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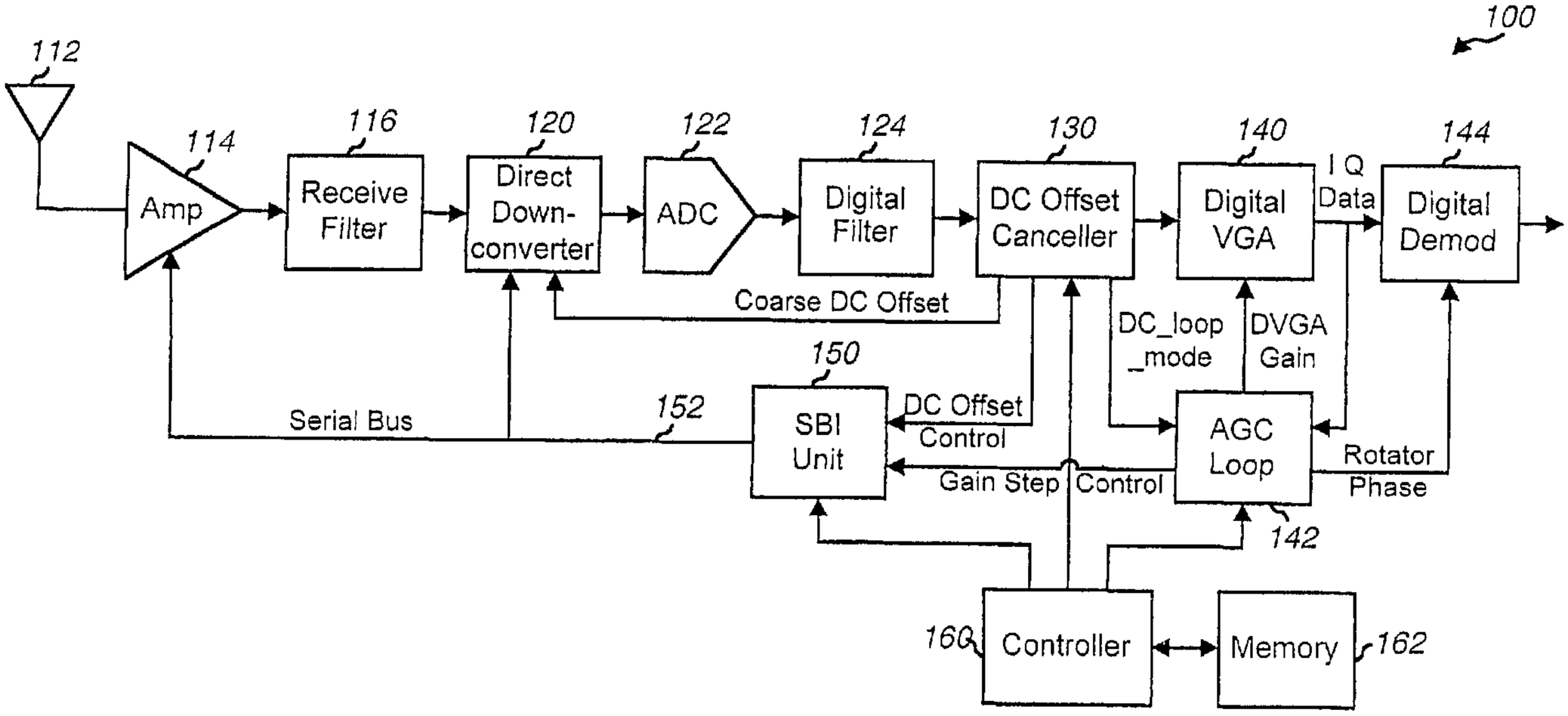
(54) Title: DIRECT CONVERSION RECEIVER ARCHITECTURE



(57) Abrégé/Abstract:
A direct downconversion receiver architecture having a DC loop to remove DC offset from the signal components, a digital variable gain amplifier (DVGA) to provide a range of gains, an automatic gain control (AGC) loop to provide gain control for the DVGA and RF/analog circuitry, and a serial bus interface (SBI) unit to provide controls for the RF/analog circuitry via a serial bus. The DVGA may be advantageously designed and located as described herein. The operating mode of the VGA loop may be selected based on the operating mode of the DC loop, since these two loops interact with one another. The duration of time the DC loop is operated in an acquisition mode may be selected to be inversely proportional to the DC loop bandwidth in the acquisition mode. The controls for some or all of the RF/analog circuitry may be provided via the serial bus.

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74769-718E

ABSTRACT

A direct downconversion receiver architecture having a DC loop to remove DC offset from the signal components, a digital variable gain amplifier (DVGA) to provide a range of gains, an automatic gain control (AGC) loop to provide gain control for the DVGA and RF/analog circuitry, and a serial bus interface (SBI) unit to provide controls for the RF/analog circuitry via a serial bus. The DVGA may be advantageously designed and located as described herein. The operating mode of the VGA loop may be selected based on the operating mode of the DC loop, since these two loops interact with one another. The duration of time the DC loop is operated in an acquisition mode may be selected to be inversely proportional to the DC loop bandwidth in the acquisition mode. The controls for some or all of the RF/analog circuitry may be provided via the serial bus.

