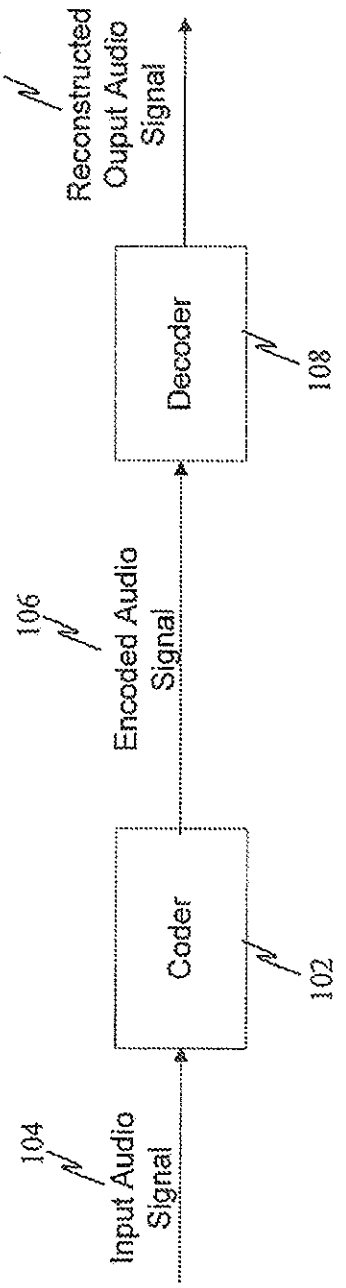

110
Reconstructed Ouput Audio Signal
Decoder
108
106
Encoded Audio Signal
Coder
102
104
Input Audio Signal

FIGURE 1

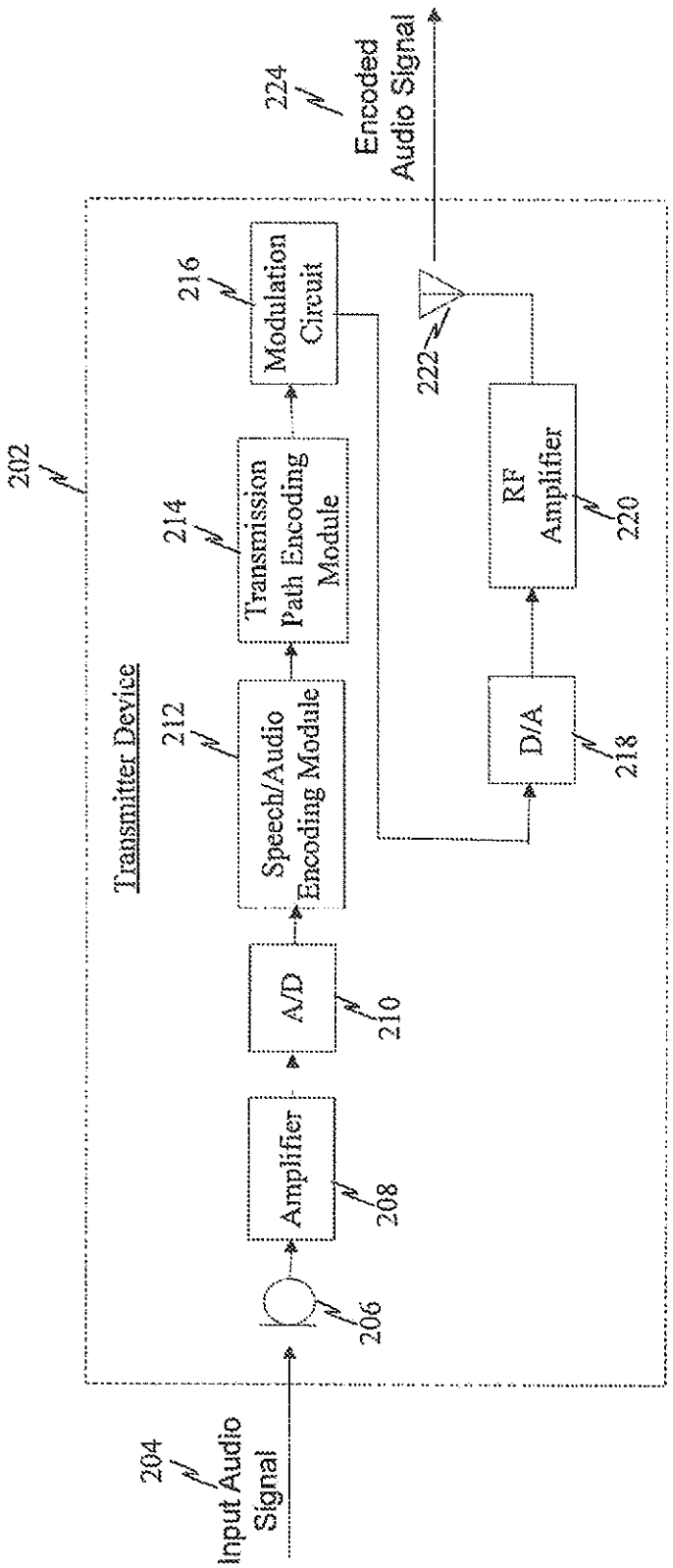

Input Audio Signal
204
Transmitter Device
202
206
Amplifier
208
A/D
210
Speech/Audio Encoding Module
212
Transmission Path Encoding Module
214
Modulation Circuit
216
D/A
218
RF Amplifier
220
222
224
Encoded Audio Signal

