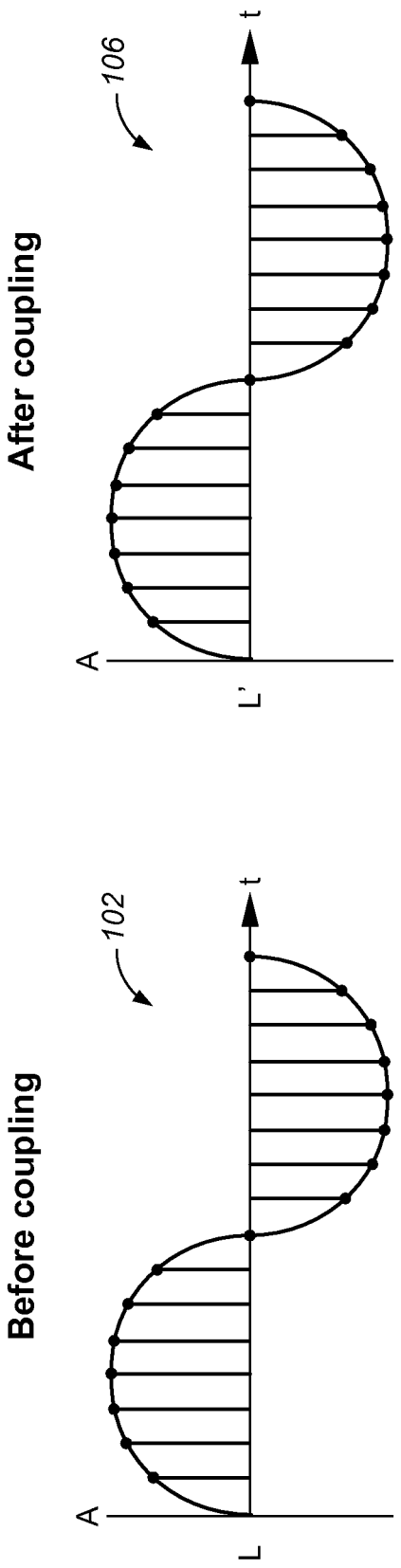

Before coupling
102
t
A
L
104
t
A
R

FIG. 1A

After coupling
106
t
A
L'
108
t
A
R'

FIG. 1B

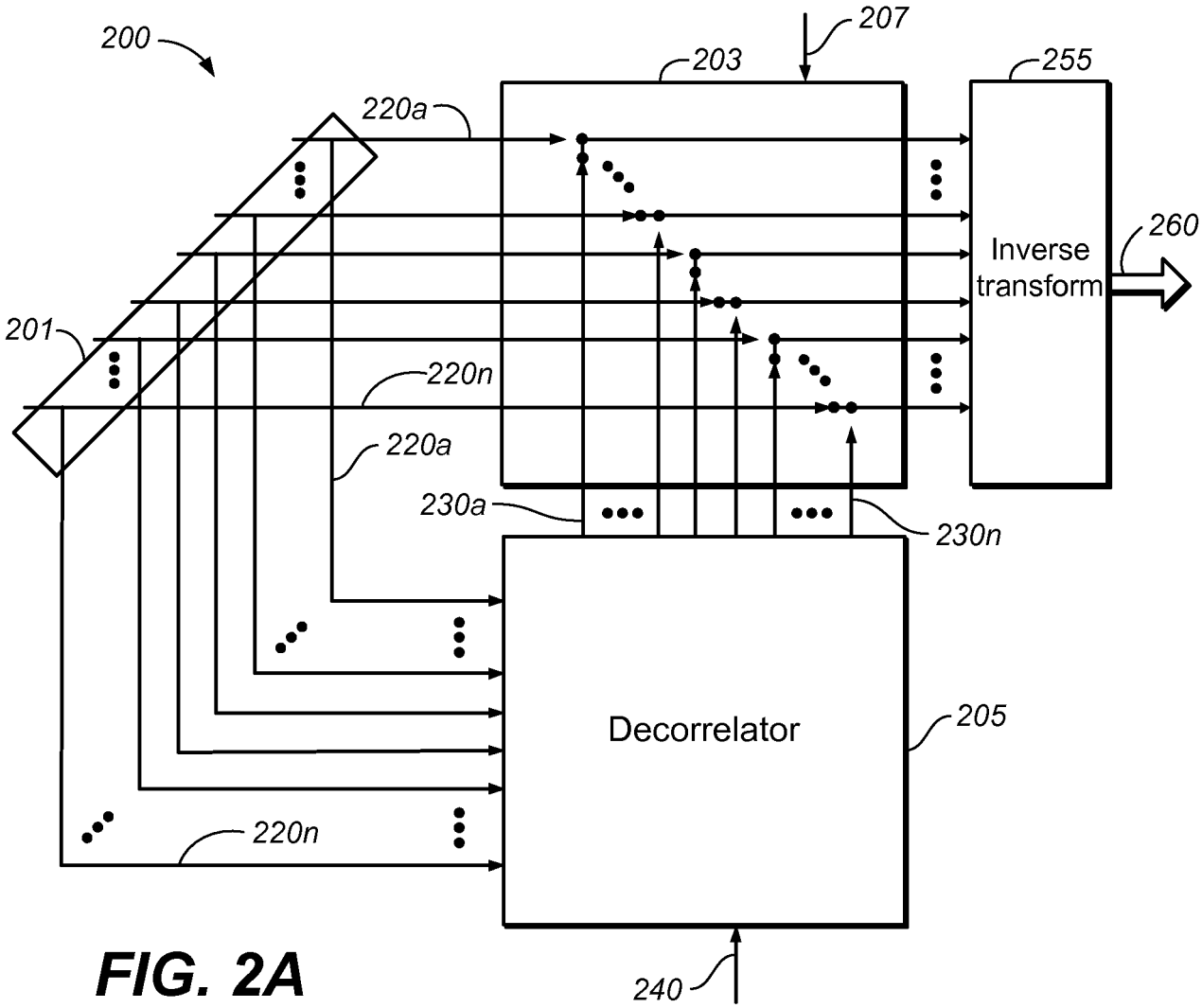

200
207
203
255
220a
Inverse transform
260
201
220n
220a
230a
230n
Decorrelator
205
220n
240

FIG. 2A

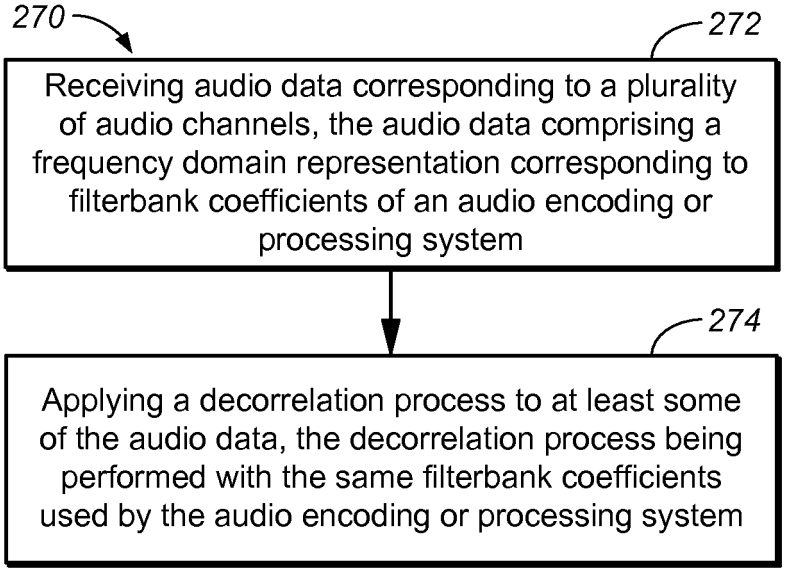

270
272
Receiving audio data corresponding to a plurality of audio channels, the audio data comprising a frequency domain representation corresponding to filterbank coefficients of an audio encoding or processing system
274
Applying a decorrelation process to at least some of the audio data, the decorrelation process being performed with the same filterbank coefficients used by the audio encoding or processing system

FIG. 2B

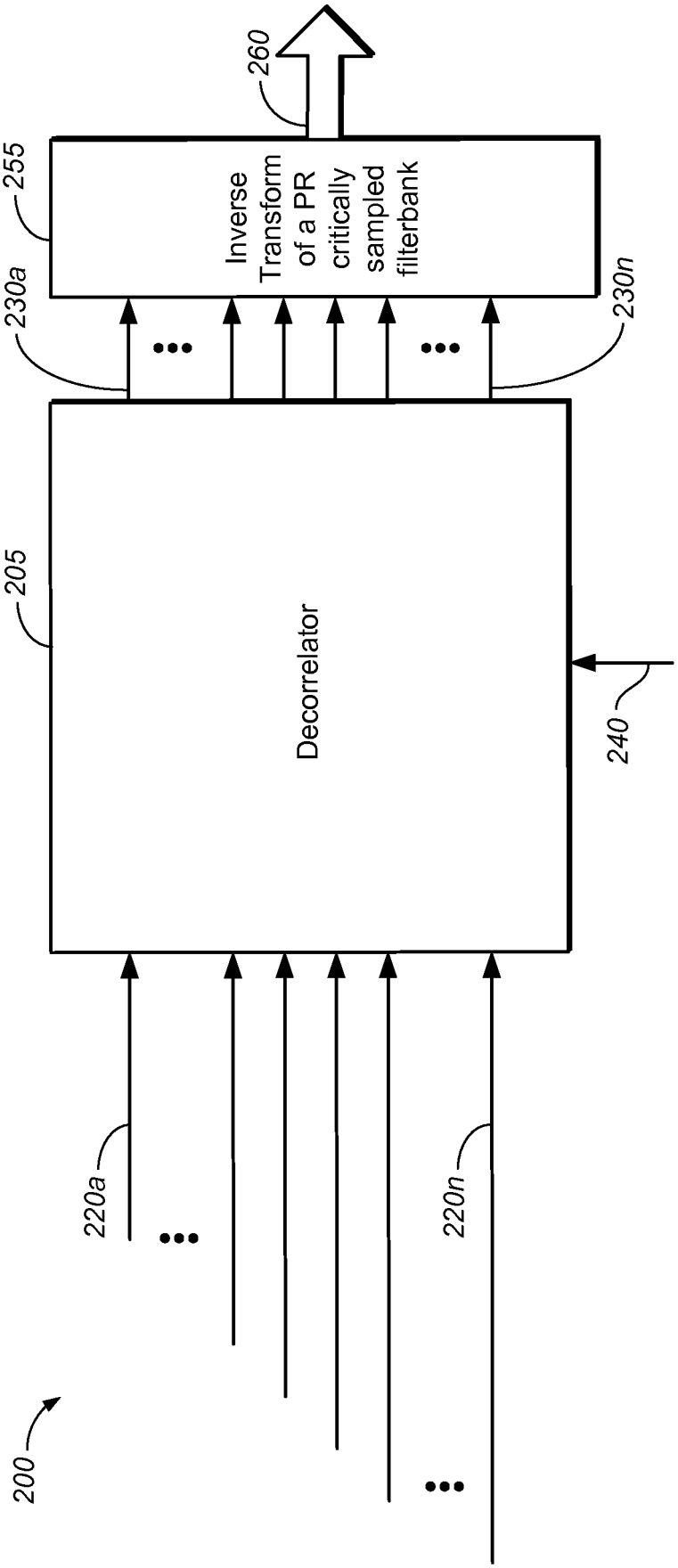

260
255
Inverse Transform of a PR critically sampled filterbank
230a
230n
205
Decorrelator
240
220a
220n
200

FIG. 2C

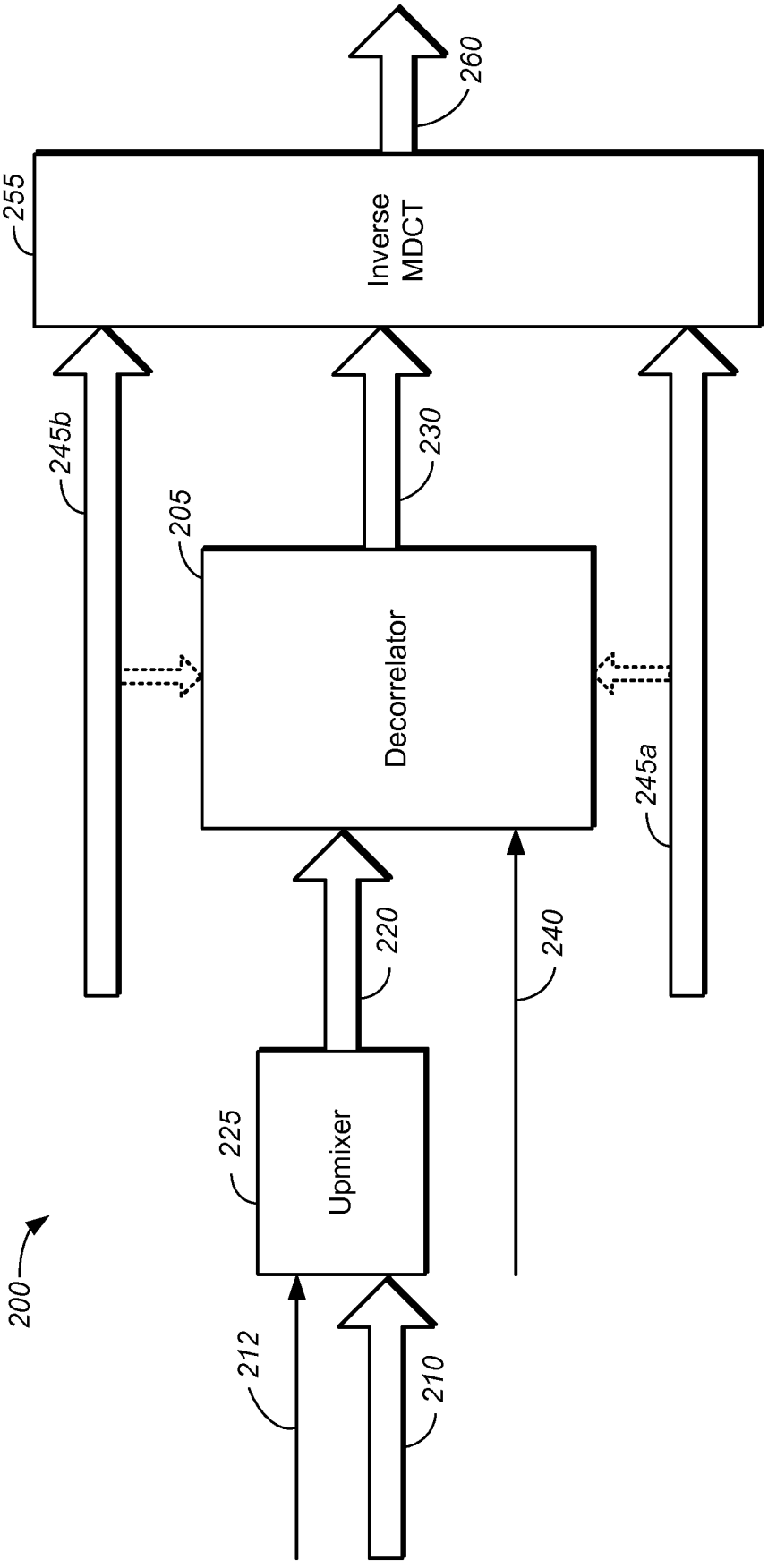

260
255
Inverse MDCT
245b
230
205
Decorrelator
245a
220
240
225
Upmixer
200
212
210