74769-718E

CLAIMS:

1. A method of processing a desired signal in a wireless communication system, comprising:

amplifying the desired signal with a first gain having a coarse resolution;

downconverting the amplified signal from radio frequency (RF) to baseband with a single frequency downconversion stage;

digitizing the downconverted signal to provide samples;

correcting for DC offset in the downconverted signal with a DC loop; and

digitally amplifying the samples with a second gain having a fine resolution to provide output data having a desired signal amplitude.

2. A direct downconversion receiver comprising:

an RF front-end unit operative to amplify, downconvert at essentially constant gain, and digitize a received signal to provide samples;

a digital variable gain amplifier (DVGA) operative to amplify the samples with a first gain to provide output data having a desired signal amplitude; and

an automatic gain control (AGC) loop operative to provide the first gain for the DVGA based in part on the output data.

3. The direct downconversion receiver of claim 2, further comprising:

a DC offset canceller operative to correct for DC offset in the samples, and wherein the DVGA is operative to amplify the DC offset corrected samples.

4. The direct downconversion receiver of claim 2, wherein the AGC loop is further operative to provide a second gain for the RF front-end unit.

5. An apparatus in a wireless communication system, comprising:

first means for amplifying a received signal;

means for cancelling a DC offset in the amplified signal;

second means for digitally amplifying the DC offset cancelled signal; and

means for measuring the digitally amplified signal and to control the gains of the first and second amplifying means.

6. A receiver unit comprising:

an analog variable gain amplifier;

a DC offset canceller coupled to an output of the analog variable gain amplifier;

a digital variable gain amplifier coupled to an output of the DC offset canceller;

a gain controller adapted to measure a signal output from the digital variable gain amplifier and to control the gains of the analog and digital variable gain amplifiers; and

a control interface operative to provide the gain for the analog variable gain amplifier.

7. A receiver unit comprising:

an RF front-end unit operative to amplify, downconvert, and digitize a received signal to provide samples;

a DC loop operative to cancel DC offset in the samples;

a digital variable gain amplifier (DVGA) operative to amplify the DC offset cancelled samples with a first gain to provide output data having a desired signal amplitude;

an automatic gain control (AGC) loop operative to provide the first gain for the DVGA and a second gain for the RF front-end unit based in part on the output data; and

a serial control interface operative to provide the second gain to the RF front-end unit.

8. The receiver unit of claim 7, wherein the control interface is further operative to provide a DC offset control value to the RF front-end unit.

9. The method of claim 1, further comprising detecting a DC offset value in the downconverted signal.

10. The method of claim 9, wherein the correcting for DC offset samples includes removing at least a portion of the detected DC offset value from the desired signal prior to digitizing.

11. The method of claim 9, wherein the correcting for DC offset samples includes removing at least a portion of

the detected DC offset value from the desired subsequent to digitizing.

12. The method of claim 9, wherein the DC offset value is detected in the digitized samples.

13. The receiver unit of claim 6, wherein the control interface is a bus interface.

14. The receiver unit of claim 13, wherein the bus interface is a Serial Bus Interface (SBI) unit.

15. The receiver unit of claim 6, wherein the control interface comprises dedicated control signals.

16. The receiver unit of claim 7, wherein the control interface is a bus interface.

17. The receiver unit of claim 16, wherein the bus interface is a Serial Bus Interface (SBI) unit.

18. The receiver unit of claim 7, wherein the control interface comprises dedicated control signals.

19. A method of processing a received signal in a wireless communication system, comprising:

amplifying a received signal with a first variable gain;

cancelling a DC offset in the amplified received signal;

digitally amplifying with a second variable gain the DC offset cancelled signal;

measuring the digitally amplified signal; and

determining the first and second variable gains in response to the digitally amplified signal measurements.

20. An apparatus comprising:

analog means for amplifying a received signal with a first variable gain;

means for cancelling a DC offset coupled to the analog amplifying means;

digital means for amplifying with a second variable gain coupled to an output of the DC offset cancelling means;

means for measuring a signal output from the digital amplification means and to control the first and second variable gains; and

means operative to provide the second gain to the analog amplification means.

21. A method comprising:

amplifying with a second gain, downconverting and digitizing a received signal to provide samples;

cancelling a DC offset in the samples;

digitally amplifying the DC offset cancelled samples with a first gain to provide output data;

determining the first gain and a second gain, based in part on the output data, such that the output data have a desired signal amplitude; and

providing the second gain to the amplifying, downconverting and digitizing means.