FIGURE 2

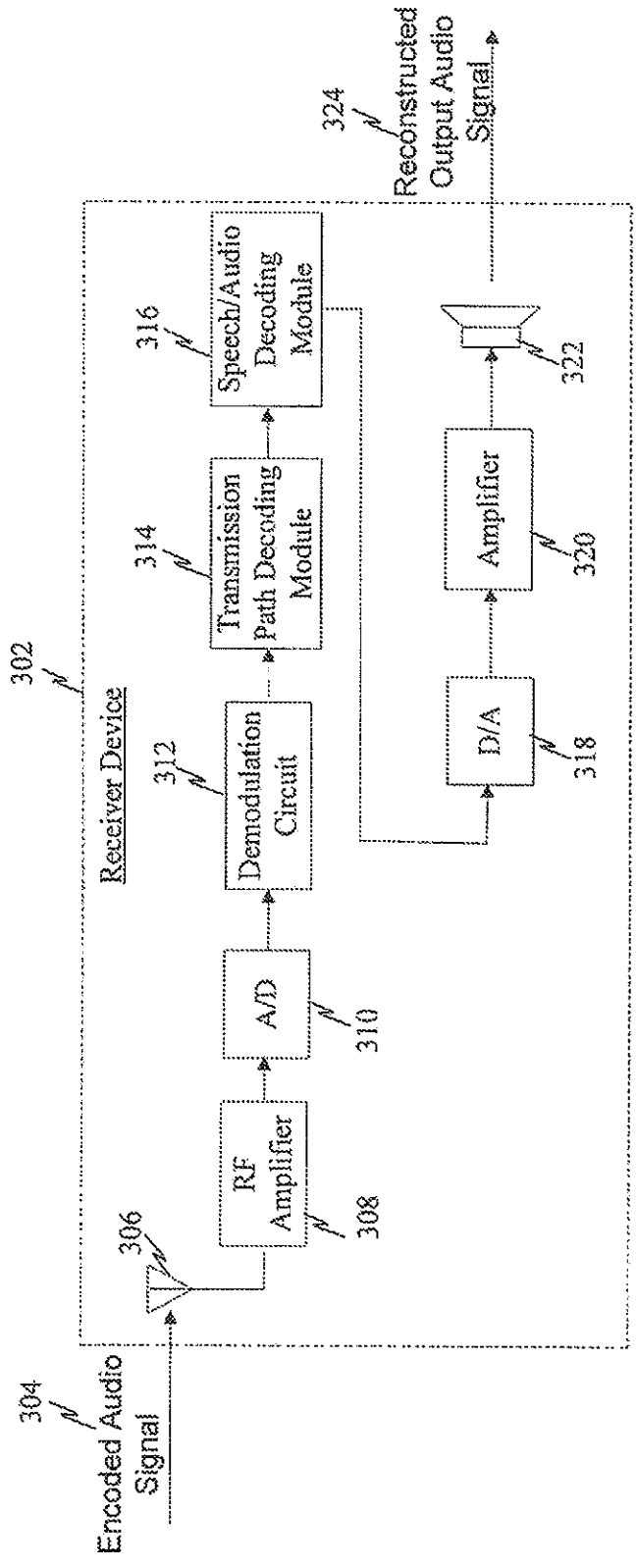
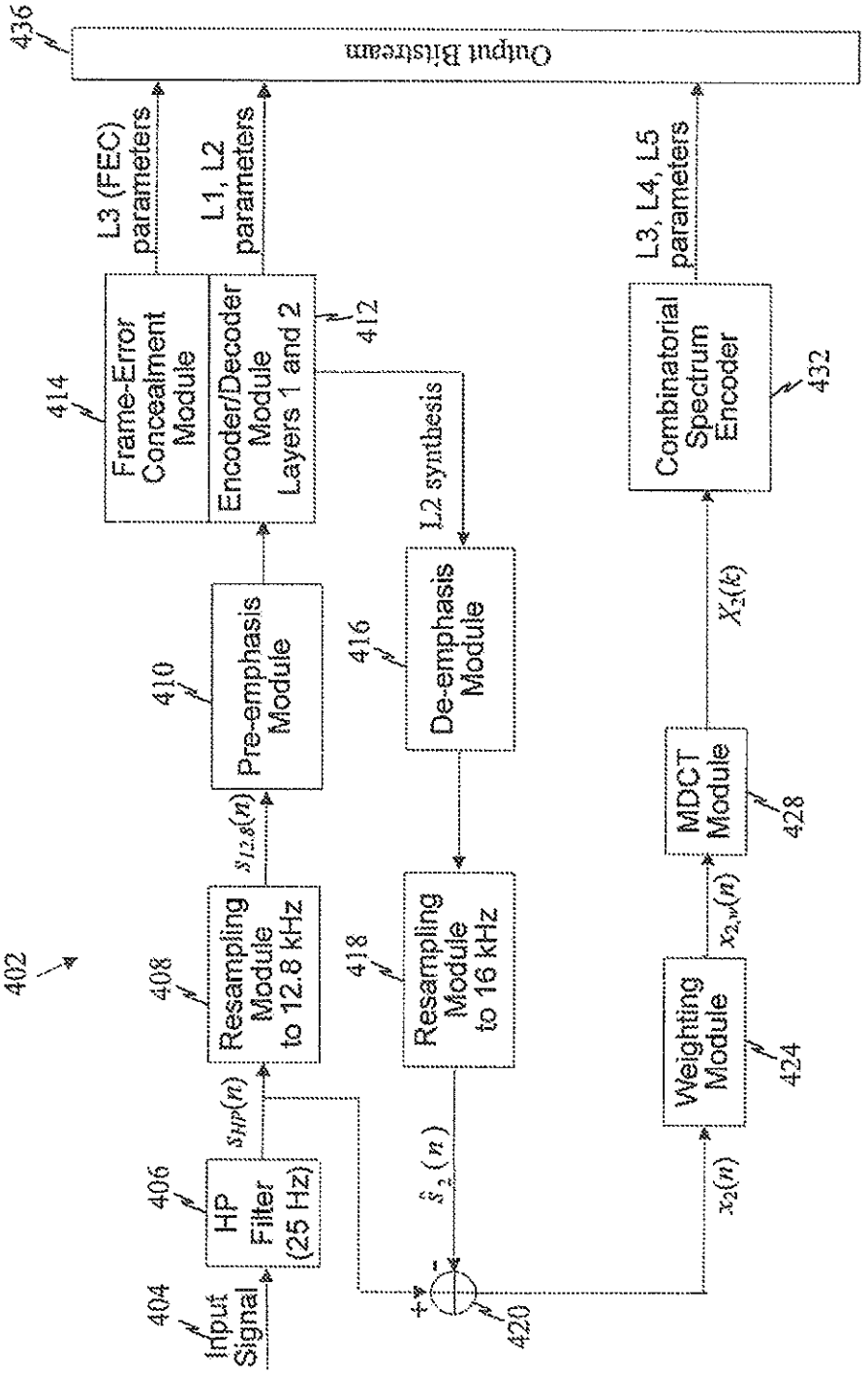

Encoded Audio Signal
304
Receiver Device
302
306
RF Amplifier
308
A/D
310
Demodulation Circuit
312
Transmission Path Decoding Module
314
Speech/Audio Decoding Module
316
D/A
318
Amplifier
320
322
Reconstructed Output Audio Signal
324