FIG. 2D

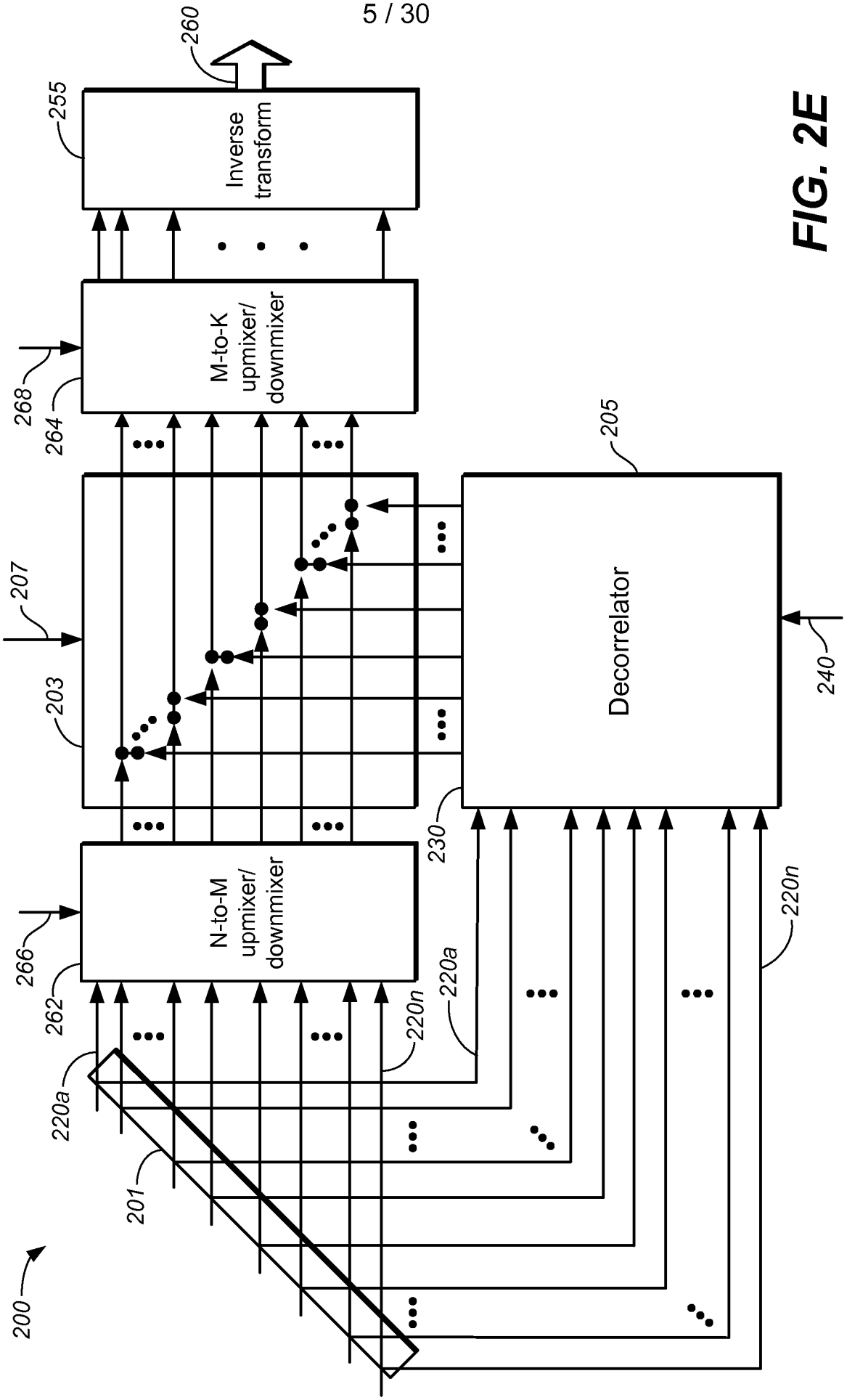

260
255
Inverse transform
M-to-K upmixer/ downmixer
268
264
205
207
Decorrelator
203
240
N-to-M upmixer/ downmixer
266
262
230
220n
220a
220a
201
200

FIG. 2E

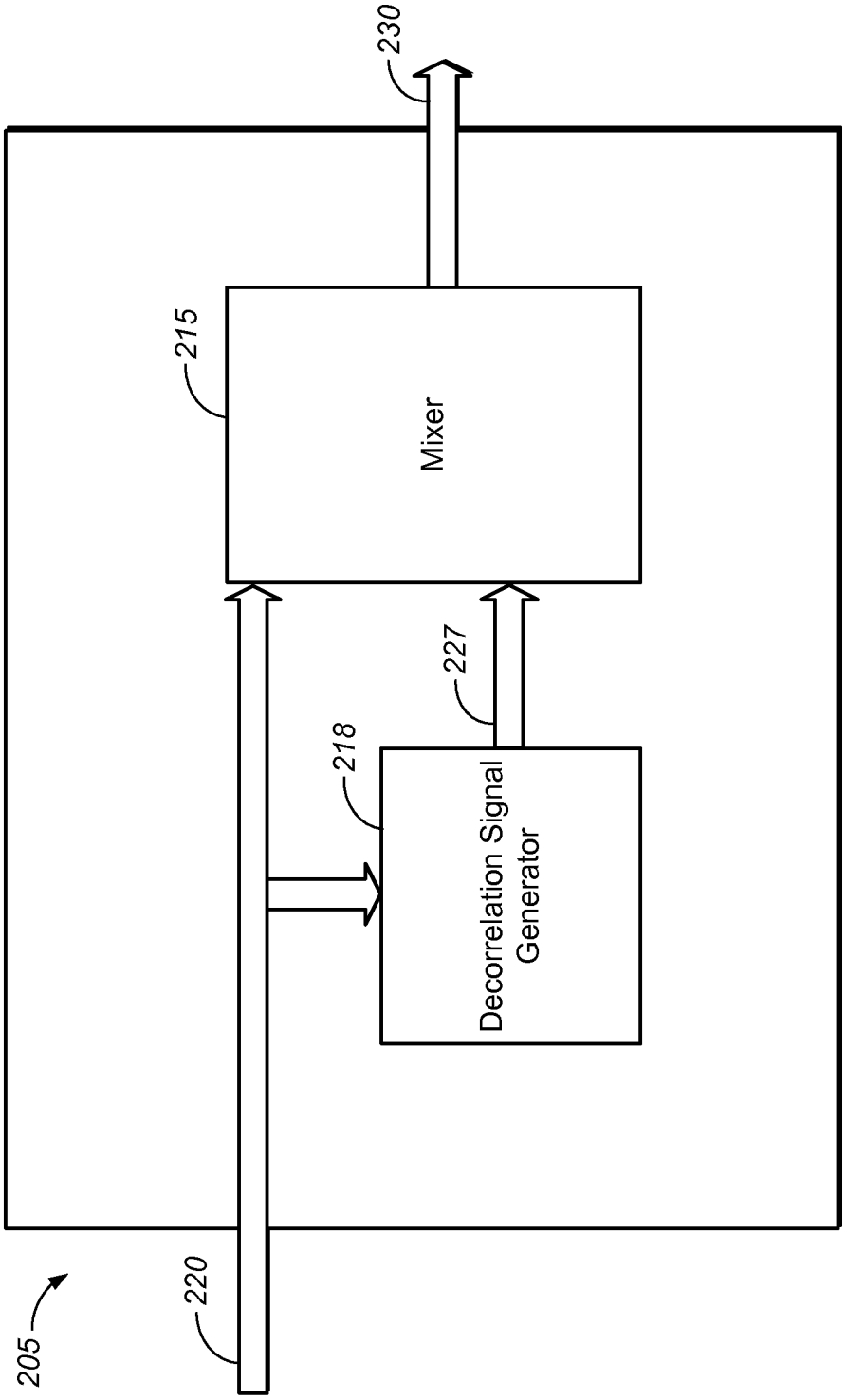

230
215
Mixer
227
218
Decorrelation Signal Generator
220
205

FIG. 2F

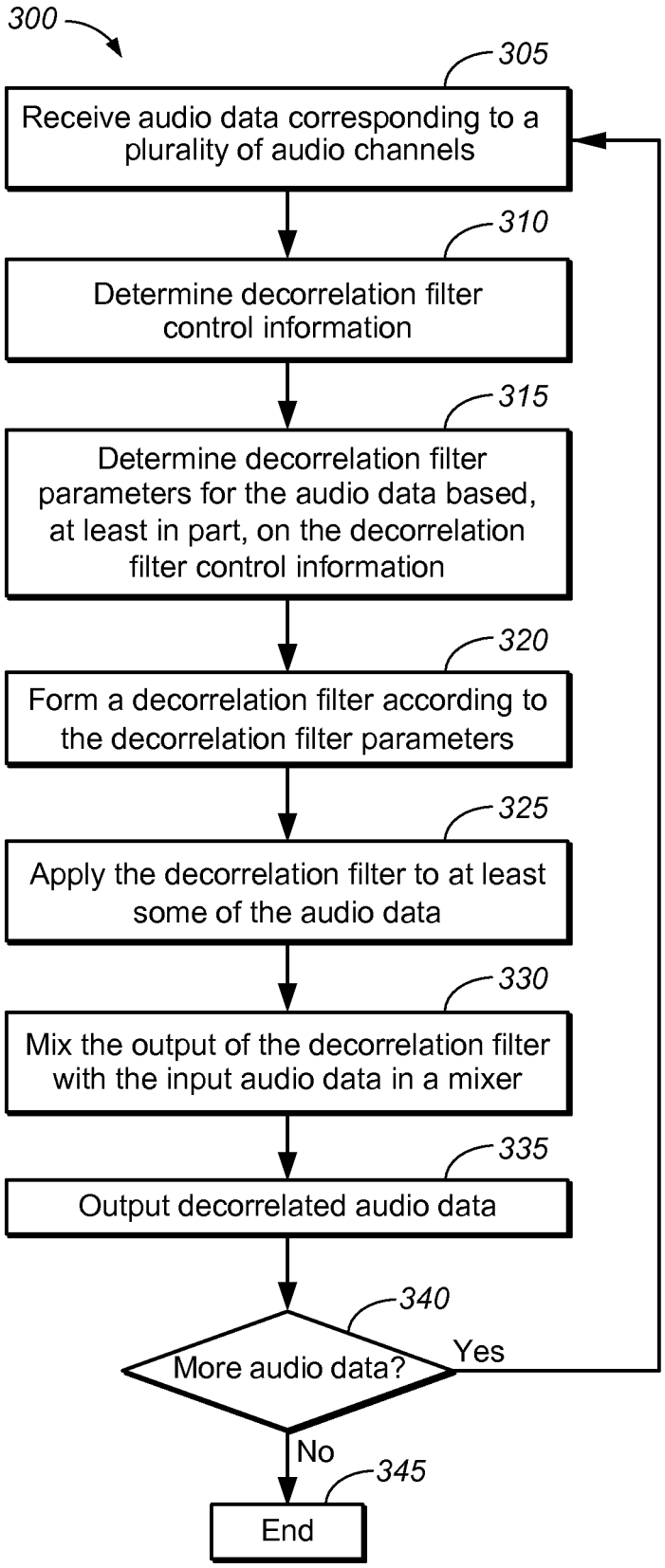

300
305
Receive audio data corresponding to a plurality of audio channels
310
Determine decorrelation filter control information
315
Determine decorrelation filter parameters for the audio data based, at least in part, on the decorrelation filter control information
320
Form a decorrelation filter according to the decorrelation filter parameters
325
Apply the decorrelation filter to at least some of the audio data
330
Mix the output of the decorrelation filter with the input audio data in a mixer
335
Output decorrelated audio data
340
More audio data?
Yes
No
345
End

FIG. 3

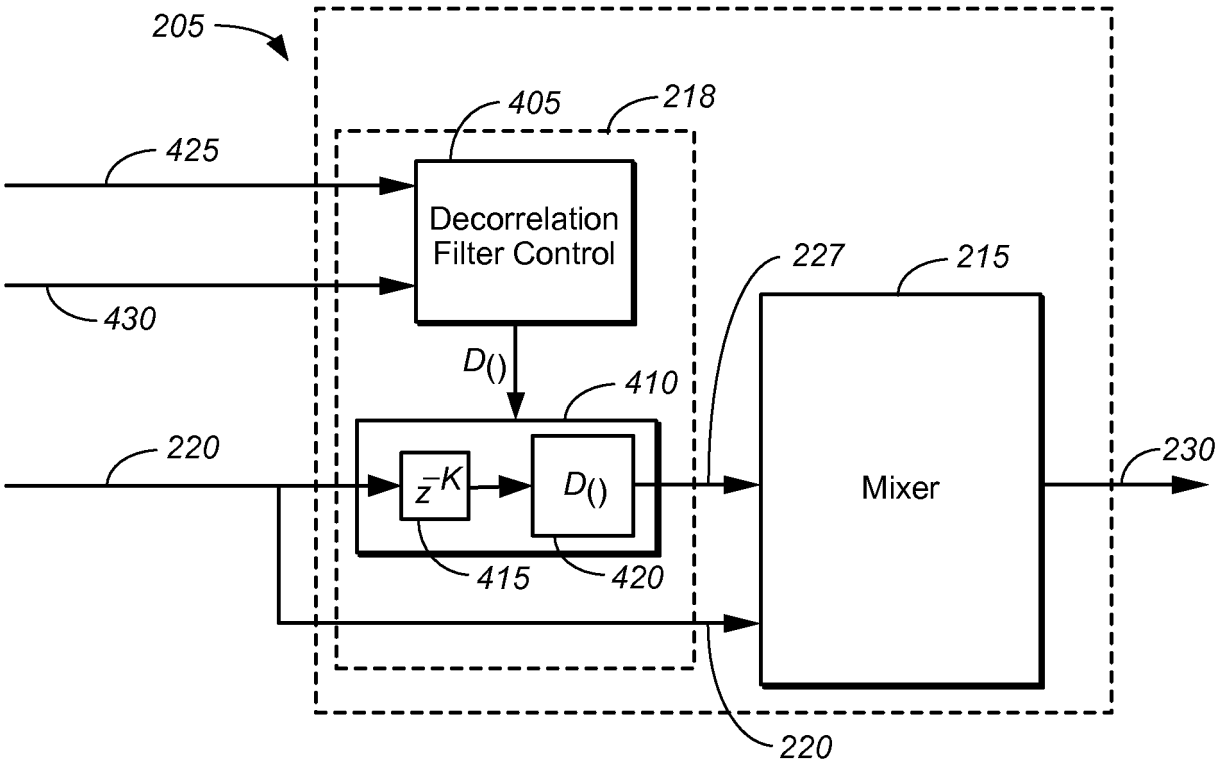

205
405
218
425
Decorrelation
Filter Control
227
215
430
D()
410
220
z^{-K}
D()
Mixer
230
415
420
220