22. An apparatus comprising:

means for amplifying, downconverting and digitizing a received signal to provide samples;

means for cancelling a DC offset in the samples;

means for digitally amplifying the DC offset cancelled samples with a first gain to provide output data having a desired signal amplitude;

means for determining the first gain and a second gain based in part on the output data; and

means for providing the second gain to the amplifying, downconverting and digitizing means.

23. A method, comprising:

amplifying the desired signal with a first gain having a coarse resolution;

downconverting the amplified signal from radio frequency (RF) to baseband with a single frequency downconversion stage;

digitizing the downconverted signal to provide samples;

correcting for DC offset in the downconverted signal with a DC loop;

digitally amplifying the samples with a second gain having a fine resolution to provide output data having a desired signal amplitude.

24. An apparatus, comprising:

means for amplifying the desired signal with a first gain having a coarse resolution;

means for downconverting the amplified signal from radio frequency (RF) to baseband with a single frequency downconversion stage;

means for digitizing the downconverted signal to provide samples;

means for correcting for DC offset in the downconverted signal with a DC loop;

means for digitally amplifying the samples with a second gain having a fine resolution to provide output data having a desired signal amplitude.

25. A method comprising:

amplifying, downconverting at essentially constant gain, and digitizing a received signal to provide samples;

digitally amplifying the samples with a variable gain to provide output data having a desired signal amplitude; and

determining the variable gain based in part on the output data.

26. An apparatus comprising:

means for amplifying, downconverting at essentially constant gain, and digitizing a received signal to provide samples;

means for digitally amplifying the samples with a variable gain to provide output data having a desired signal amplitude; and

means for determining the variable gain based in part on the output data.

27. An RF module, adapted to operate with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, an automatic gain control loop operative to provide a first gain value and the second gain value, the first and second gain values determined in accordance with a desired signal amplitude, the RF module comprising:

an analog variable gain amplifier having a signal input, a gain input, and a signal output, the signal input receiving a radio frequency (RF) signal and the gain input adapted to receive the first gain value; and

a downconverter having an input coupled to the signal output of the variable gain amplifier, directly downconverting the downconverter input from RF to baseband to produce a downconverted output.

28. The RF module of claim 27, further comprising a DC offset canceller coupled to the output of the downconverter.

29. The RF module of claim 27, further comprising an analog to digital converter coupled to the output of the downconverter.

30. A method, operable with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, an automatic gain control loop operative to provide a first gain value and the second gain value, the first and second gain values determined in accordance with a desired signal amplitude, the method comprising:

amplifying a radio frequency (RF) signal according to the first gain value; and

directly downconverting the amplified RF signal from RF to baseband to produce a downconverted output.

31. An apparatus, adapted to operate with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, an automatic gain control loop operative to provide a first gain value and the second gain value, the first and second gain values determined in accordance with a desired signal amplitude, the apparatus comprising:

means for amplifying a radio frequency (RF) signal according to the first gain value; and

means for directly downconverting the amplified RF signal from RF to baseband to produce a downconverted output.

32. An RF module, adapted to operate with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, and a gain controller adapted to measure the output from the digital variable gain amplifier and to generate a first gain value and the second gain value, the RF module comprising:

an analog variable gain amplifier having a signal input, a gain input, and a signal output, the signal input receiving a radio frequency (RF) signal and the gain input adapted to receive the first gain value; and

a downconverter having an input coupled to the signal output of the variable gain amplifier, directly

downconverting the downconverter input from RF to baseband to produce a downconverted output.

33. The RF module of claim 32, further comprising a DC offset canceller coupled to the output of the downconverter.

34. The RF module of claim 32, further comprising an analog to digital converter coupled to the output of the downconverter.

35. A method, operable with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, and a gain controller adapted to measure the output from the digital variable gain amplifier and to generate a first gain value and the second gain value, the method comprising:

amplifying a radio frequency (RF) signal according to the first gain value; and

directly downconverting the amplified RF signal from RF to baseband to produce a downconverted output.

36. An apparatus, adapted to operate with a baseband integrated circuit, the baseband integrated circuit comprising a digital variable gain amplifier amplifying according to a second gain value, and a gain controller adapted to measure the output from the digital variable gain amplifier and to generate a first gain value and the second gain value, the apparatus comprising:

means for amplifying a radio frequency (RF) signal according to the first gain value; and

means for directly downconverting the amplified RF signal from RF to baseband to produce a downconverted output.

37. A baseband integrated circuit, adapted to operate with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output coupled to a downconverter directly downconverting a downconverter input from RF to baseband to produce a downconverted signal, the apparatus comprising:

a digital variable gain amplifier having an amplifier input adapted to couple with the downconverted signal, a gain input receiving a second gain value, and an amplifier output; and

an automatic gain control loop operative to provide the first gain value and the second gain value to produce the digital variable gain amplifier output at a desired signal amplitude.