FIGURE 3


Output Bitstream
436
L3 (FEC) parameters
L1, L2 parameters
L3, L4, L5 parameters
Frame-Error Concealment Module
414
Encoder/Decoder Module Layers 1 and 2
412
Combinatorial Spectrum Encoder
432
L2 synthesis
Pre-emphasis Module
410
De-emphasis Module
416
MDCT Module
428
$X_2(k)$
$s_{12.8}(n)$
Resampling Module to 12.8 kHz
408
Resampling Module to 16 kHz
418
$x_{2,w}(n)$
Weighting Module
424
$x_2(n)$
$s_{HP}(n)$
HP Filter (25 Hz)
406
$\hat{s}_2(n)$
Input Signal
404
420
402

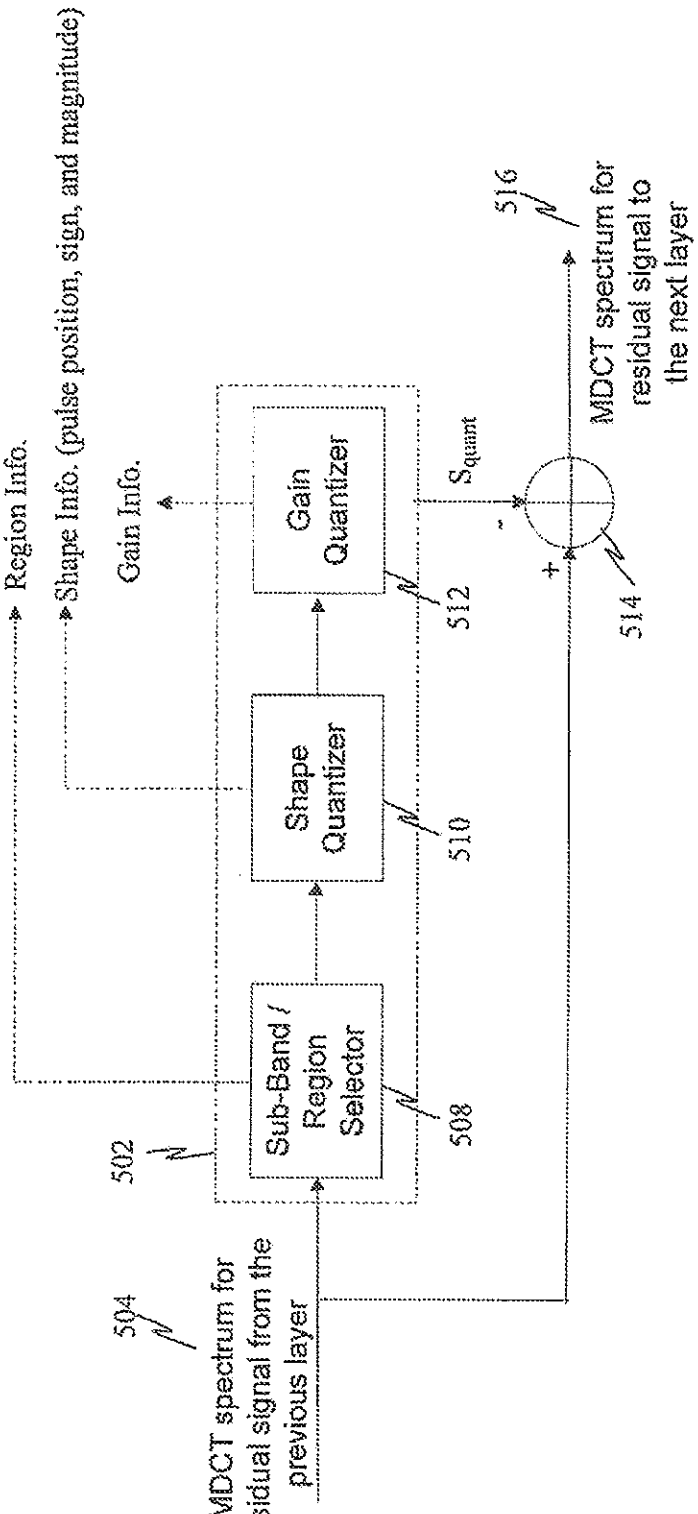

Region Info.
Shape Info. (pulse position, sign, and magnitude)
Gain Info.
Gain Quantizer
Shape Quantizer
Sub-Band / Region Selector
502
504
508
510
512
514
516
S_{quant}
MDCT spectrum for residual signal from the previous layer
MDCT spectrum for residual signal to the next layer