FIG. 4

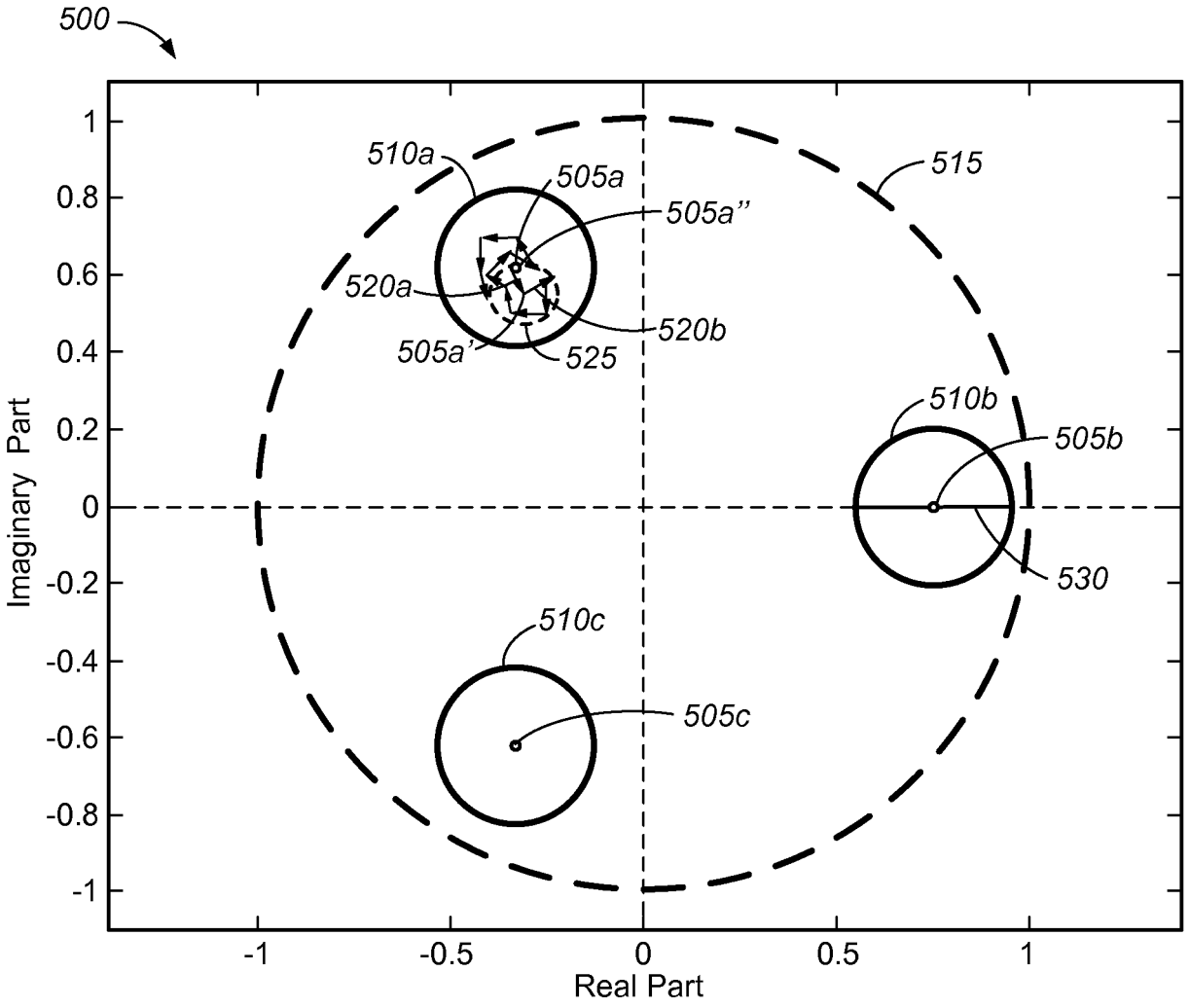

500
510a
505a
505a''
515
520a
520b
505a'
525
510b
505b
530
510c
505c
Imaginary Part
Real Part
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1

FIG. 5A

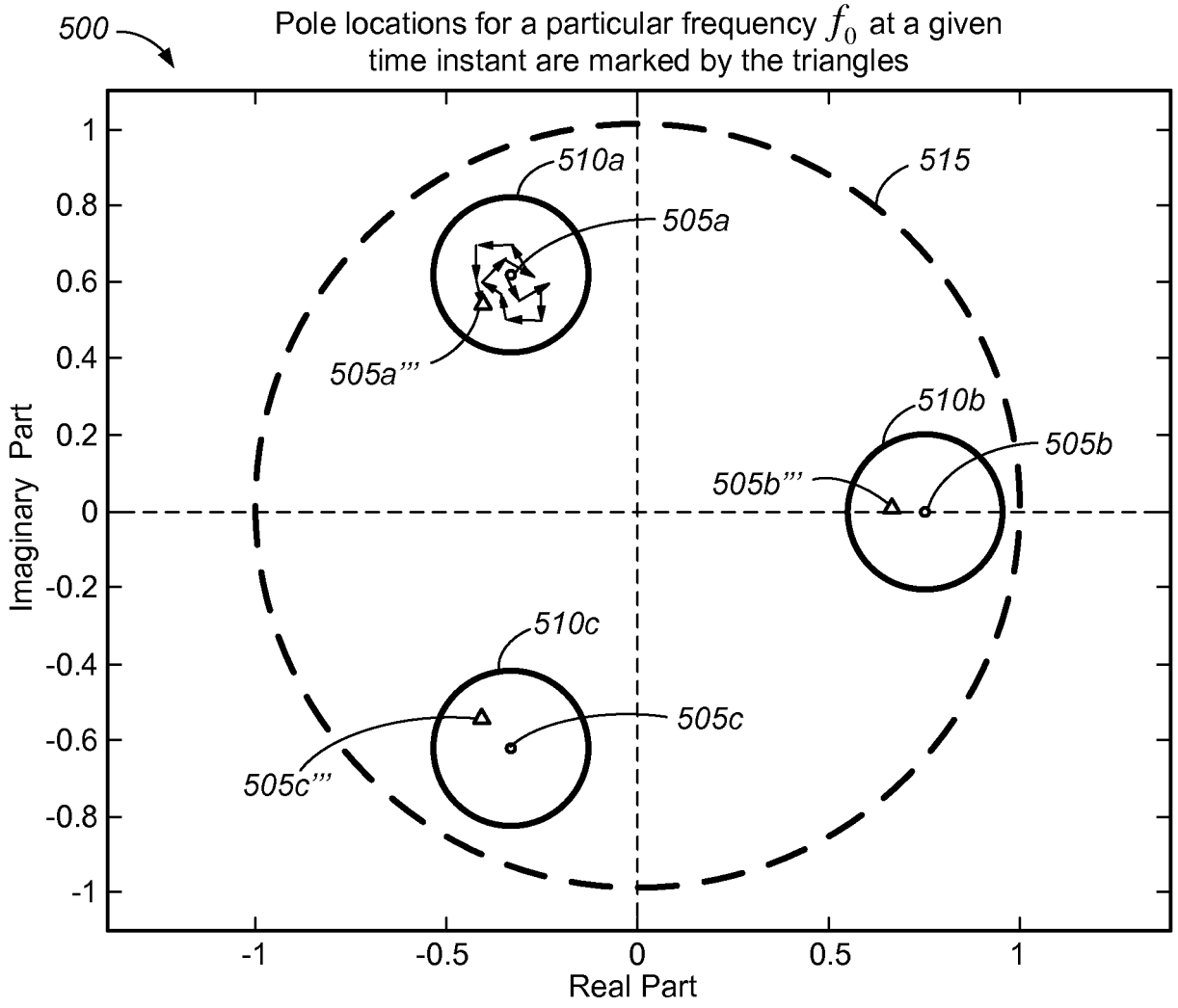

500
Pole locations for a particular frequency f_0 at a given time instant are marked by the triangles
510a
515
505a
505a'''
510b
505b
505b'''
510c
505c
505c'''
Imaginary Part
Real Part
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1

FIG. 5B

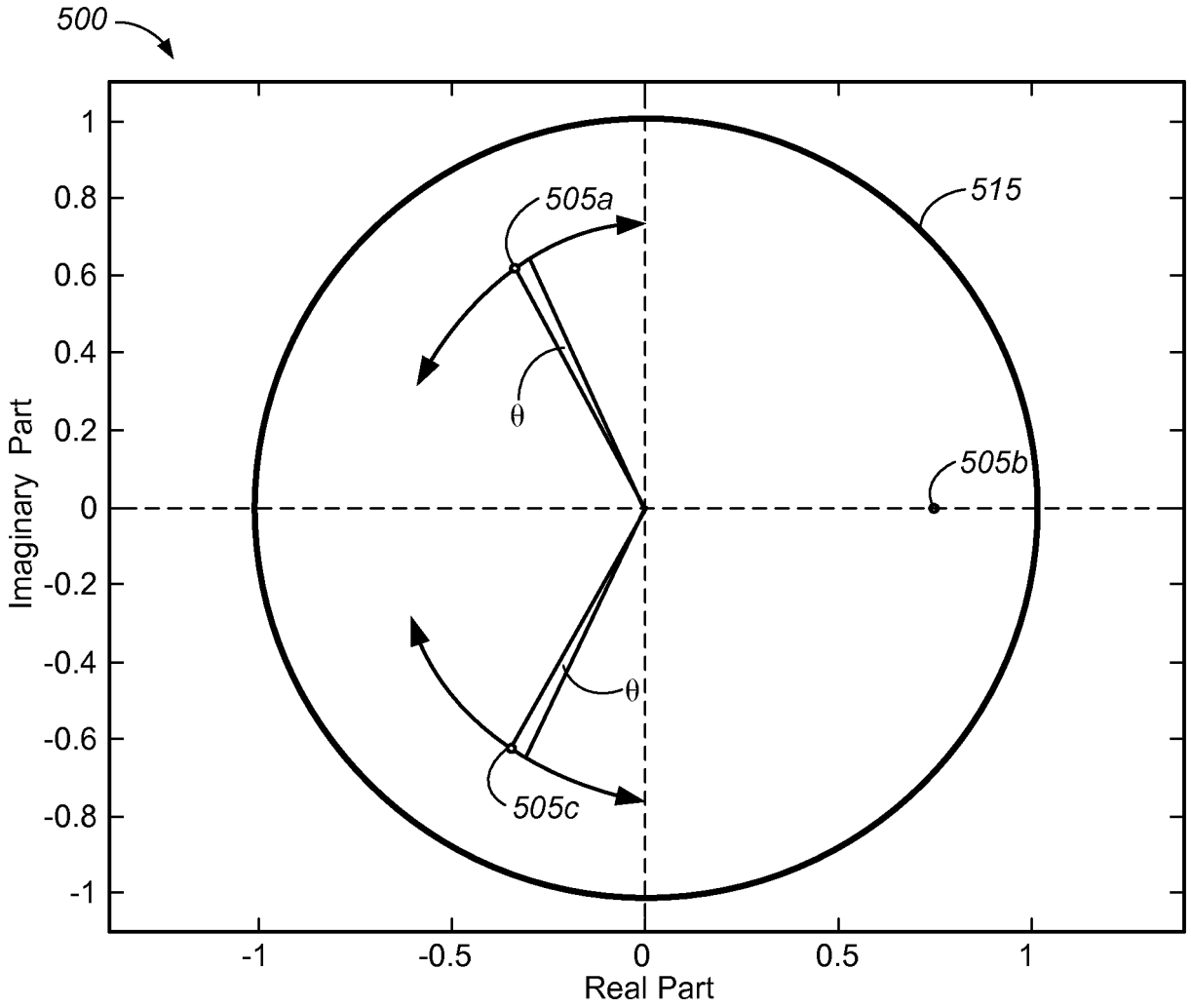

500
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Imaginary Part
-1
-0.5
0
0.5
1
Real Part
505a
515
θ
505b
θ
505c

FIG. 5C

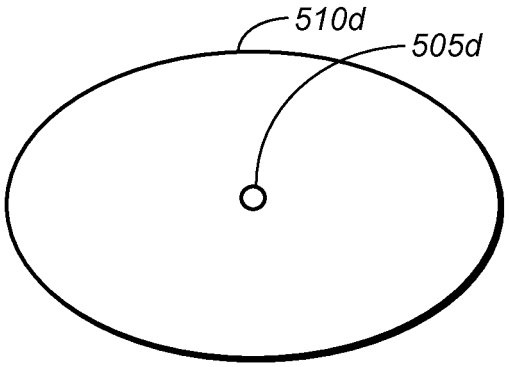


FIG. 5D

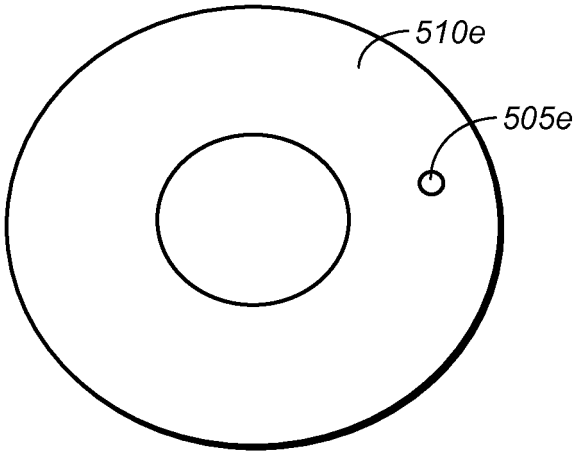


FIG. 5E

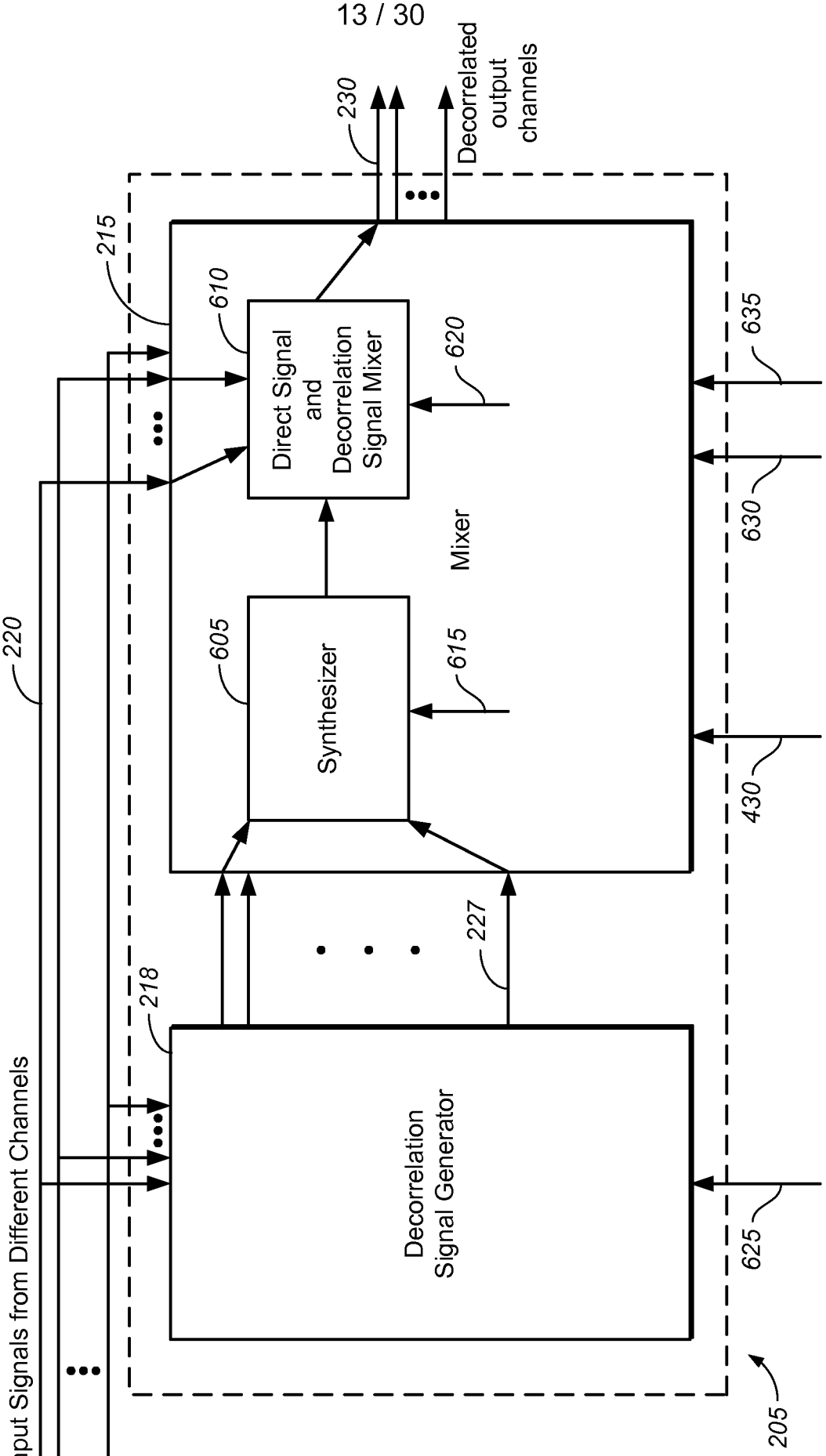

Input Signals from Different Channels
220
218
Decorrelation Signal Generator
227
605
Synthesizer
615
610
Direct Signal and Decorrelation Signal Mixer
620
Mixer
215
230
Decorrelated output channels
625
430
630
635
205