38. The baseband integrated circuit of claim 37, further comprising a DC offset canceller coupled to the input of the digital variable gain amplifier.

39. The baseband integrated circuit of claim 37, further comprising an analog to digital converter coupled to the input of the digital variable gain amplifier.

40. A method, operable with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output coupled to a downconverter directly downconverting a downconverter input

from RF to baseband to produce a downconverted signal, the method comprising:

digitally amplifying the downconverted signal in accordance with a second gain value to produce a digitally amplified output; and

providing the first gain value and the second gain value with an automatic gain control loop to produce the digitally amplified output at a desired signal amplitude.

41. An apparatus, adapted to operate with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output coupled to a downconverter directly downconverting a downconverter input from RF to baseband to produce a downconverted signal, the apparatus comprising:

means for digitally amplifying the downconverted signal in accordance with a second gain value to produce a digitally amplified output; and

means for providing the first gain value and the second gain value with an automatic gain control loop to produce the digitally amplified output at a desired signal amplitude.

42. A baseband integrated circuit, adapted to operate with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output coupled to a downconverter directly downconverting a downconverter input from RF to baseband to produce a downconverted signal, the apparatus comprising:

a digital variable gain amplifier having an amplifier input adapted to couple with the downconverted signal, a gain input receiving a second gain value, and an amplifier output; and

a gain controller adapted to measure the amplifier output from the digital variable gain amplifier and to generate the first and second gain values.

43. The baseband integrated circuit of claim 37, further comprising a DC offset canceller coupled to the input of the digital variable gain amplifier.

44. The baseband integrated circuit of claim 37, further comprising an analog to digital converter coupled to the input of the digital variable gain amplifier.

45. A method, operable with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output coupled to a downconverter directly downconverting a downconverter input from RF to baseband to produce a downconverted signal, the method comprising:

digitally amplifying the downconverted signal in accordance with a second gain value to produce a digitally amplified output;

measuring the digitally amplified output; and

generating the first and second gain values.

46. An apparatus, adapted to operate with an RF module, the RF module comprising an analog variable gain amplifier amplifying a received radio frequency (RF) signal according to a first gain value, the amplifier output

coupled to a downconverter directly downconverting a downconverter input from RF to baseband to produce a downconverted signal, the apparatus comprising:

means for digitally amplifying the downconverted signal in accordance with a second gain value to produce a digitally amplified output;

measuring the digitally amplified output; and

generating the first and second gain values.