FIGURE 5

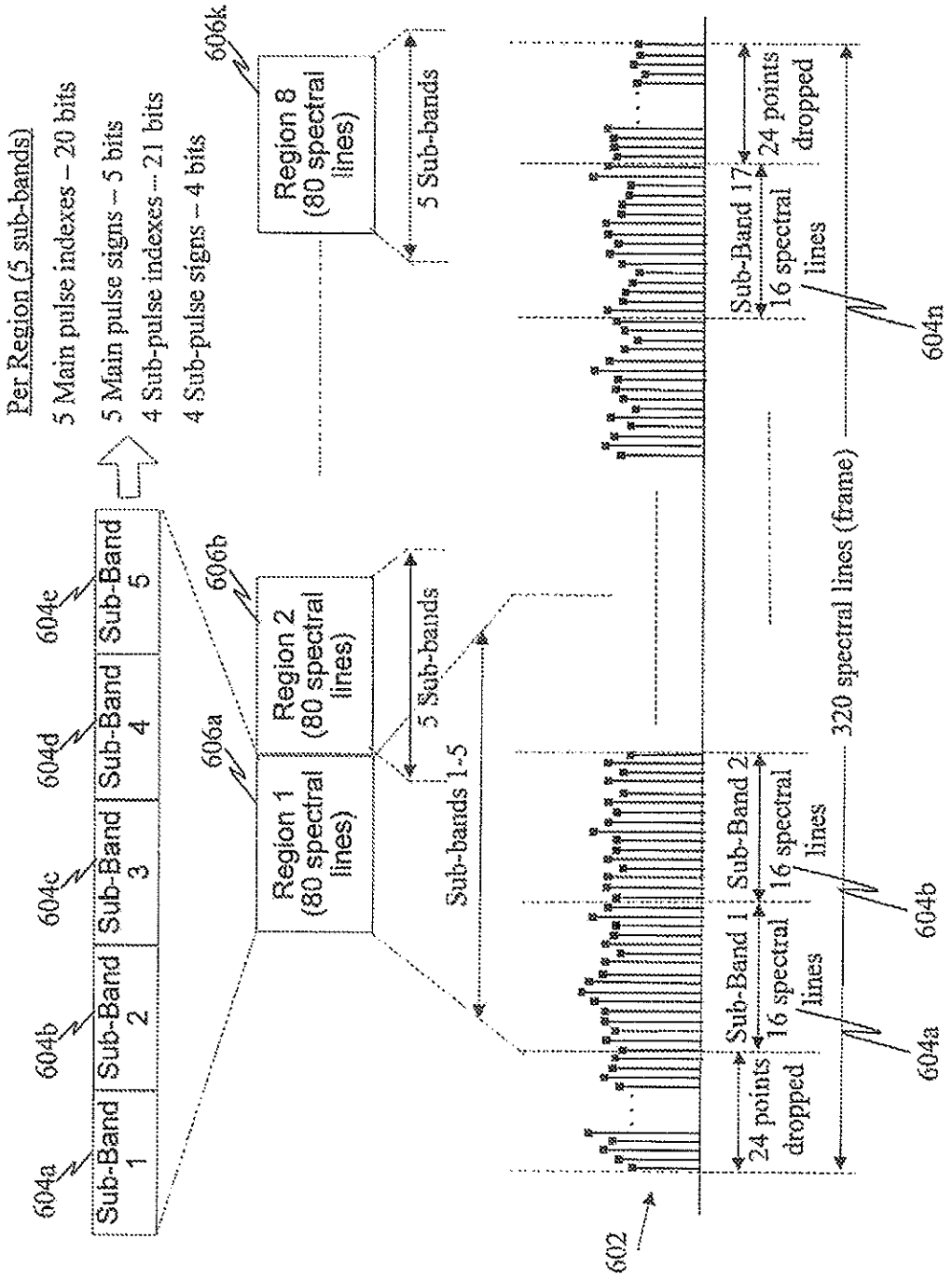

Per Region (5 sub-bands)
5 Main pulse indexes – 20 bits
5 Main pulse signs – 5 bits
4 Sub-pulse indexes – 21 bits
4 Sub-pulse signs – 4 bits
Sub-Band 1
Sub-Band 2
Sub-Band 3
Sub-Band 4
Sub-Band 5
604a
604b
604c
604d
604e
606a
606b
606k
Region 1 (80 spectral lines)
Region 2 (80 spectral lines)
Region 8 (80 spectral lines)
5 Sub-bands
Sub-bands 1-5
602
Sub-Band 1
Sub-Band 2
Sub-Band 17
24 points dropped
16 spectral lines
24 points dropped
16 spectral lines
320 spectral lines (frame)
604a
604b
604n

