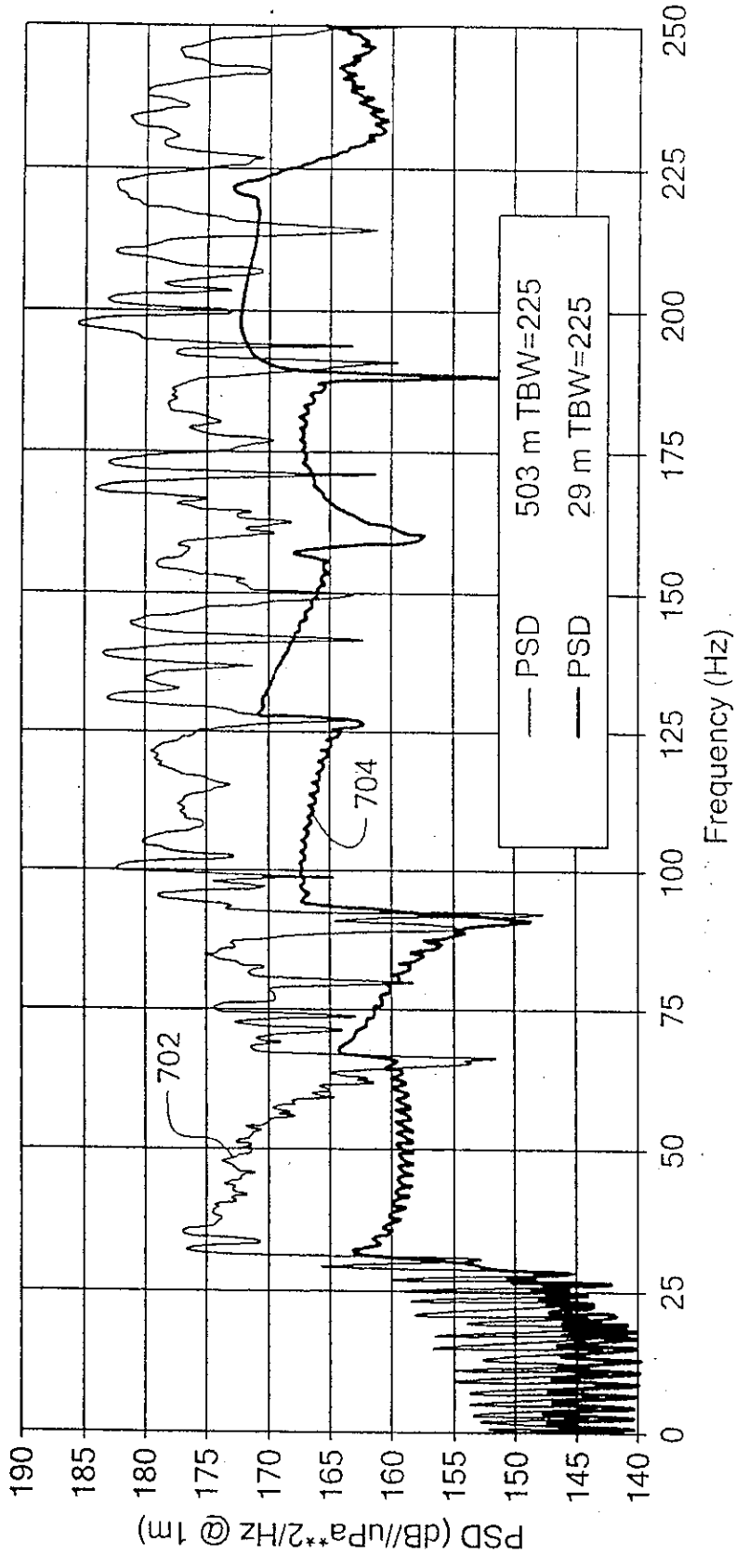

PSD (dB//uPa**2/Hz @ 1m)
190
185
180
175
170
165
160
155
150
145
140
0
25
50
75
100
125
150
175
200
225
250
Frequency (Hz)
PSD 503 m TBW=225
PSD 29 m TBW=225
702
704