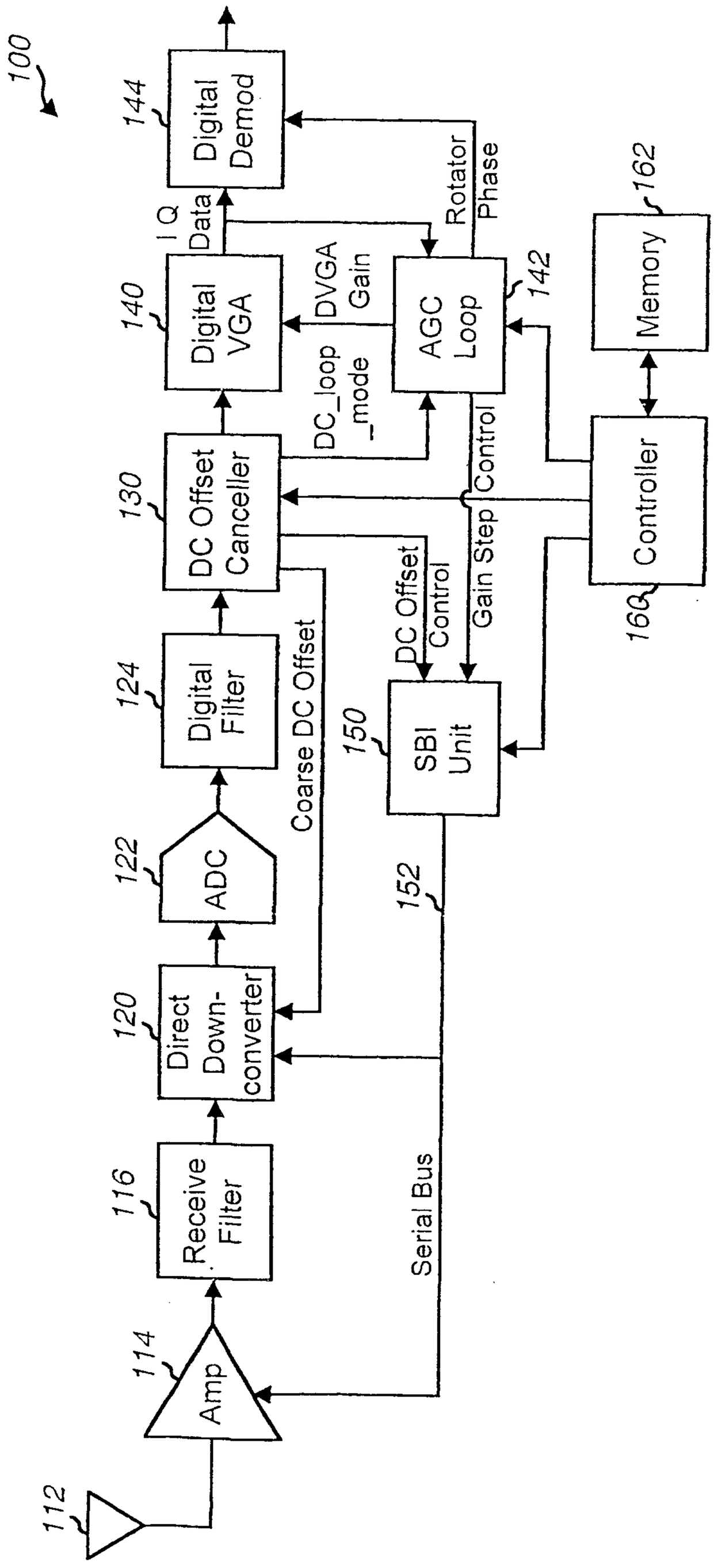

100
144
Digital Demod
I Q Data
140
Digital VGA
DVGA Gain
AGC Loop
142
Rotator Phase
162
Memory
DC_loop _mode
130
DC Offset Canceller
Control
Gain Step
Controller
160
124
Digital Filter
DC Offset Control
150
SBI Unit
Coarse DC Offset
122
ADC
120
Direct Down-converter
152
116
Receive Filter
Serial Bus
114
Amp
112