FIGURE 6

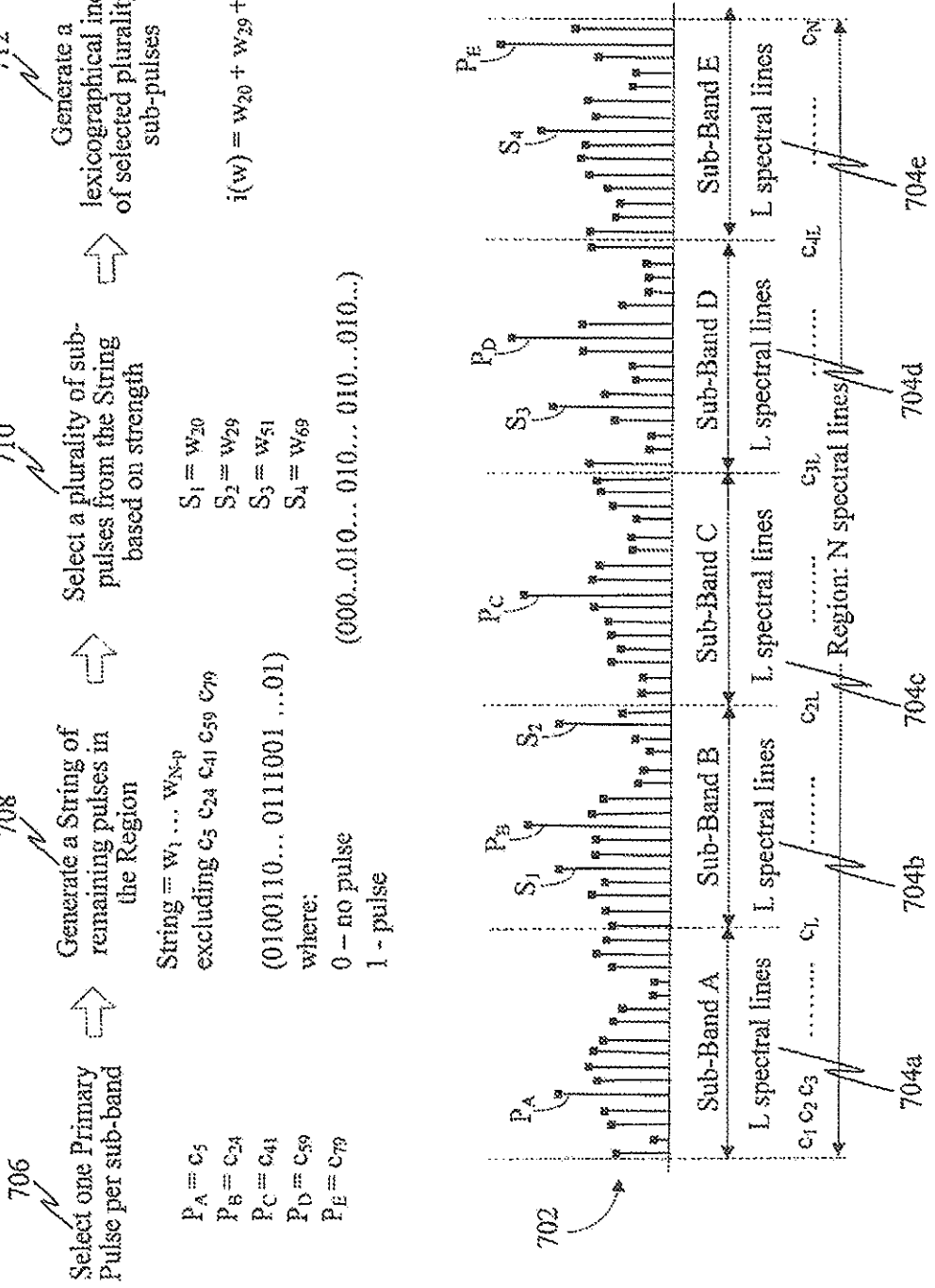

706
Select one Primary Pulse per sub-band
708
Generate a String of remaining pulses in the Region
String = $w_1 \ldots w_{N-9}$
excluding $c_5\ c_{24}\ c_{41}\ c_{59}\ c_{79}$
(0100110... 0111001 ...01)
where:
0 – no pulse
1 - pulse
710
Select a plurality of sub-pulses from the String based on strength
$S_1 = w_{20}$
$S_2 = w_{29}$
$S_3 = w_{51}$
$S_4 = w_{69}$
(000...010... 010... 010...010...)
712
Generate a lexicographical index of selected plurality of sub-pulses
$i(w) = w_{20} + w_{29} + w_{51} + w_{69}$
702
P_A
P_B
P_C
P_D
P_E
S_1
S_2
S_3
S_4
Sub-Band A
Sub-Band B
Sub-Band C
Sub-Band D
Sub-Band E
L spectral lines
$c_1\ c_2\ c_3$
c_L
c_{2L}
c_{3L}
c_{4L}
c_N
Region: N spectral lines
704a
704b
704c
704d
704e

FIGURE 7

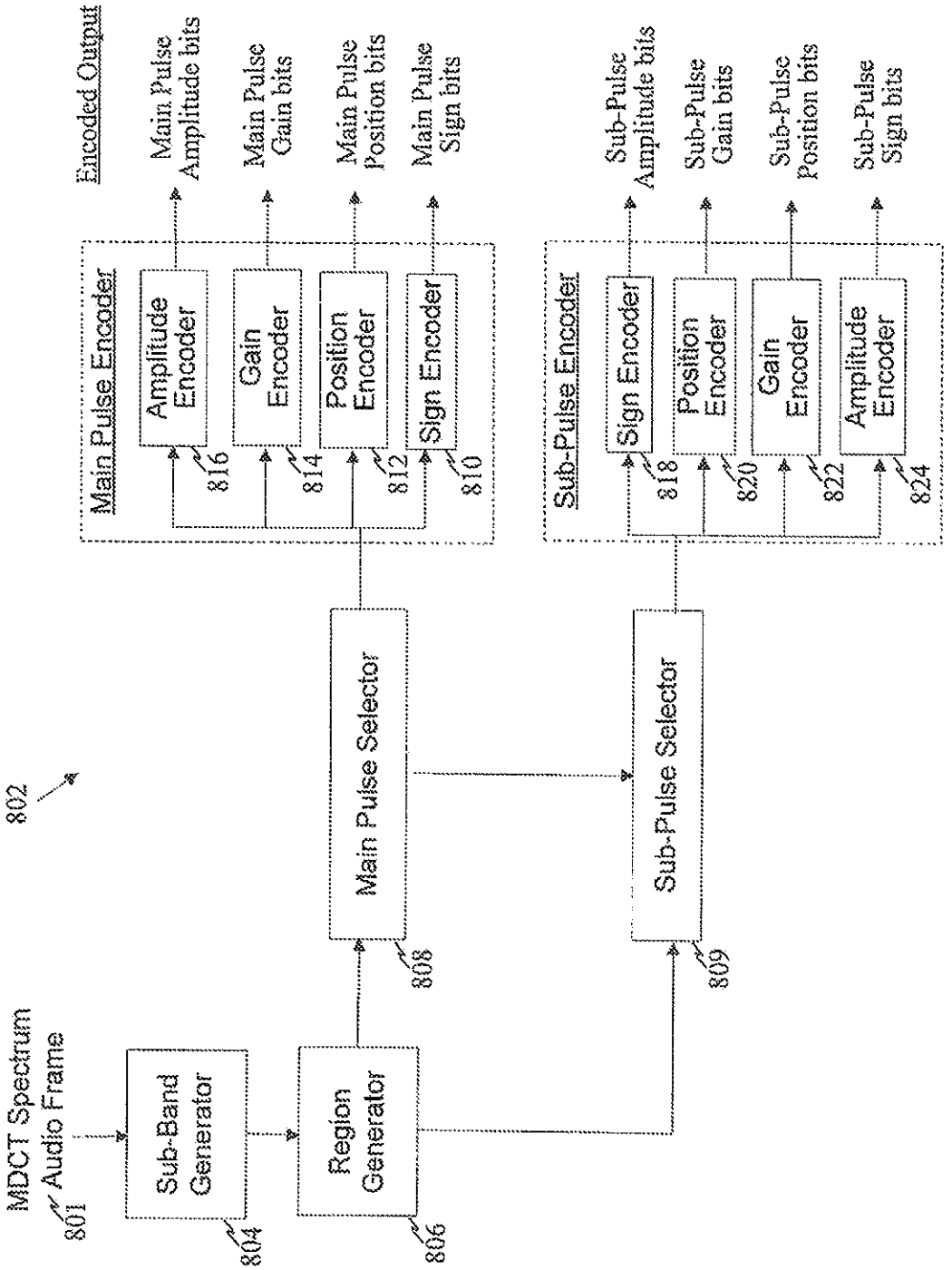

MDCT Spectrum Audio Frame
801
Sub-Band Generator
804
Region Generator
806
802
Main Pulse Selector
808
Sub-Pulse Selector
809
Encoded Output
Main Pulse Encoder
Amplitude Encoder
816
Gain Encoder
814
Position Encoder
812
Sign Encoder
810
Main Pulse Amplitude bits
Main Pulse Gain bits
Main Pulse Position bits
Main Pulse Sign bits
Sub-Pulse Encoder
Sign Encoder
818
Position Encoder
820
Gain Encoder
822
Amplitude Encoder
824
Sub-Pulse Amplitude bits
Sub-Pulse Gain bits
Sub-Pulse Position bits
Sub-Pulse Sign bits