FIG. 7

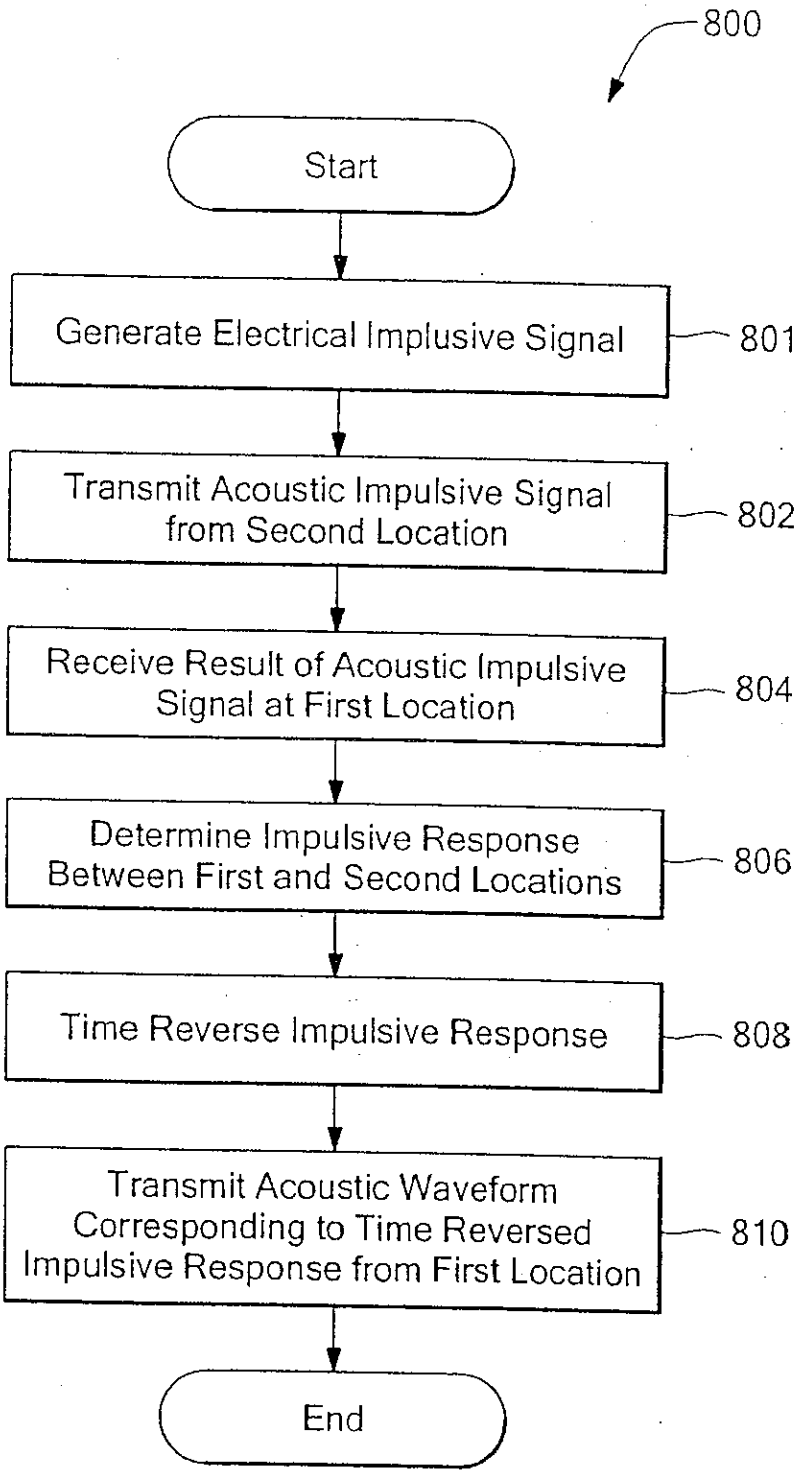

800
Start
Generate Electrical Implusive Signal
801
Transmit Acoustic Impulsive Signal from Second Location
802
Receive Result of Acoustic Impulsive Signal at First Location
804
Determine Impulsive Response Between First and Second Locations
806
Time Reverse Impulsive Response
808
Transmit Acoustic Waveform Corresponding to Time Reversed Impulsive Response from First Location
810
End

FIG. 8

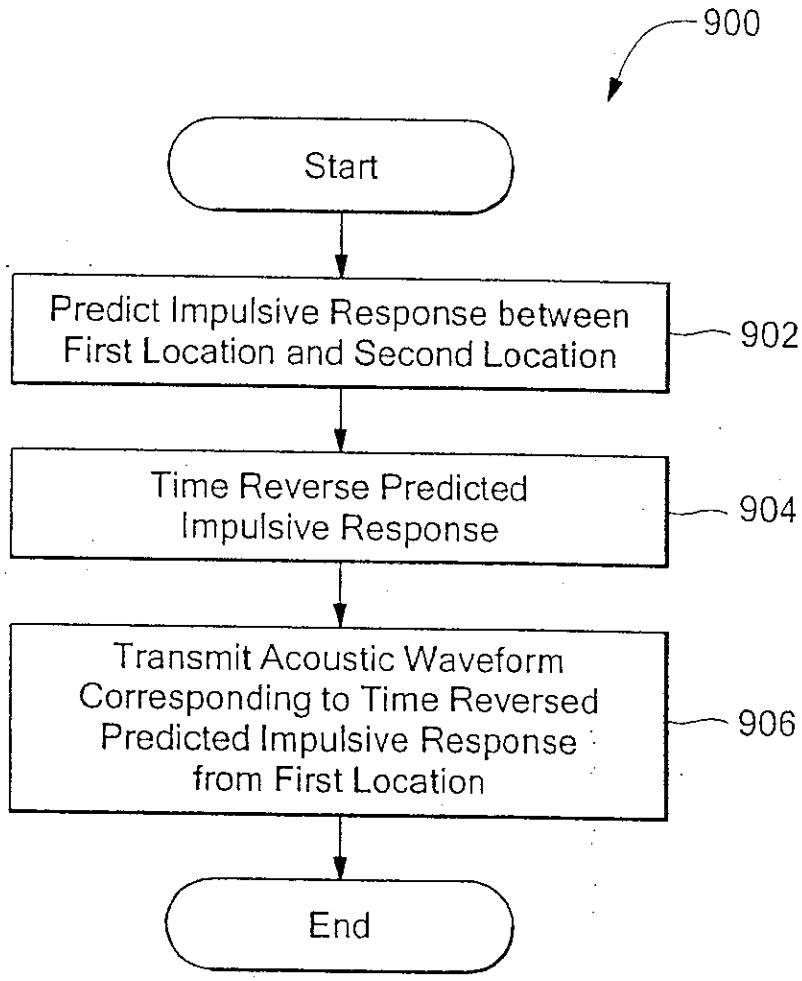

900
Start
Predict Impulsive Response between First Location and Second Location
902
Time Reverse Predicted Impulsive Response
904
Transmit Acoustic Waveform Corresponding to Time Reversed Predicted Impulsive Response from First Location
906
End

FIG. 9