FIG. 1

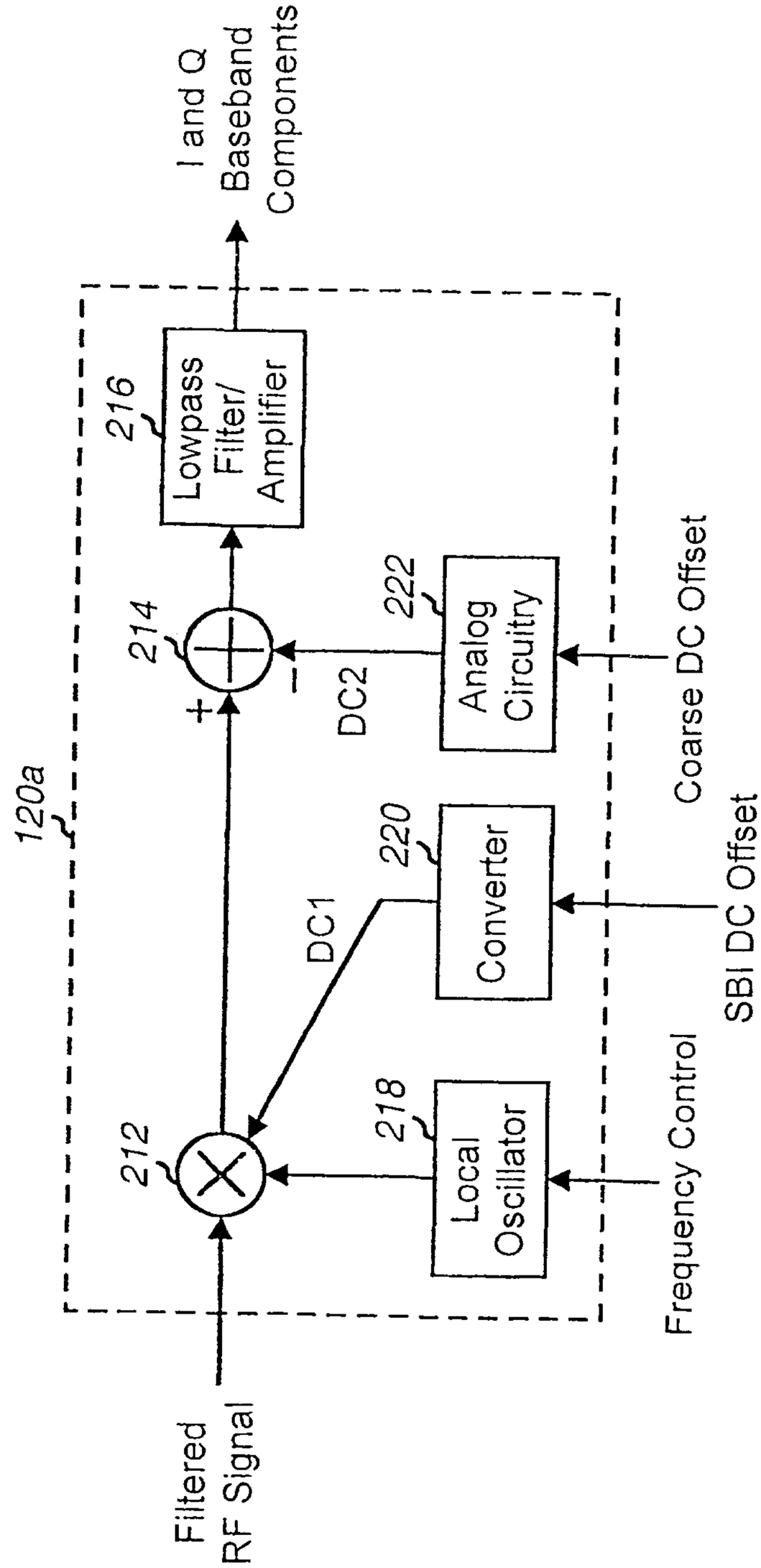

120a
Filtered RF Signal
212
DC1
218
Local Oscillator
Frequency Control
220
Converter
SBI DC Offset
214
+
-
DC2
222
Analog Circuitry
Coarse DC Offset
216
Lowpass Filter/ Amplifier
I and Q Baseband Components

FIG. 2A

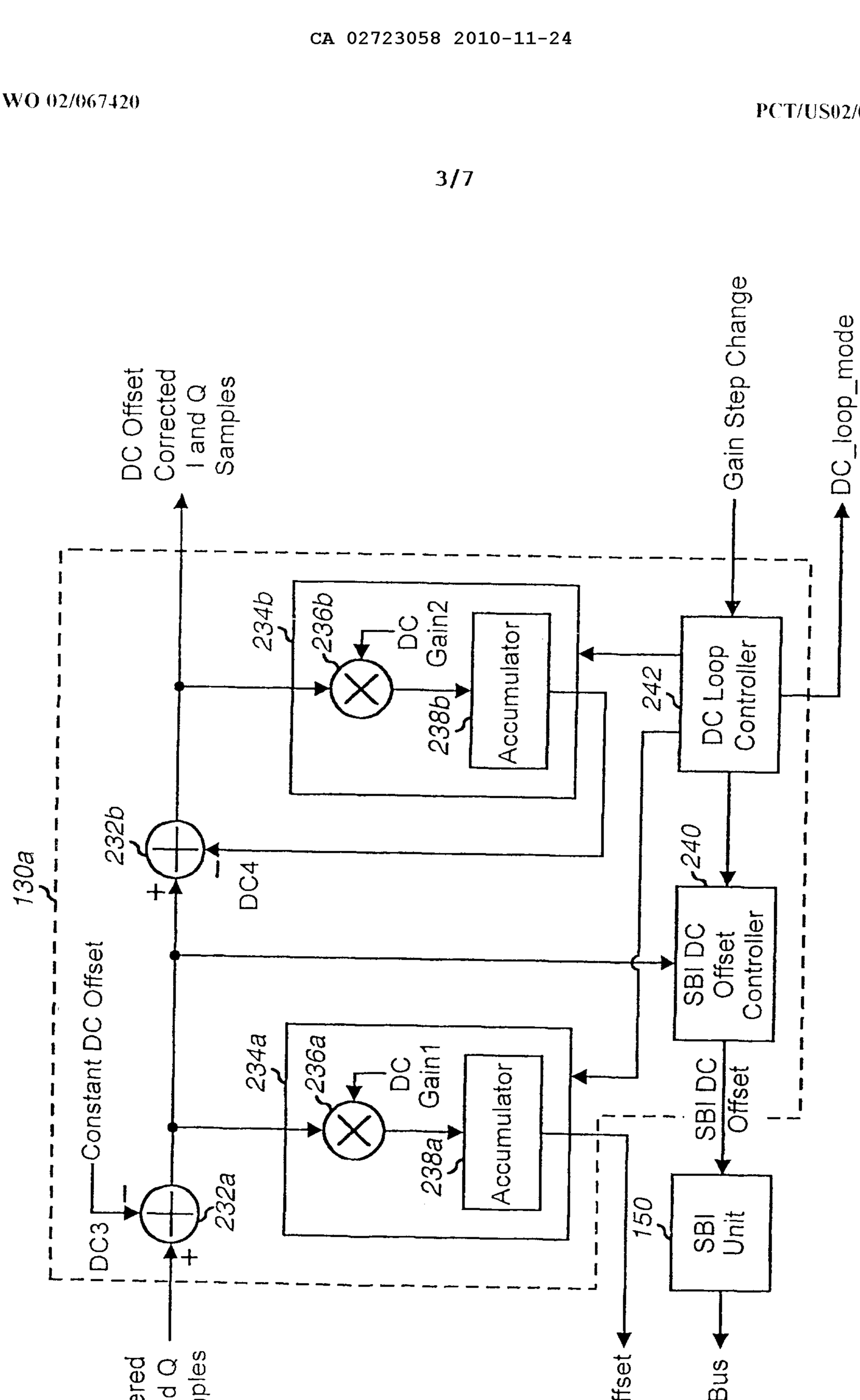

DC Offset Corrected I and Q Samples
Gain Step Change
DC_loop_mode
130a
232b
DC4
234b
236b
DC Gain2
238b
Accumulator
242
DC Loop Controller
240
SBI DC Offset Controller
Constant DC Offset
DC3
232a
234a
236a
DC Gain1
238a
Accumulator
150
SBI Unit
SBI DC Offset
Filtered I and Q Samples
Coarse DC Offset
Serial Bus