FIGURE 8

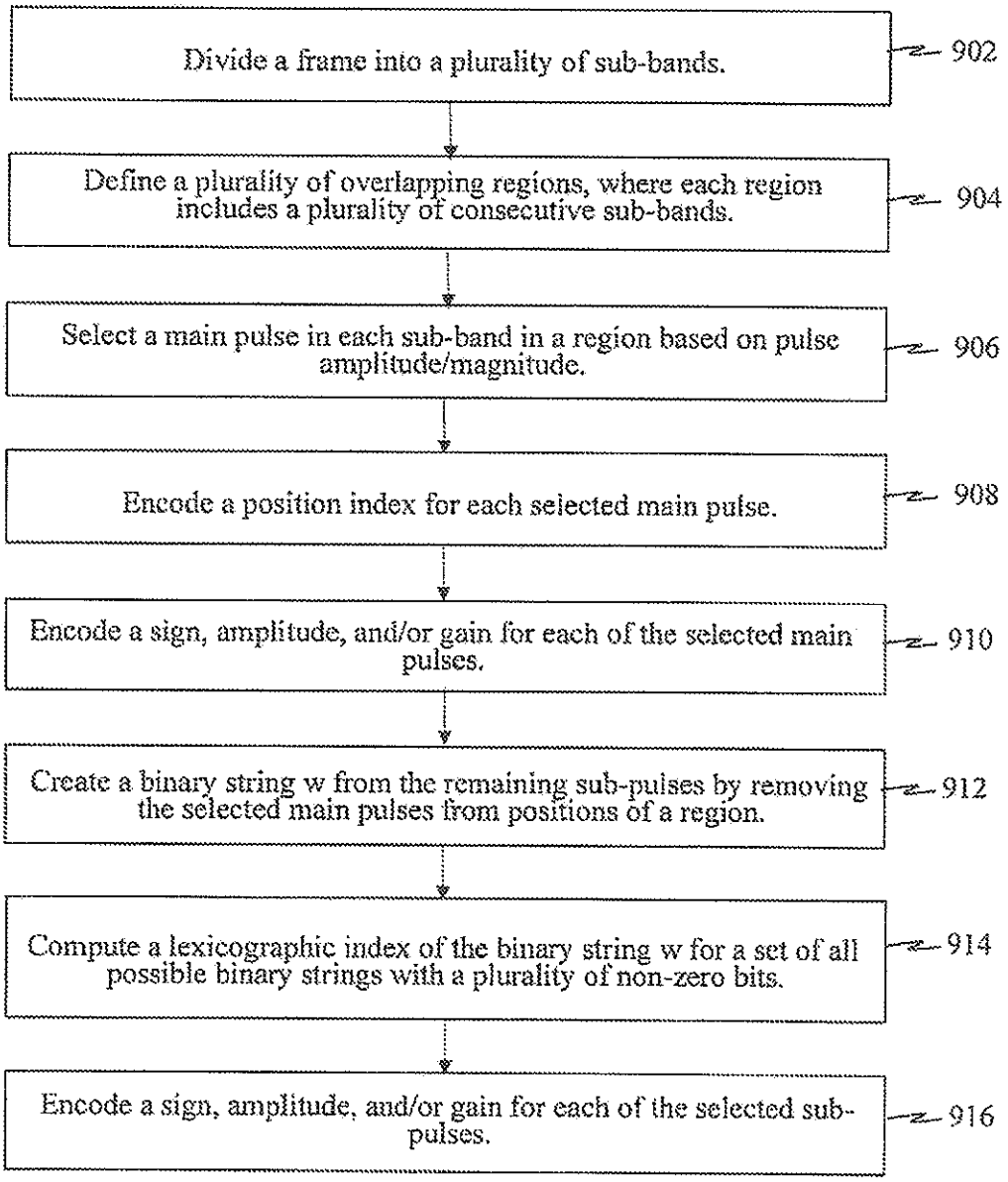

Divide a frame into a plurality of sub-bands.
902
Define a plurality of overlapping regions, where each region includes a plurality of consecutive sub-bands.
904
Select a main pulse in each sub-band in a region based on pulse amplitude/magnitude.
906
Encode a position index for each selected main pulse.
908
Encode a sign, amplitude, and/or gain for each of the selected main pulses.
910
Create a binary string w from the remaining sub-pulses by removing the selected main pulses from positions of a region.
912
Compute a lexicographic index of the binary string w for a set of all possible binary strings with a plurality of non-zero bits.
914
Encode a sign, amplitude, and/or gain for each of the selected sub-pulses.
916

FIGURE 9

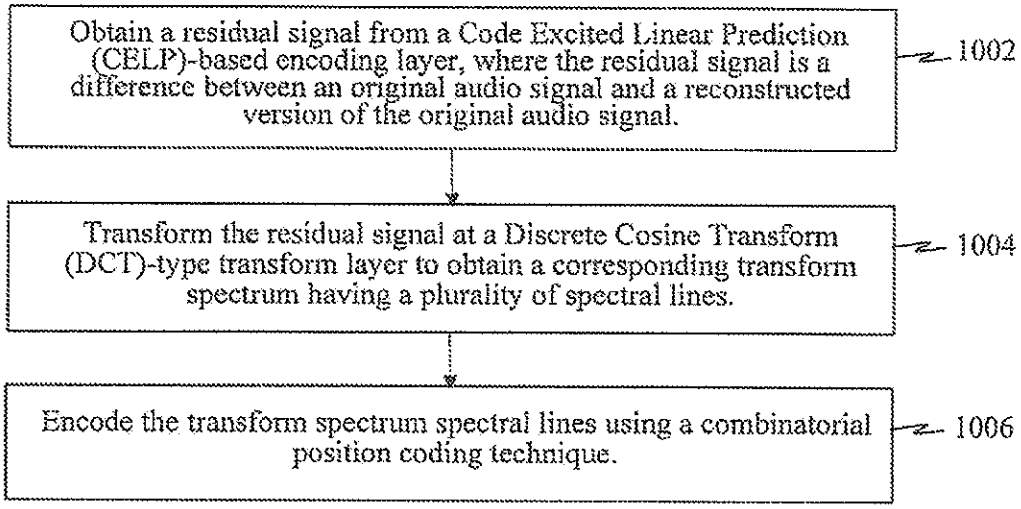

Obtain a residual signal from a Code Excited Linear Prediction (CELP)-based encoding layer, where the residual signal is a difference between an original audio signal and a reconstructed version of the original audio signal.
1002
Transform the residual signal at a Discrete Cosine Transform (DCT)-type transform layer to obtain a corresponding transform spectrum having a plurality of spectral lines.
1004
Encode the transform spectrum spectral lines using a combinatorial position coding technique.
1006