FIG. 6A

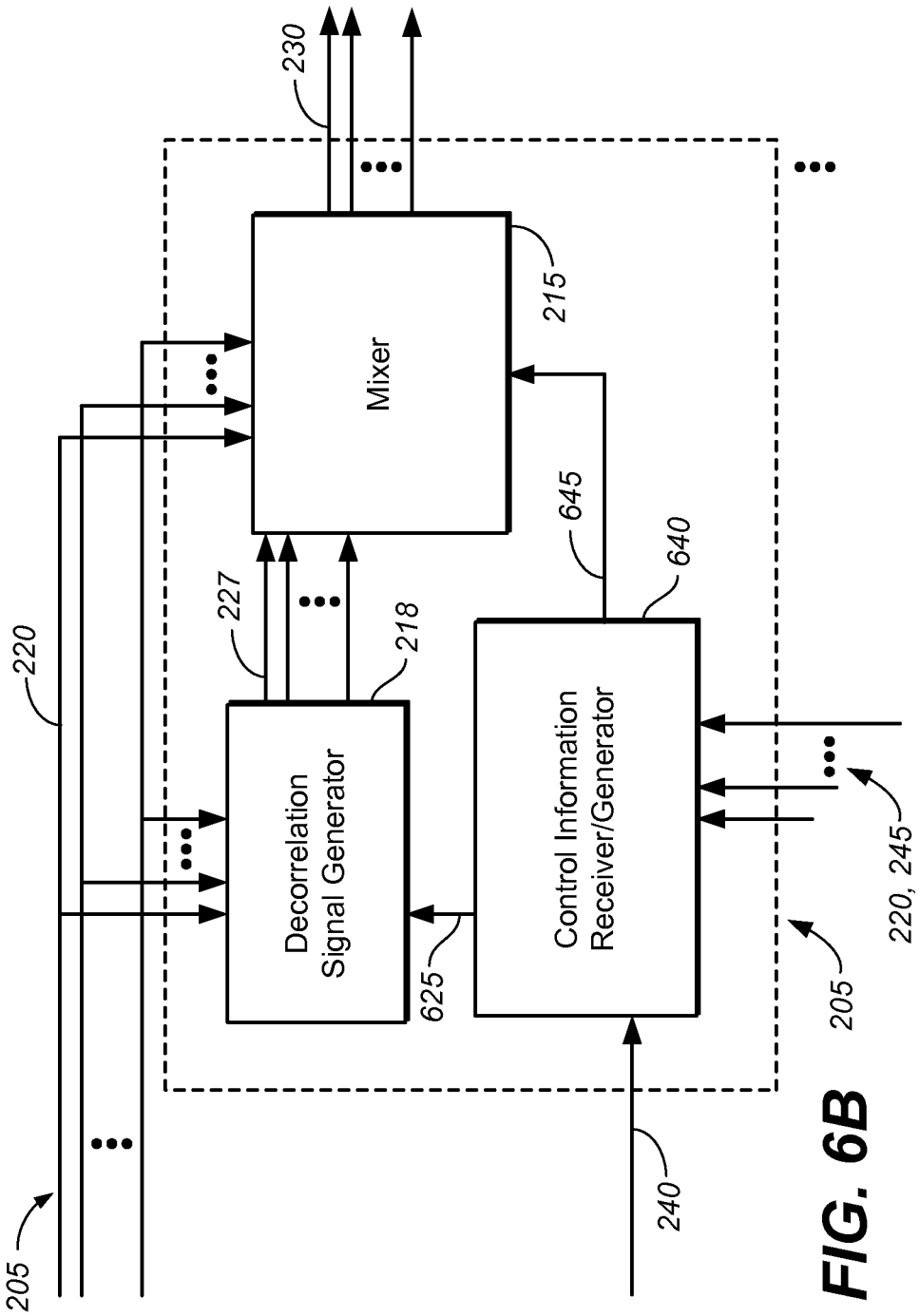

230
215
Mixer
645
640
227
218
220
Decorrelation Signal Generator
Control Information Receiver/Generator
625
220, 245
205
240
205

FIG. 6B

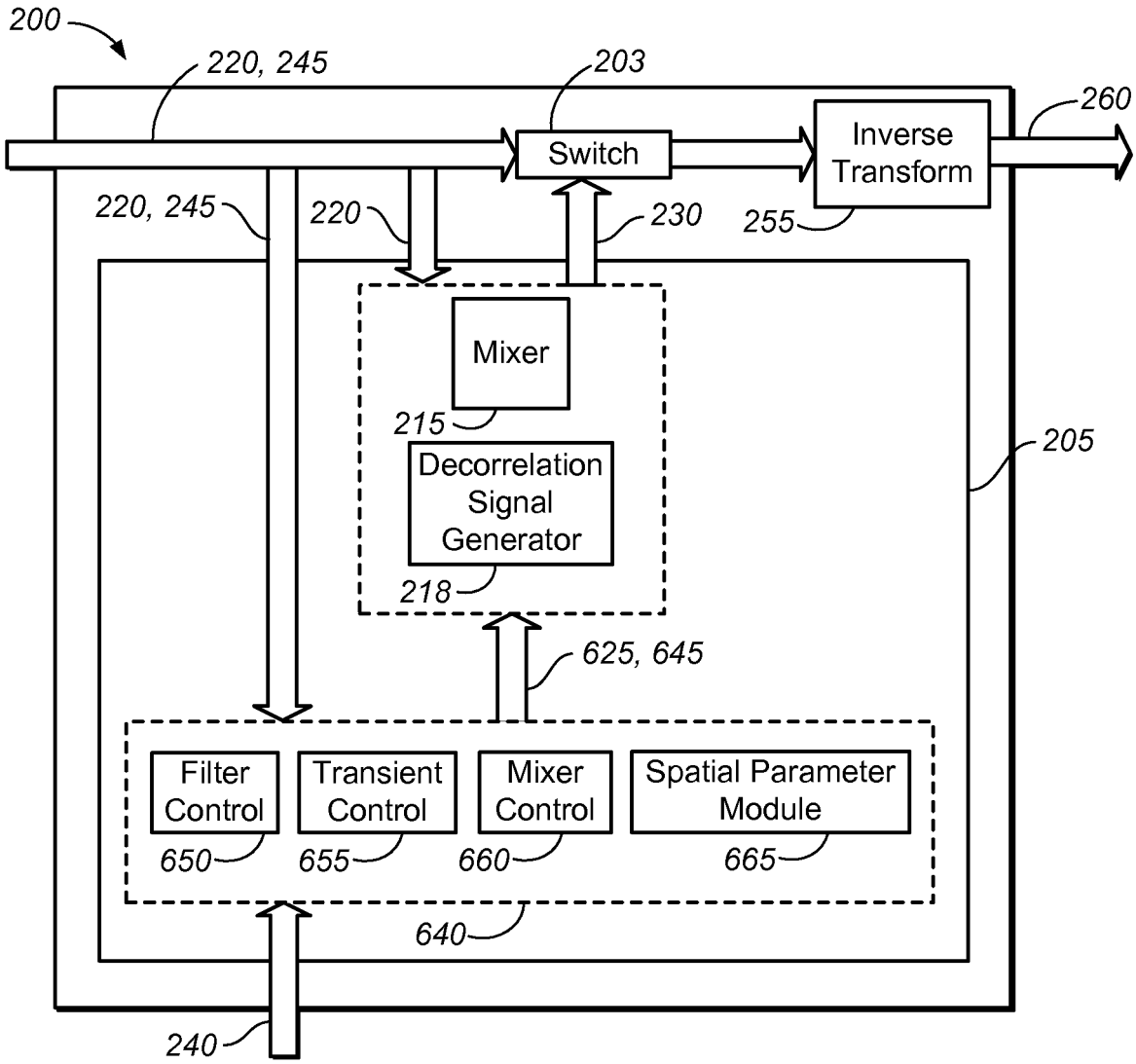

200
220, 245
203
260
Switch
Inverse Transform
220, 245
220
230
255
Mixer
215
Decorrelation Signal Generator
218
205
625, 645
Filter Control
Transient Control
Mixer Control
Spatial Parameter Module
650
655
660
665
640
240

FIG. 6C

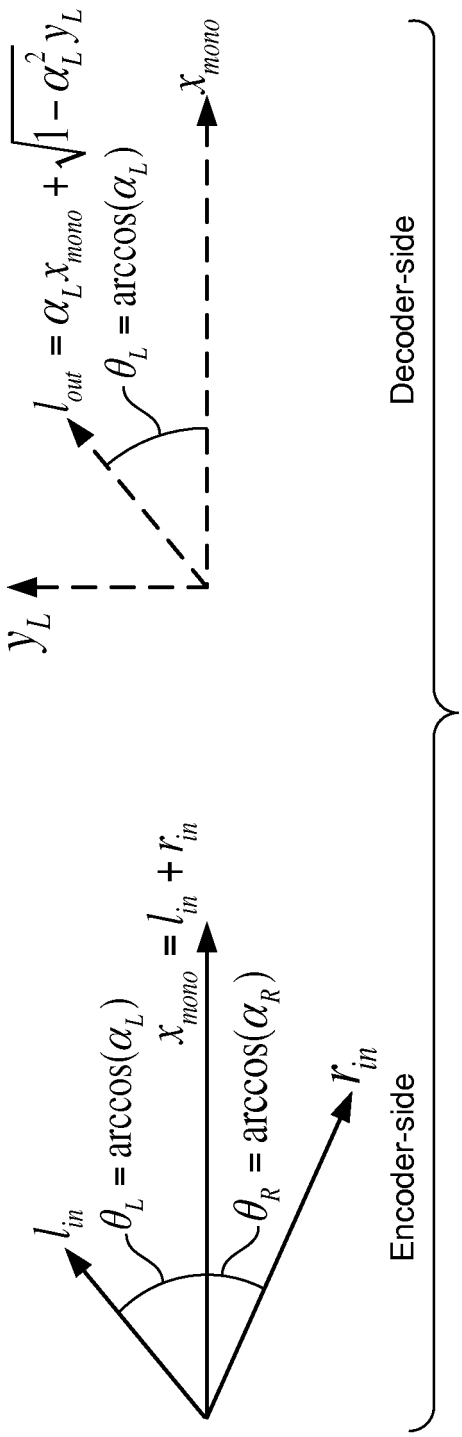

l_{in}
$\theta_L = \arccos(\alpha_L)$
$x_{mono} = l_{in} + r_{in}$
$\theta_R = \arccos(\alpha_R)$
r_{in}
Encoder-side
y_L
$l_{out} = \alpha_L x_{mono} + \sqrt{1-\alpha_L^2}\, y_L$
$\theta_L = \arccos(\alpha_L)$
x_{mono}
Decoder-side

FIG. 7A

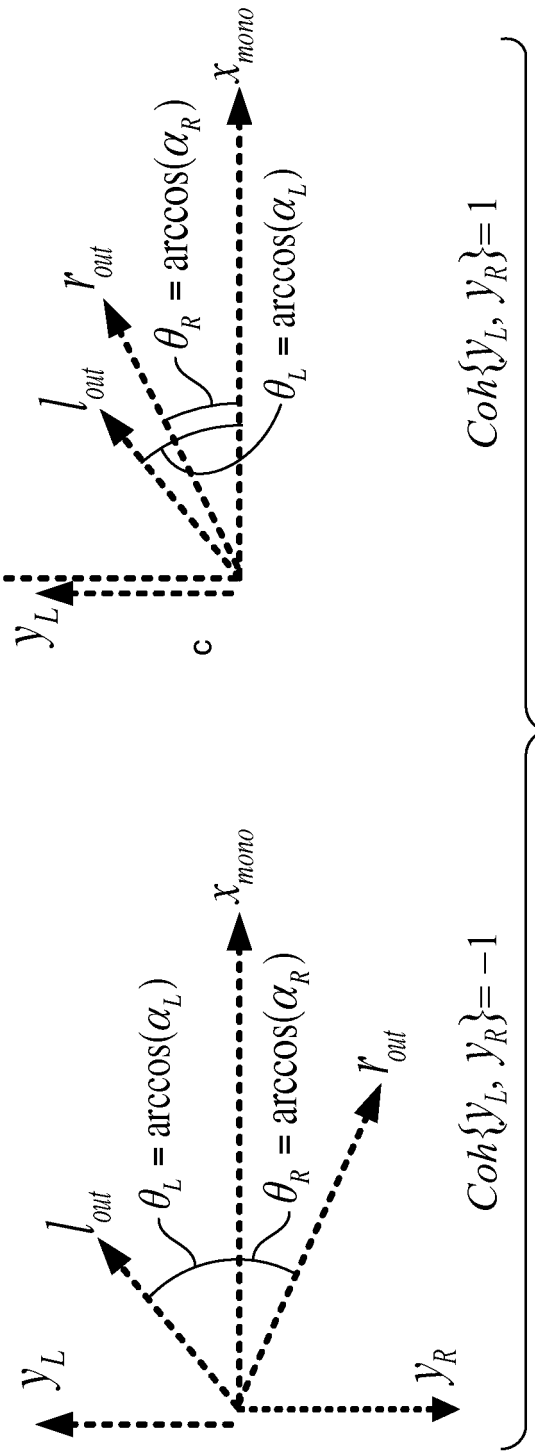

y_L
l_{out}
$\theta_L = \arccos(\alpha_L)$
x_{mono}
$\theta_R = \arccos(\alpha_R)$
r_{out}
y_R
$Coh\{y_L, y_R\} = -1$
y_R
y_L
l_{out}
r_{out}
$\theta_R = \arccos(\alpha_R)$
x_{mono}
$\theta_L = \arccos(\alpha_L)$
c
$Coh\{y_L, y_R\} = 1$