FIG. 2B

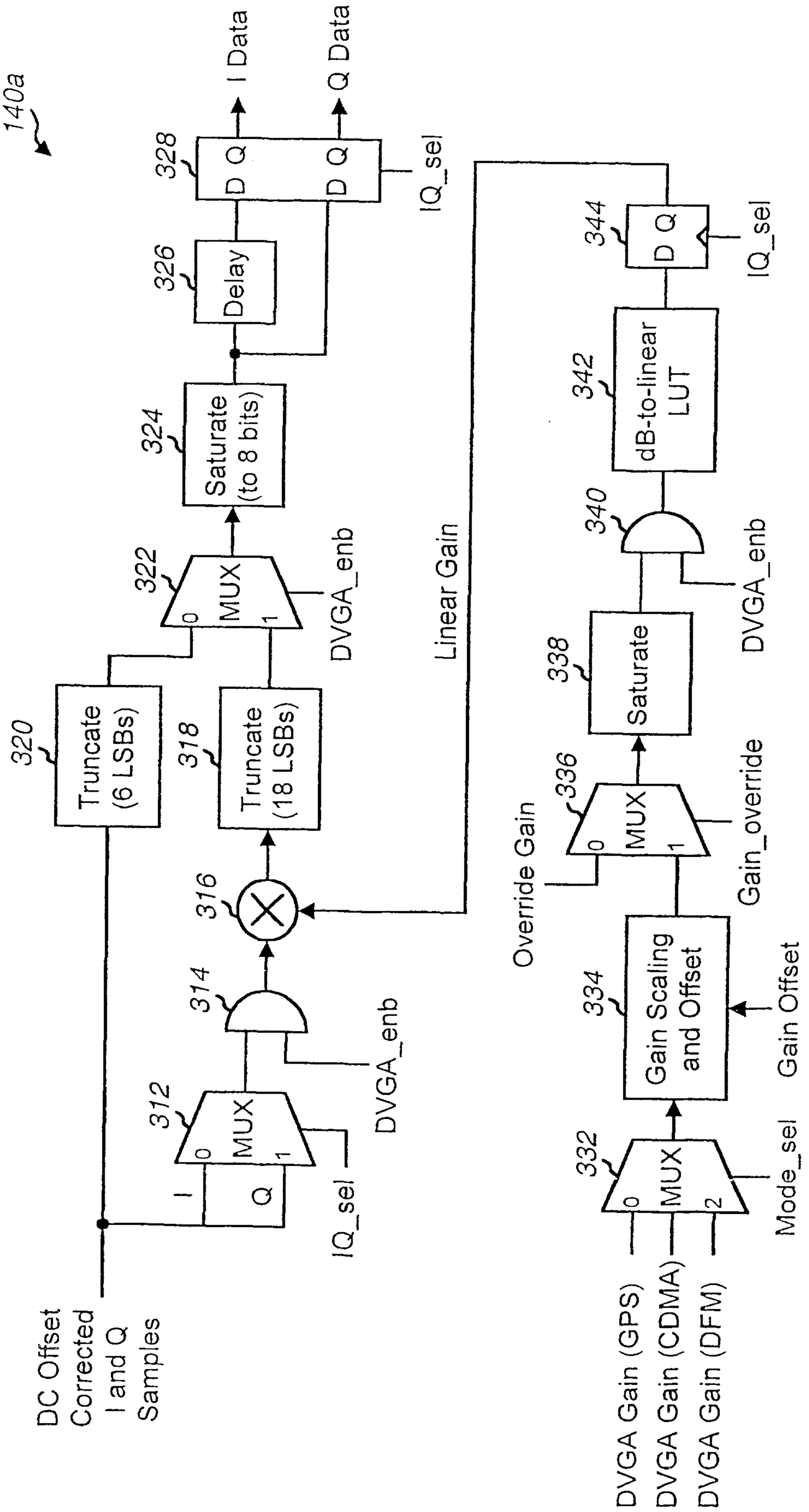

DC Offset Corrected I and Q Samples
Truncate (6 LSBs)
320
Truncate (18 LSBs)
318
316
314
312
MUX
I
Q
Q_sel
DVGA_enb
Linear Gain
Override Gain
336
MUX
Gain_override
334
Gain Scaling and Offset
Gain Offset
332
MUX
Mode_sel
DVGA Gain (GPS)
DVGA Gain (CDMA)
DVGA Gain (DFM)
338
Saturate
340
342
dB-to-linear LUT
344
D Q
IQ_sel
DVGA_enb
322
MUX
324
Saturate (to 8 bits)
326
Delay
328
D Q
D Q
I Data
Q Data
IQ_sel
140a