FIGURE 10

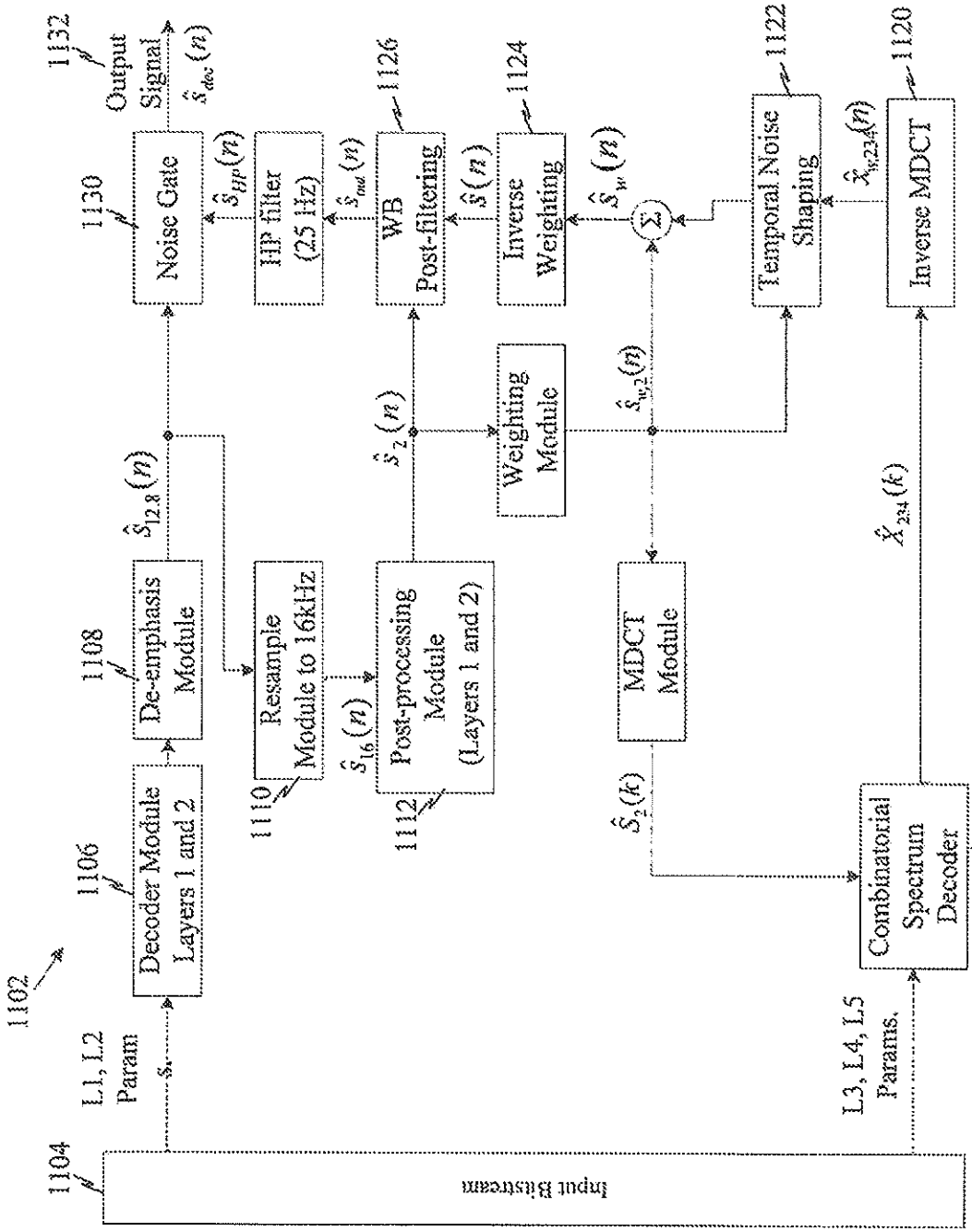

1102
1104
Input Bitstream
L1, L2 Param
L3, L4, L5 Params.
1106
Decoder Module Layers 1 and 2
1108
De-emphasis Module
1110
Resample Module to 16kHz
1112
Post-processing Module (Layers 1 and 2)
1116
Combinatorial Spectrum Decoder
MDCT Module
Weighting Module
1120
Inverse MDCT
1122
Temporal Noise Shaping
1124
Inverse Weighting
1126
WB Post-filtering
HP filter (25 Hz)
1130
Noise Gate
1132
Output Signal