FIG. 7B

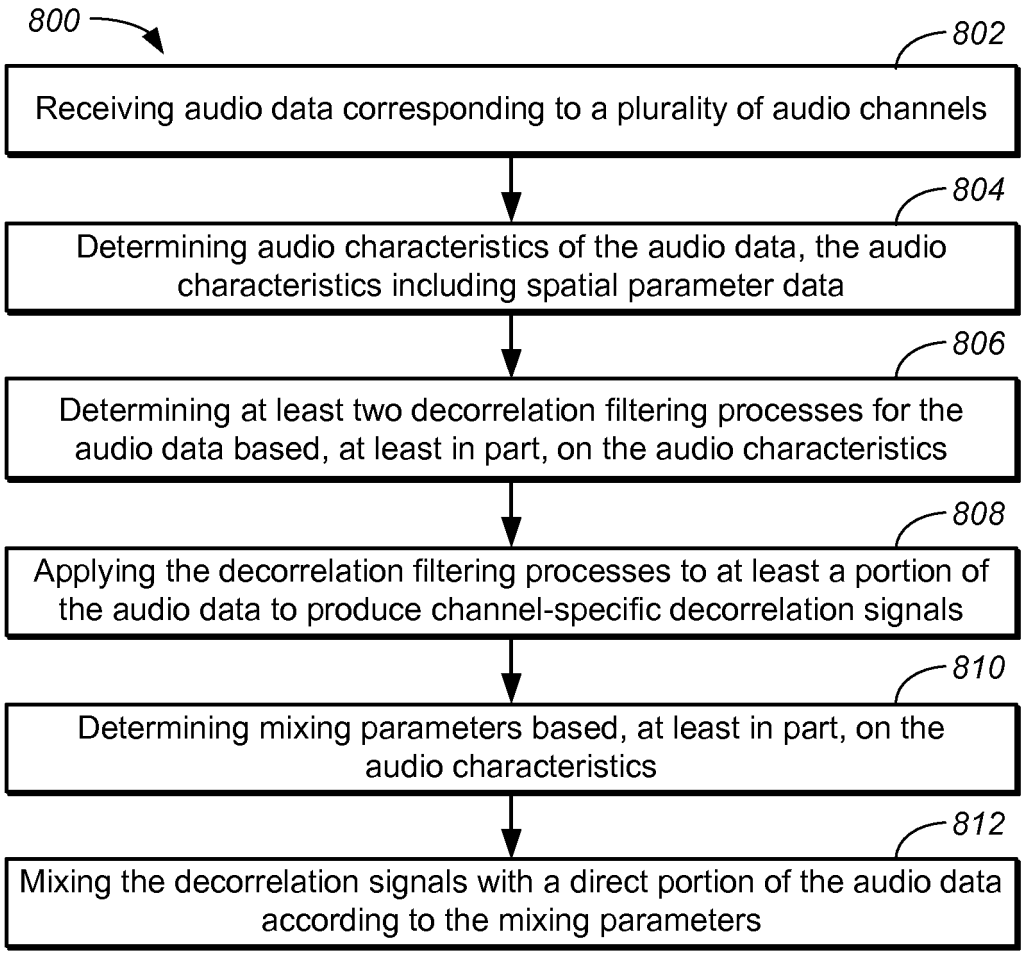

800
802
Receiving audio data corresponding to a plurality of audio channels
804
Determining audio characteristics of the audio data, the audio characteristics including spatial parameter data
806
Determining at least two decorrelation filtering processes for the audio data based, at least in part, on the audio characteristics
808
Applying the decorrelation filtering processes to at least a portion of the audio data to produce channel-specific decorrelation signals
810
Determining mixing parameters based, at least in part, on the audio characteristics
812
Mixing the decorrelation signals with a direct portion of the audio data according to the mixing parameters

FIG. 8A

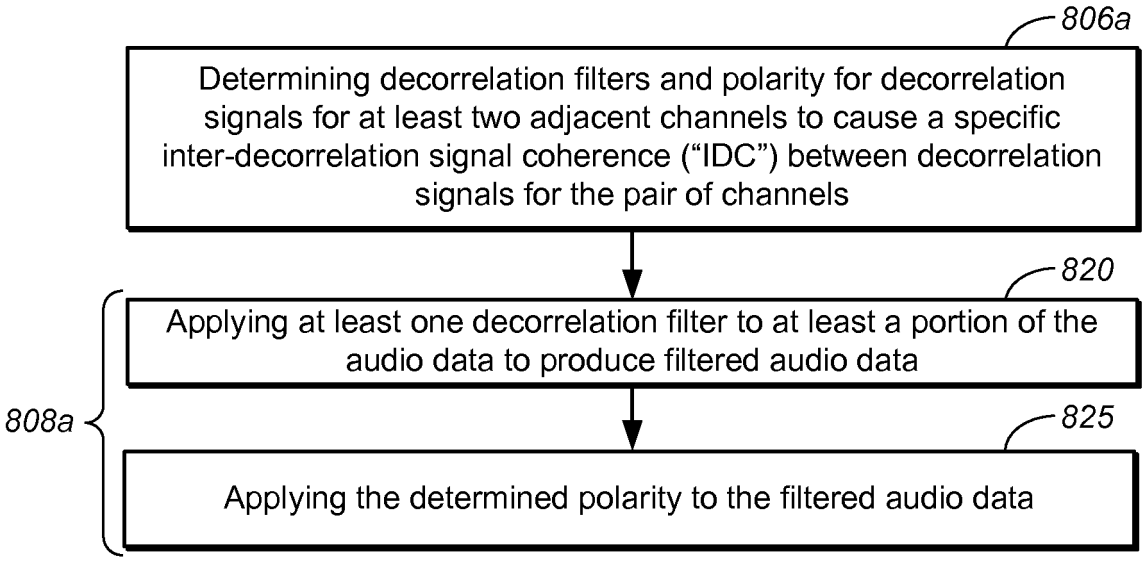

806a
Determining decorrelation filters and polarity for decorrelation signals for at least two adjacent channels to cause a specific inter-decorrelation signal coherence ("IDC") between decorrelation signals for the pair of channels
820
Applying at least one decorrelation filter to at least a portion of the audio data to produce filtered audio data
808a
825
Applying the determined polarity to the filtered audio data

FIG. 8B

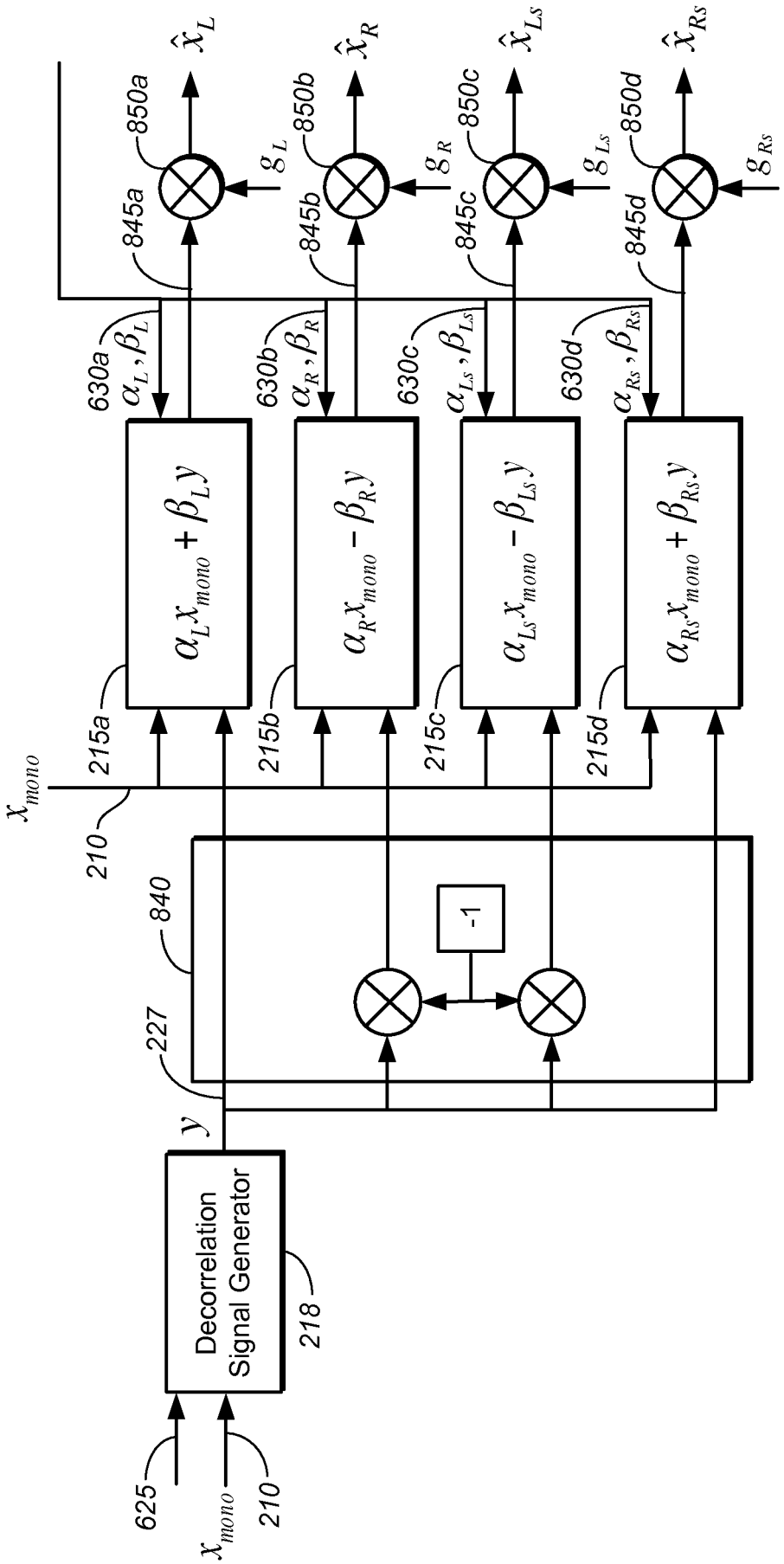

625
x_{mono}
210
Decorrelation Signal Generator
218
y
227
840
-1
x_{mono}
210
215a
215b
215c
215d
630a
α_L, β_L
630b
α_R, β_R
630c
α_{Ls}, β_{Ls}
630d
α_{Rs}, β_{Rs}
$\alpha_L x_{mono} + \beta_L y$
$\alpha_R x_{mono} - \beta_R y$
$\alpha_{Ls} x_{mono} - \beta_{Ls} y$
$\alpha_{Rs} x_{mono} + \beta_{Rs} y$
845a
845b
845c
845d
850a
850b
850c
850d
g_L
g_R
g_{Ls}
g_{Rs}
$\hat{x}_L$
$\hat{x}_R$
$\hat{x}_{Ls}$
$\hat{x}_{Rs}$

FIG. 8C

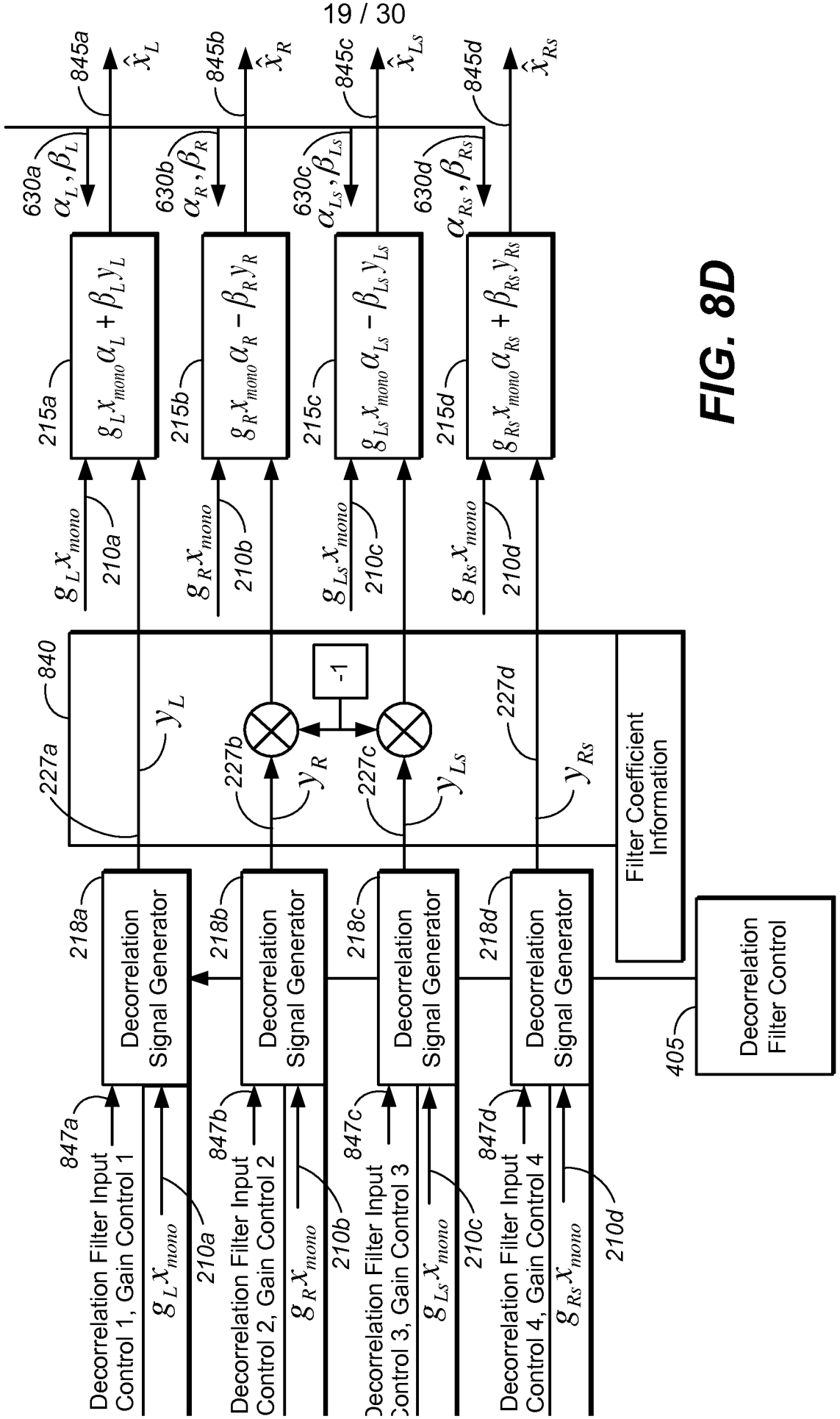

Decorrelation Filter Input Control 1, Gain Control 1
Decorrelation Filter Input Control 2, Gain Control 2
Decorrelation Filter Input Control 3, Gain Control 3
Decorrelation Filter Input Control 4, Gain Control 4
Decorrelation Signal Generator
Decorrelation Filter Control
Filter Coefficient Information
-1
$g_L x_{mono}$
$g_R x_{mono}$
$g_{Ls} x_{mono}$
$g_{Rs} x_{mono}$
$g_L x_{mono} \alpha_L + \beta_L y_L$
$g_R x_{mono} \alpha_R - \beta_R y_R$
$g_{Ls} x_{mono} \alpha_{Ls} - \beta_{Ls} y_{Ls}$
$g_{Rs} x_{mono} \alpha_{Rs} + \beta_{Rs} y_{Rs}$
α_L, β_L
α_R, β_R
α_{Ls}, β_{Ls}
α_{Rs}, β_{Rs}
y_L
y_R
y_{Ls}
y_{Rs}
$\hat{x}_L$
$\hat{x}_R$
$\hat{x}_{Ls}$
$\hat{x}_{Rs}$
210a
210b
210c
210d
215a
215b
215c
215d
218a
218b
218c
218d
227a
227b
227c
227d
405
630a
630b
630c
630d
840
845a
845b
845c
845d
847a
847b
847c
847d