FIGURE 11

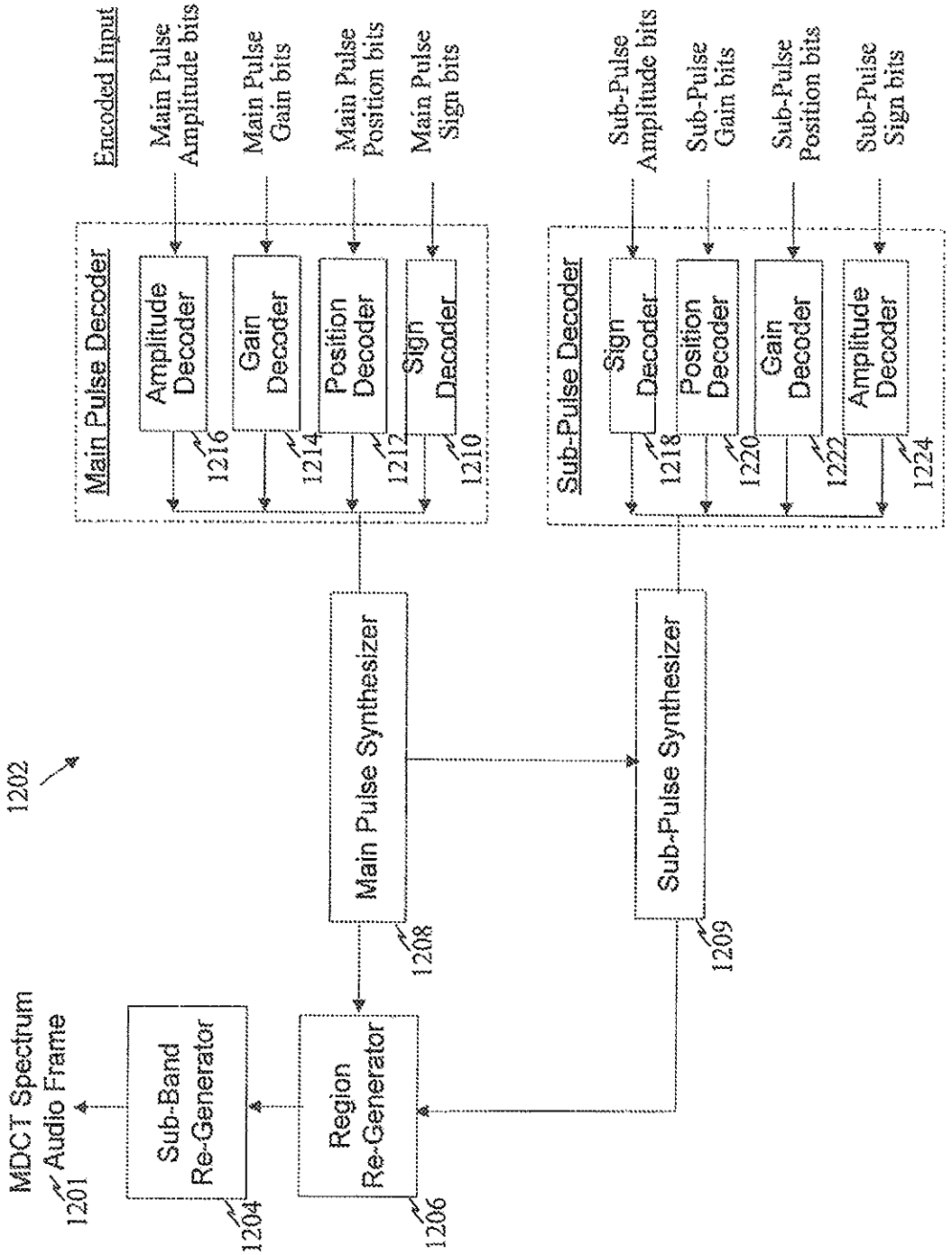

Encoded Input
Main Pulse Amplitude bits
Main Pulse Gain bits
Main Pulse Position bits
Main Pulse Sign bits
Main Pulse Decoder
Amplitude Decoder
Gain Decoder
Position Decoder
Sign Decoder
1216
1214
1212
1210
Sub-Pulse Amplitude bits
Sub-Pulse Gain bits
Sub-Pulse Position bits
Sub-Pulse Sign bits
Sub-Pulse Decoder
Sign Decoder
Position Decoder
Gain Decoder
Amplitude Decoder
1218
1220
1222
1224
1202
Main Pulse Synthesizer
Sub-Pulse Synthesizer
1208
1209
MDCT Spectrum
Audio Frame
1201
Sub-Band Re-Generator
Region Re-Generator
1204
1206

FIGURE 12

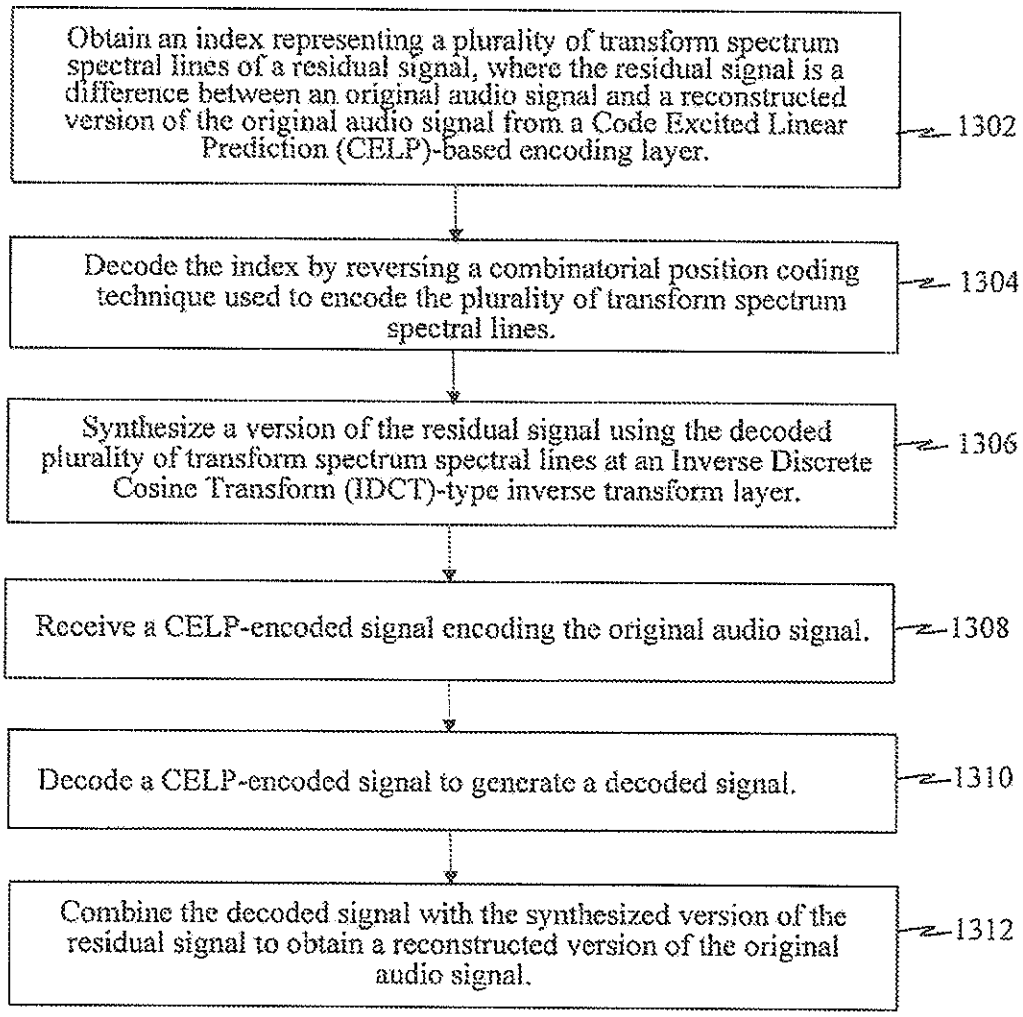

Obtain an index representing a plurality of transform spectrum spectral lines of a residual signal, where the residual signal is a difference between an original audio signal and a reconstructed version of the original audio signal from a Code Excited Linear Prediction (CELP)-based encoding layer.
1302
Decode the index by reversing a combinatorial position coding technique used to encode the plurality of transform spectrum spectral lines.
1304
Synthesize a version of the residual signal using the decoded plurality of transform spectrum spectral lines at an Inverse Discrete Cosine Transform (IDCT)-type inverse transform layer.
1306
Receive a CELP-encoded signal encoding the original audio signal.
1308
Decode a CELP-encoded signal to generate a decoded signal.
1310
Combine the decoded signal with the synthesized version of the residual signal to obtain a reconstructed version of the original audio signal.
1312

FIGURE 13