FIG. 8D

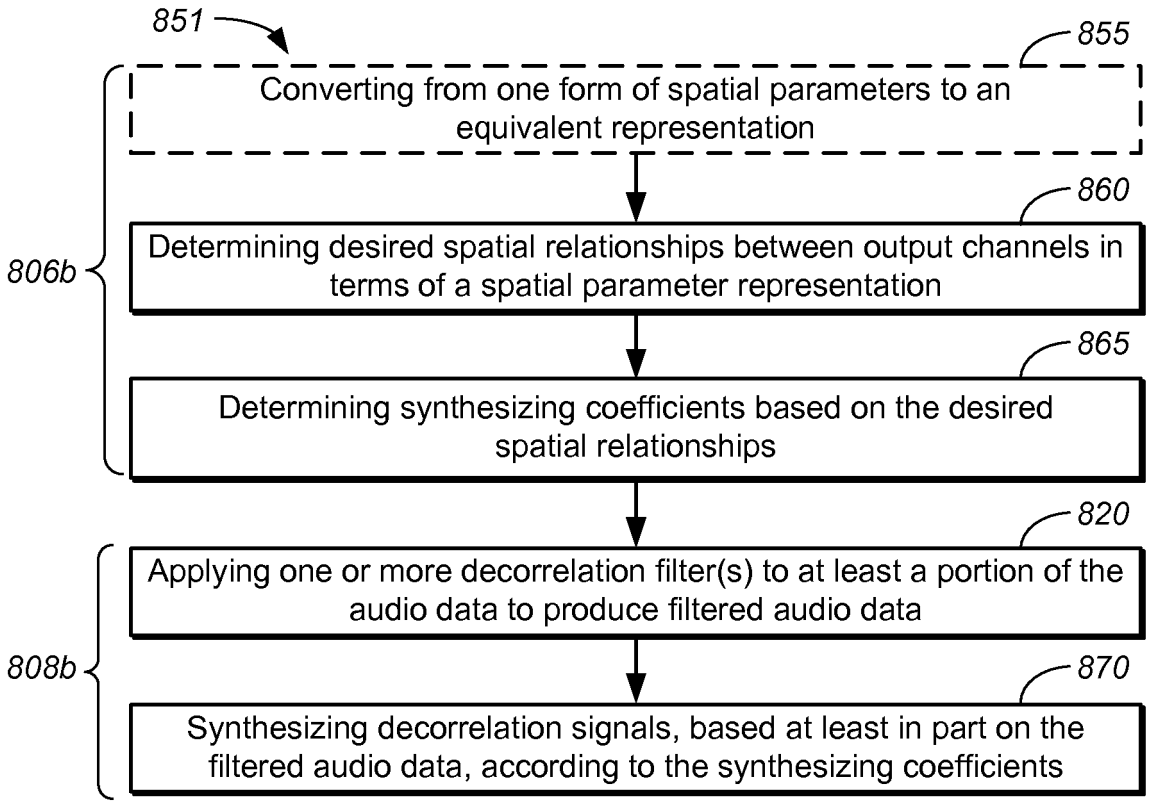

851
855
Converting from one form of spatial parameters to an equivalent representation
860
Determining desired spatial relationships between output channels in terms of a spatial parameter representation
806b
865
Determining synthesizing coefficients based on the desired spatial relationships
820
Applying one or more decorrelation filter(s) to at least a portion of the audio data to produce filtered audio data
808b
870
Synthesizing decorrelation signals, based at least in part on the filtered audio data, according to the synthesizing coefficients

FIG. 8E

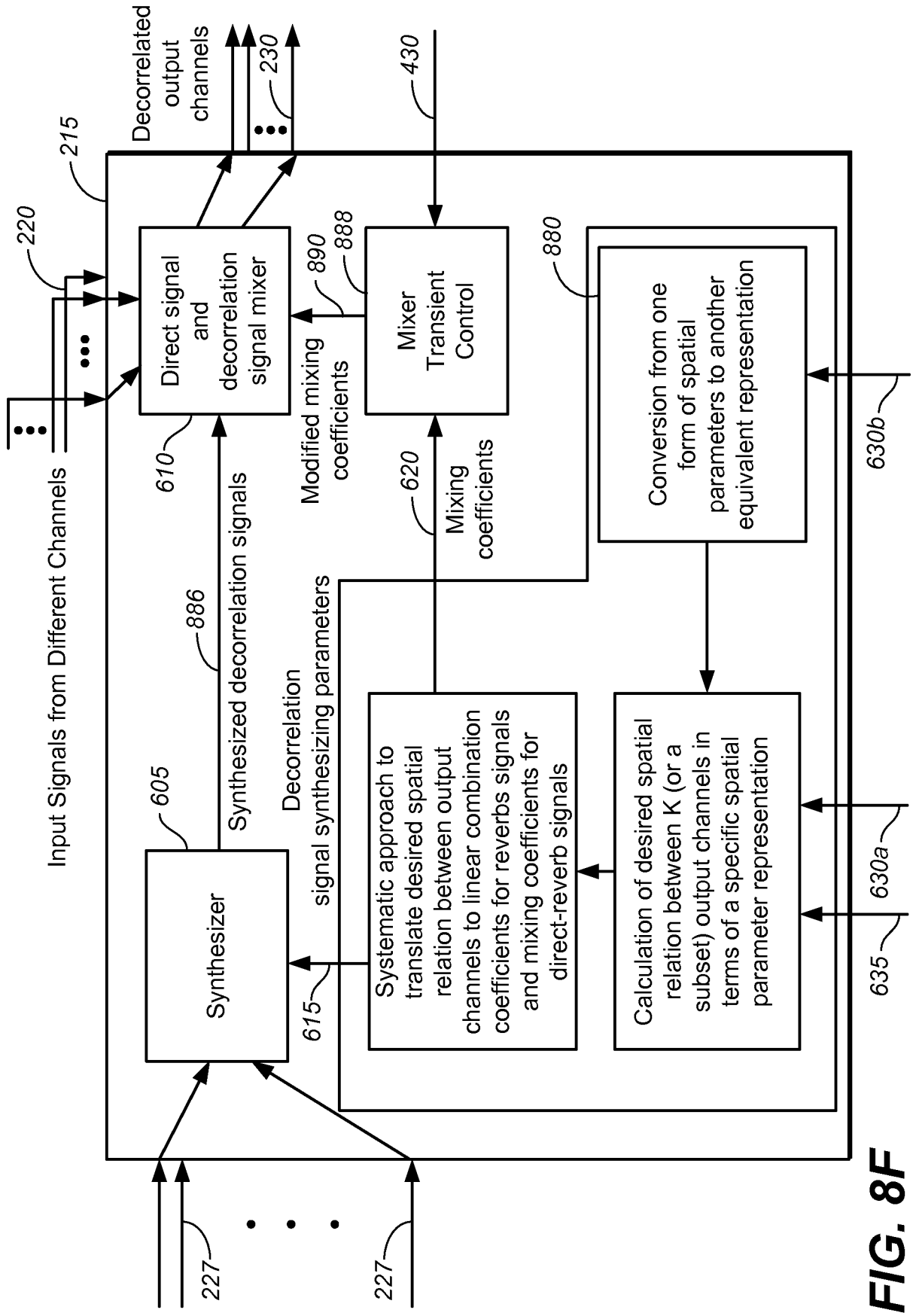

Input Signals from Different Channels
220
215
Decorrelated output channels
230
430
Direct signal and decorrelation signal mixer
610
Modified mixing coefficients
890
888
Mixer Transient Control
880
Conversion from one form of spatial parameters to another equivalent representation
630b
Mixing coefficients
620
886
Synthesized decorrelation signals
Decorrelation signal synthesizing parameters
605
Synthesizer
615
Systematic approach to translate desired spatial relation between output channels to linear combination coefficients for reverbs signals and mixing coefficients for direct-reverb signals
Calculation of desired spatial relation between K (or a subset) output channels in terms of a specific spatial parameter representation
630a
635
227
227

FIG. 8F

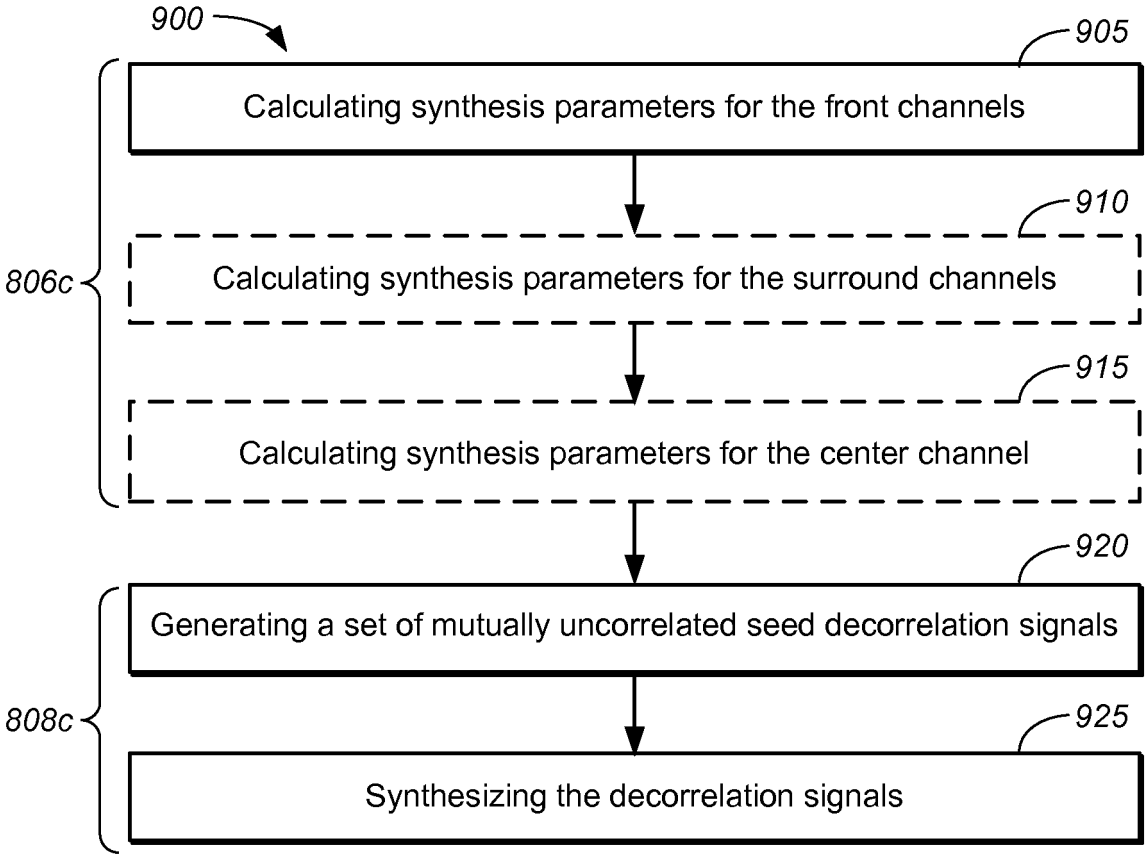

900
905
Calculating synthesis parameters for the front channels
910
Calculating synthesis parameters for the surround channels
915
Calculating synthesis parameters for the center channel
806c
920
Generating a set of mutually uncorrelated seed decorrelation signals
925
Synthesizing the decorrelation signals
808c

FIG. 9

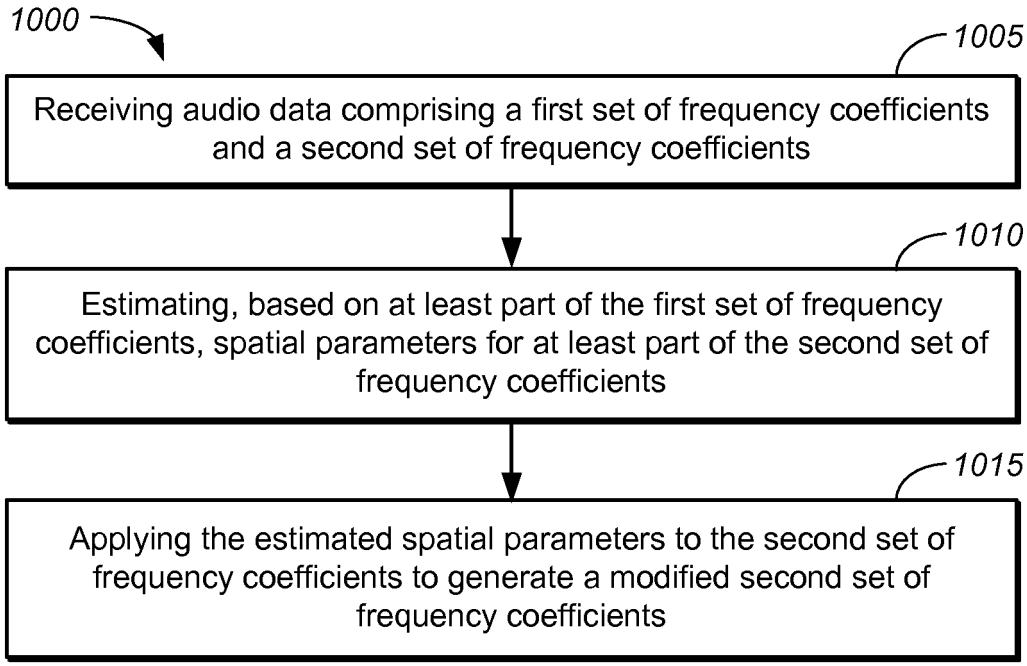

1000
1005
Receiving audio data comprising a first set of frequency coefficients and a second set of frequency coefficients
1010
Estimating, based on at least part of the first set of frequency coefficients, spatial parameters for at least part of the second set of frequency coefficients
1015
Applying the estimated spatial parameters to the second set of frequency coefficients to generate a modified second set of frequency coefficients

FIG. 10A

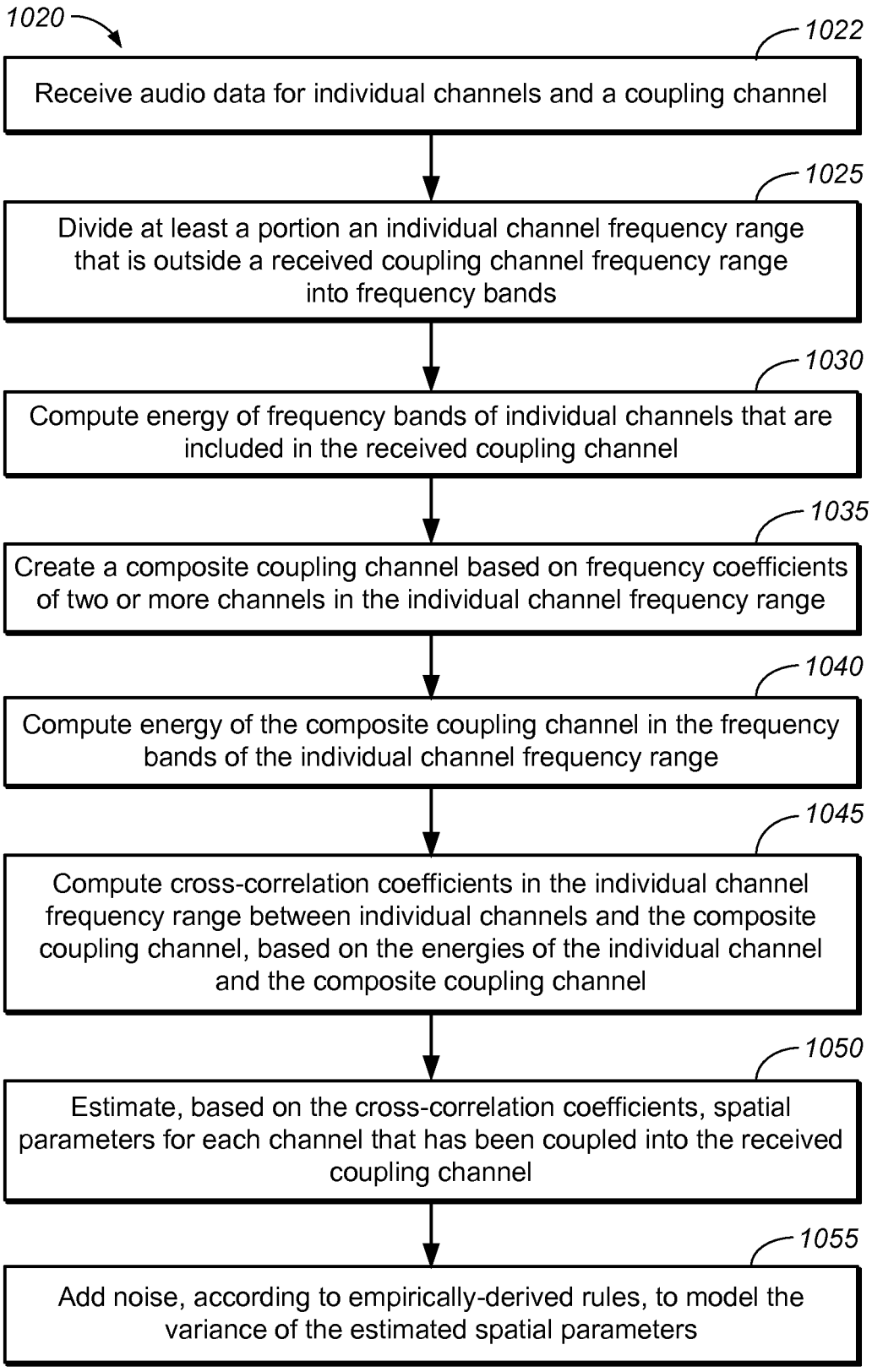

1020
1022
Receive audio data for individual channels and a coupling channel
1025
Divide at least a portion an individual channel frequency range that is outside a received coupling channel frequency range into frequency bands
1030
Compute energy of frequency bands of individual channels that are included in the received coupling channel
1035
Create a composite coupling channel based on frequency coefficients of two or more channels in the individual channel frequency range
1040
Compute energy of the composite coupling channel in the frequency bands of the individual channel frequency range
1045
Compute cross-correlation coefficients in the individual channel frequency range between individual channels and the composite coupling channel, based on the energies of the individual channel and the composite coupling channel
1050
Estimate, based on the cross-correlation coefficients, spatial parameters for each channel that has been coupled into the received coupling channel
1055
Add noise, according to empirically-derived rules, to model the variance of the estimated spatial parameters

FIG. 10B

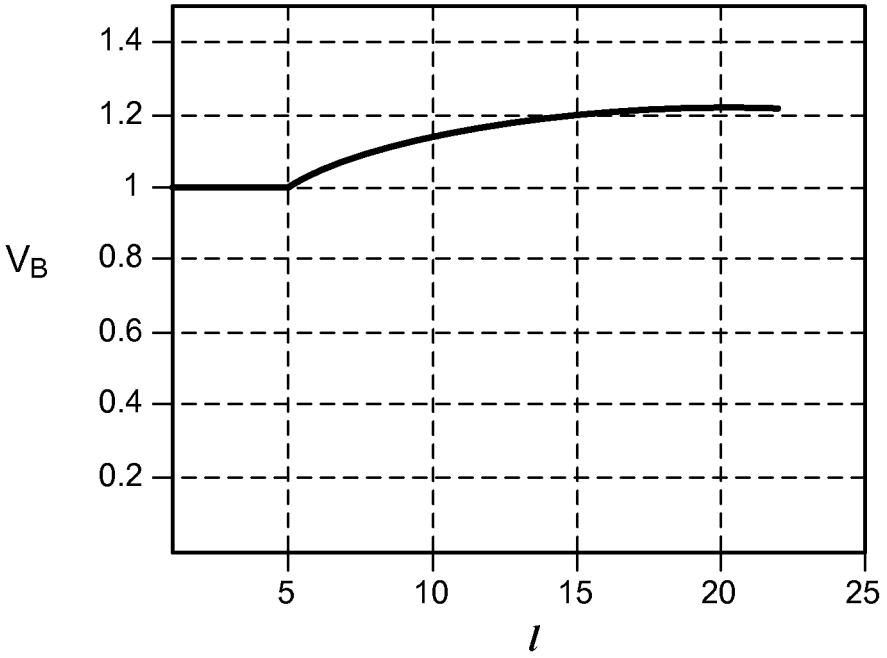


FIG. 10C

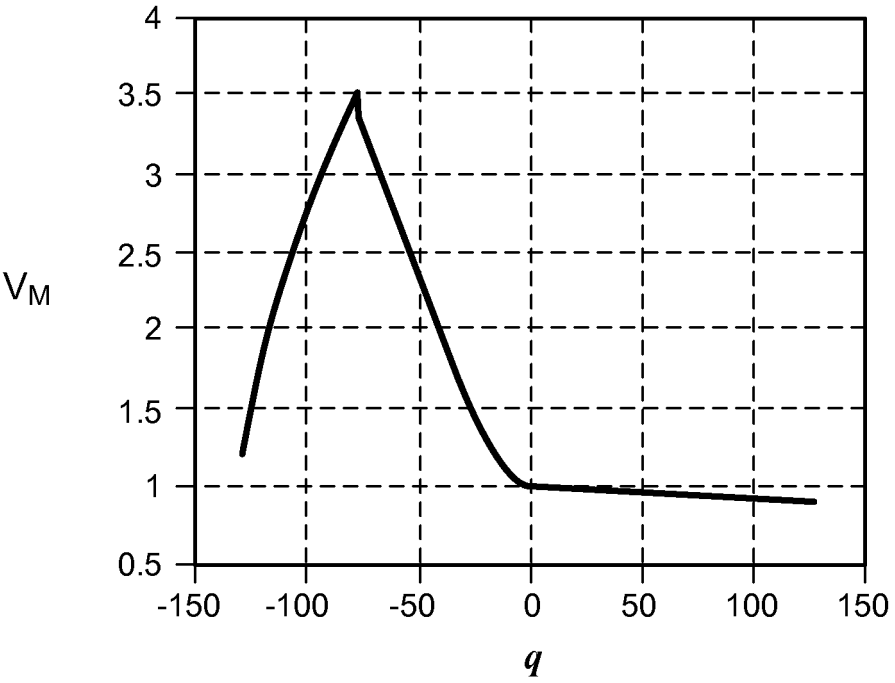


FIG. 10D

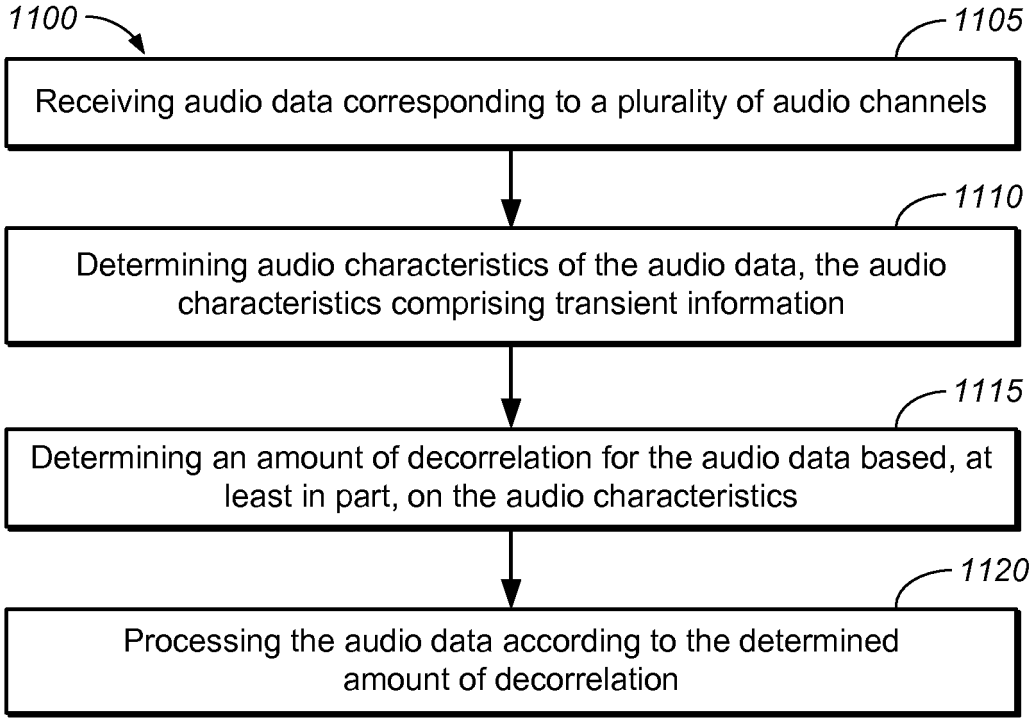

1100
1105
Receiving audio data corresponding to a plurality of audio channels
1110
Determining audio characteristics of the audio data, the audio characteristics comprising transient information
1115
Determining an amount of decorrelation for the audio data based, at least in part, on the audio characteristics
1120
Processing the audio data according to the determined amount of decorrelation

FIG. 11A

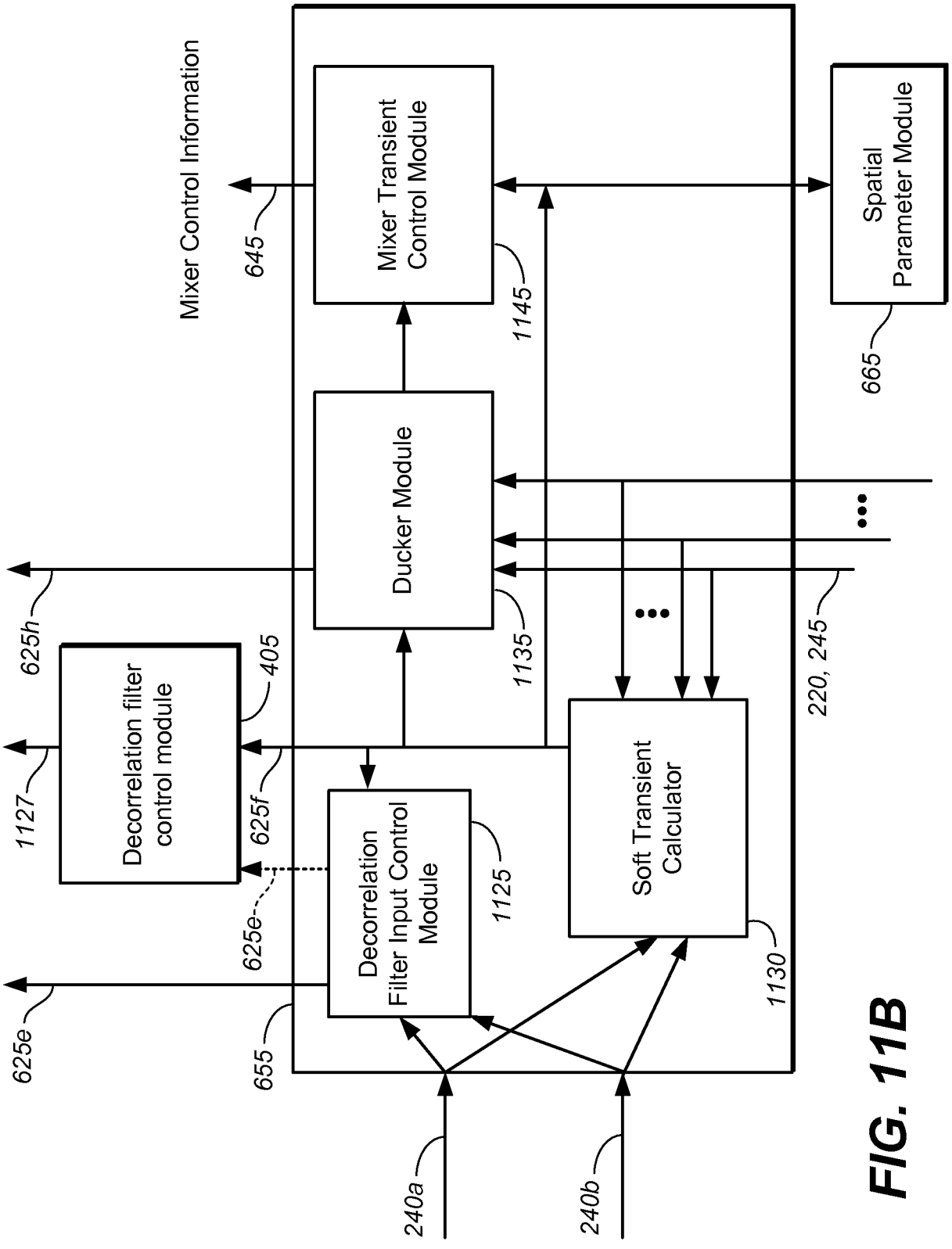

Mixer Control Information
645
Mixer Transient Control Module
1145
Spatial Parameter Module
665
Ducker Module
1135
625h
220, 245
Decorrelation filter control module
405
1127
625f
625e
Decorrelation Filter Input Control Module
1125
Soft Transient Calculator
1130
625e
655
240a
240b

FIG. 11B

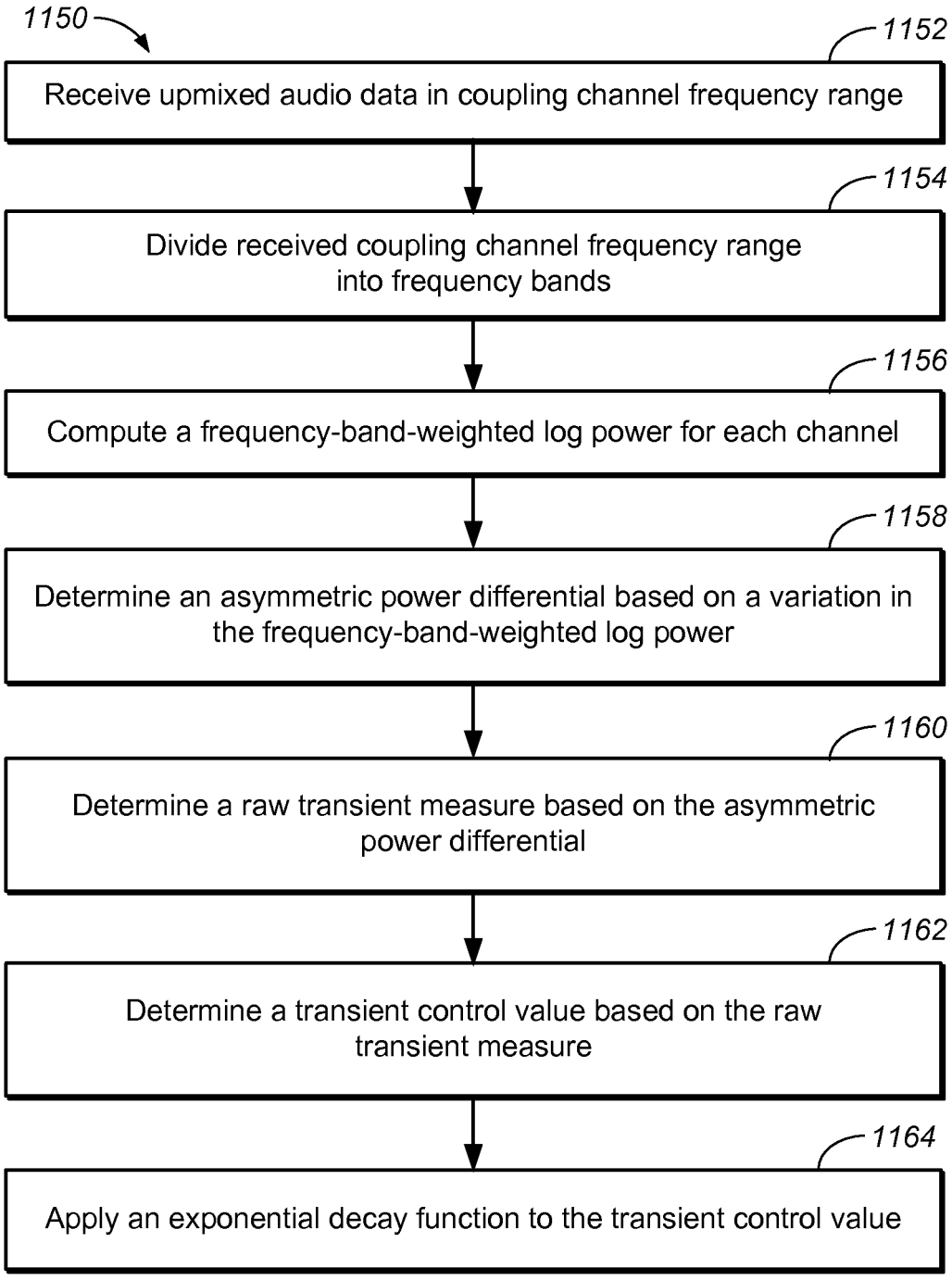

1150
1152
Receive upmixed audio data in coupling channel frequency range
1154
Divide received coupling channel frequency range into frequency bands
1156
Compute a frequency-band-weighted log power for each channel
1158
Determine an asymmetric power differential based on a variation in the frequency-band-weighted log power
1160
Determine a raw transient measure based on the asymmetric power differential
1162
Determine a transient control value based on the raw transient measure
1164
Apply an exponential decay function to the transient control value

FIG. 11C

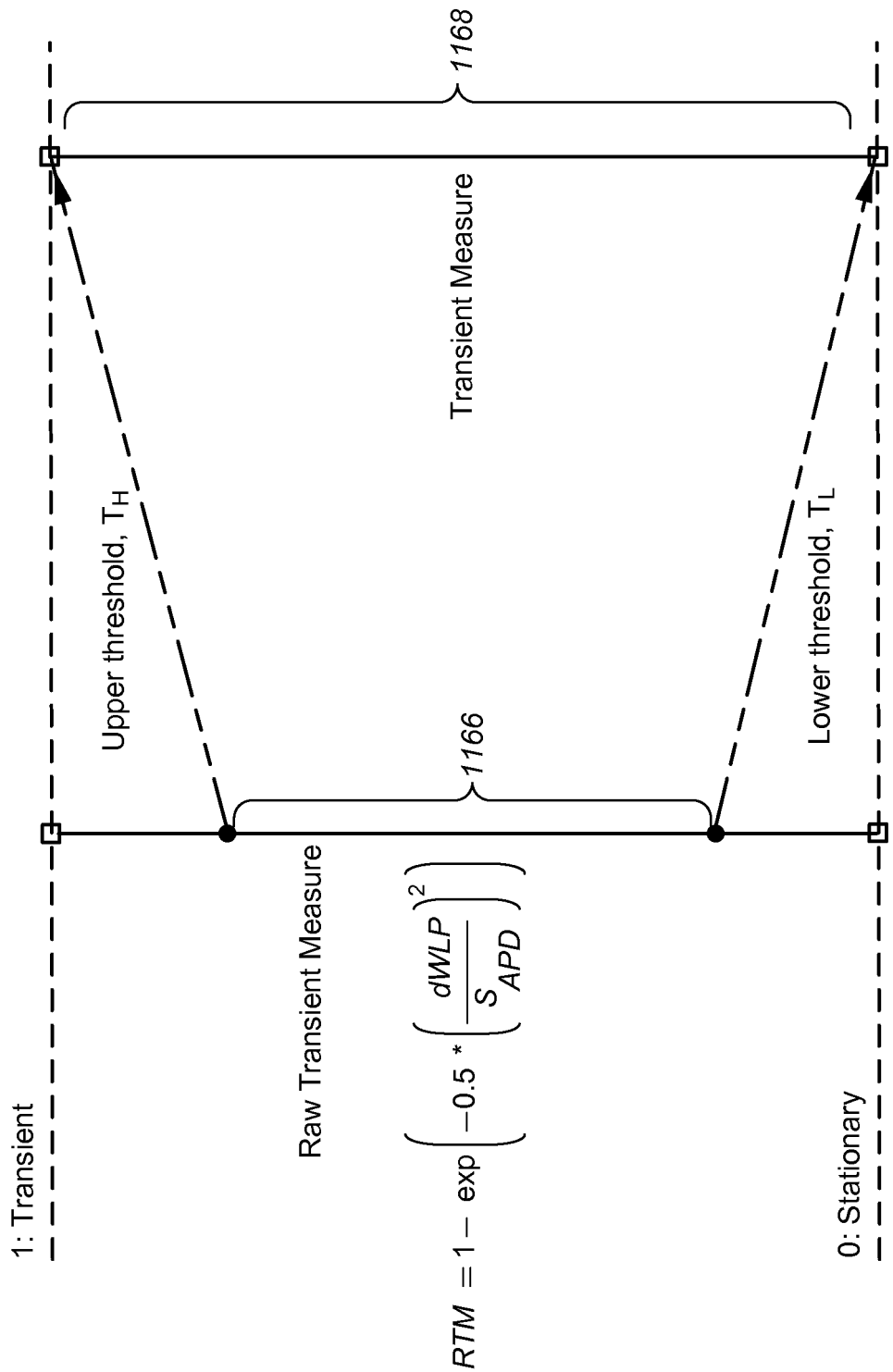

1168
Transient Measure
Upper threshold, T_H
Lower threshold, T_L
1166
Raw Transient Measure
$RTM = 1 - \exp\left(-0.5 * \left(\frac{dWLP}{S_{APD}}\right)^2\right)$
1: Transient
0: Stationary

FIG. 11D

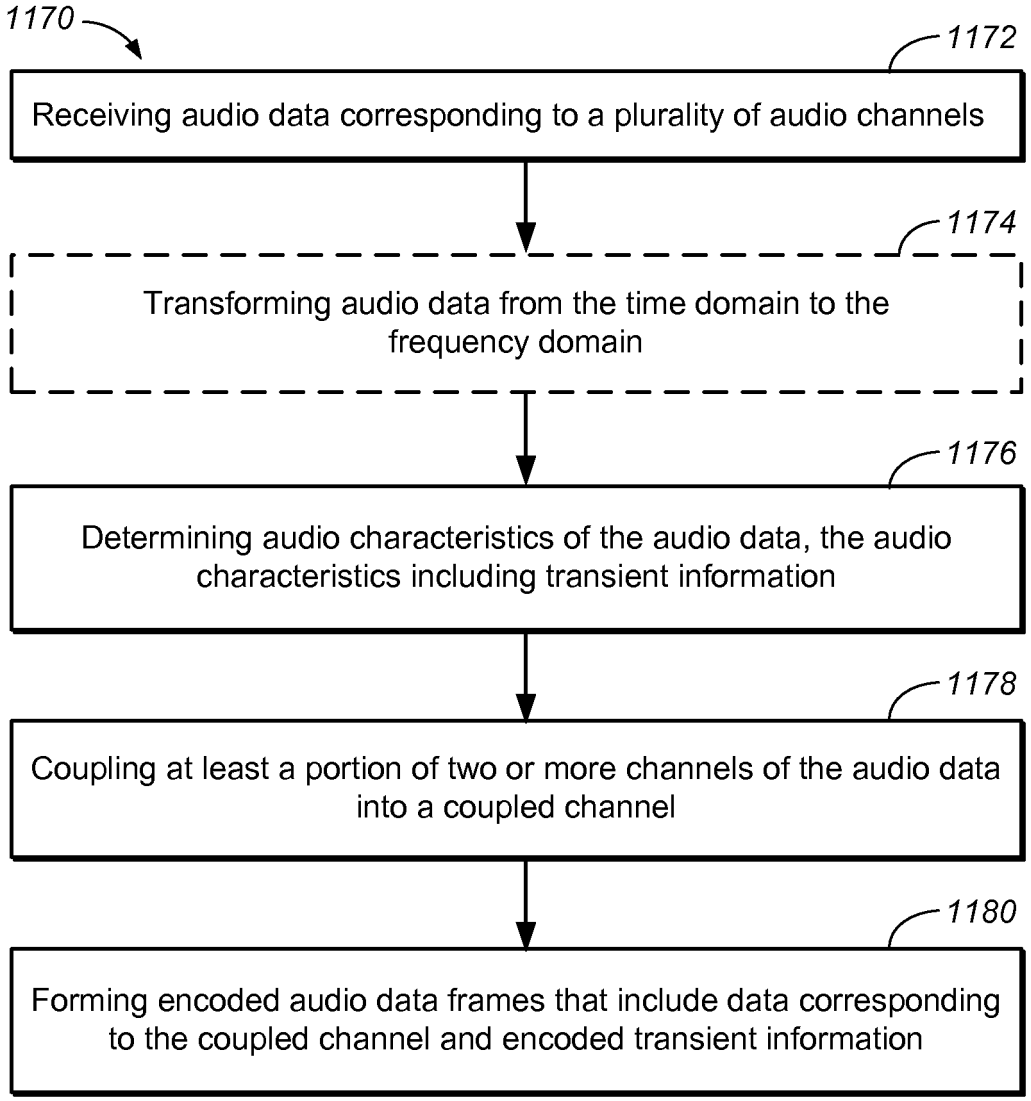

1170
1172
Receiving audio data corresponding to a plurality of audio channels
1174
Transforming audio data from the time domain to the frequency domain
1176
Determining audio characteristics of the audio data, the audio characteristics including transient information
1178
Coupling at least a portion of two or more channels of the audio data into a coupled channel
1180
Forming encoded audio data frames that include data corresponding to the coupled channel and encoded transient information

FIG. 11E

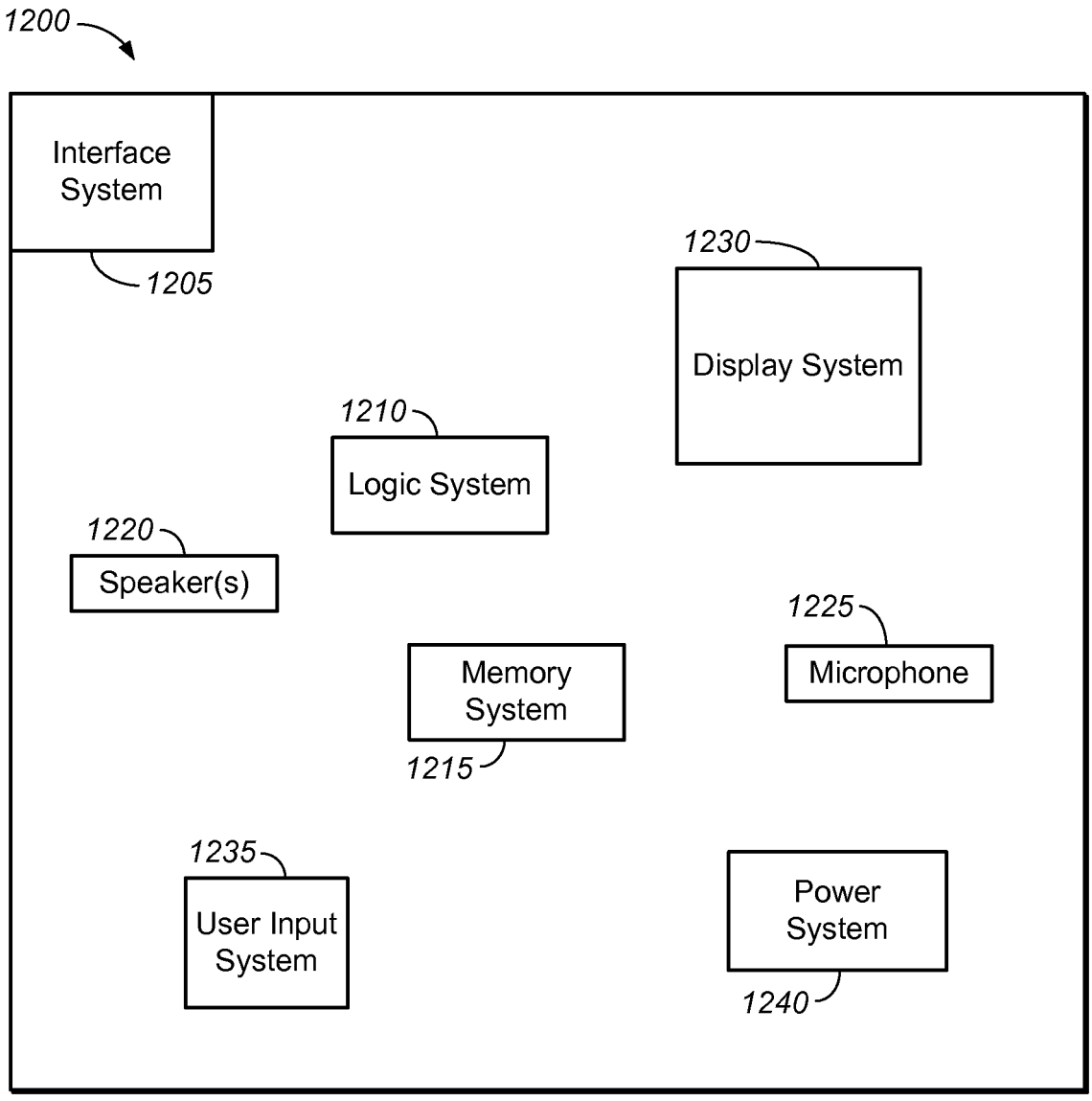

1200
Interface System
1205
1230
Display System
1210
Logic System
1220
Speaker(s)
1225
Microphone
Memory System
1215
1235
User Input System
Power System
1240

FIG. 12