FIG. 3

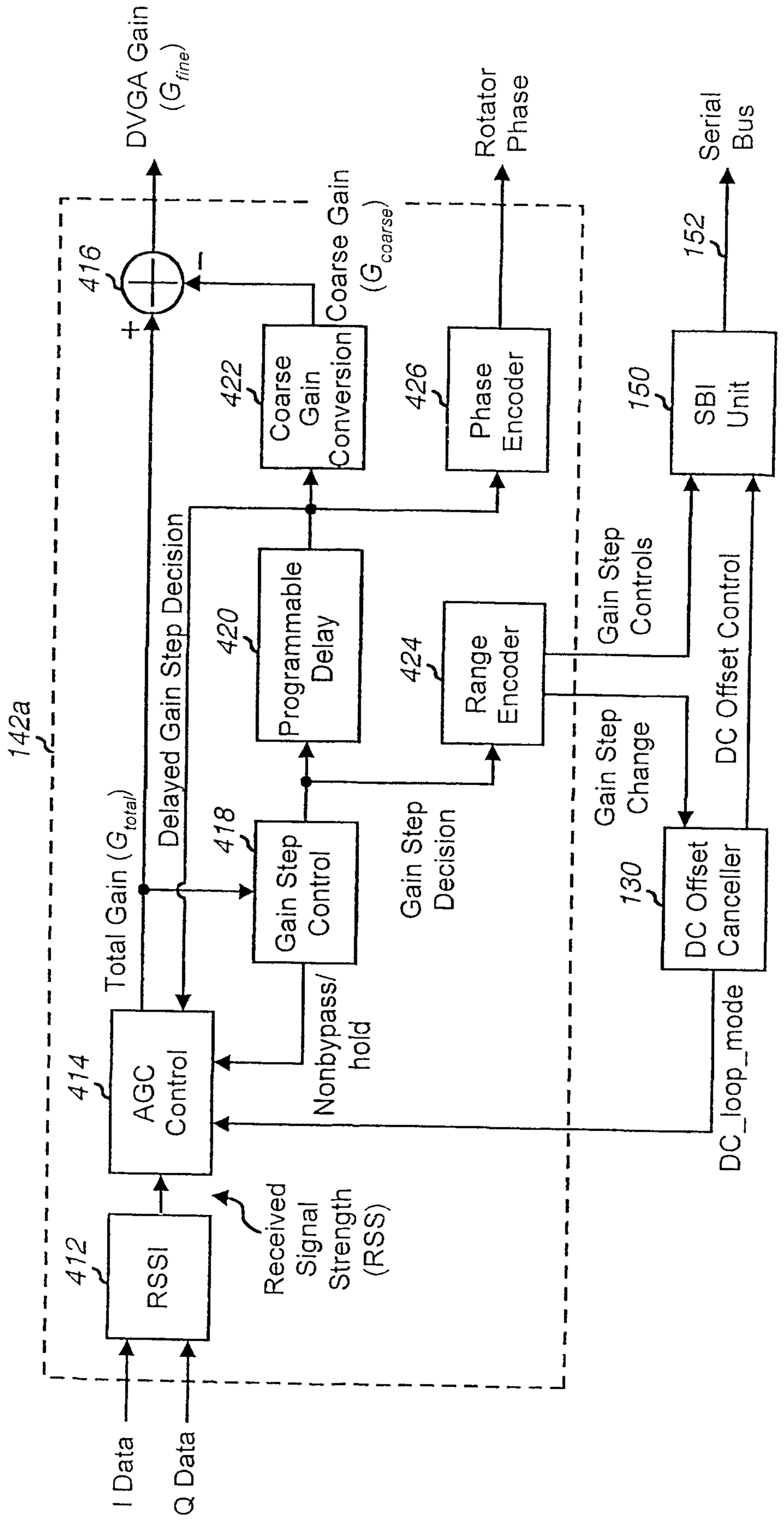

142a
DVGA Gain (G_{fine})
416
Coarse Gain (G_{coarse})
Rotator Phase
Serial Bus
152
422
Coarse Gain Conversion
426
Phase Encoder
150
SBI Unit
Total Gain (G_{total})
Delayed Gain Step Decision
420
Programmable Delay
424
Range Encoder
Gain Step Controls
418
Gain Step Control
Gain Step Decision
Gain Step Change
130
DC Offset Canceller
DC Offset Control
414
AGC Control
Nonbypass/ hold
DC_loop_mode
412
RSSI
Received Signal Strength (RSS)
I Data
Q Data

FIG. 4A

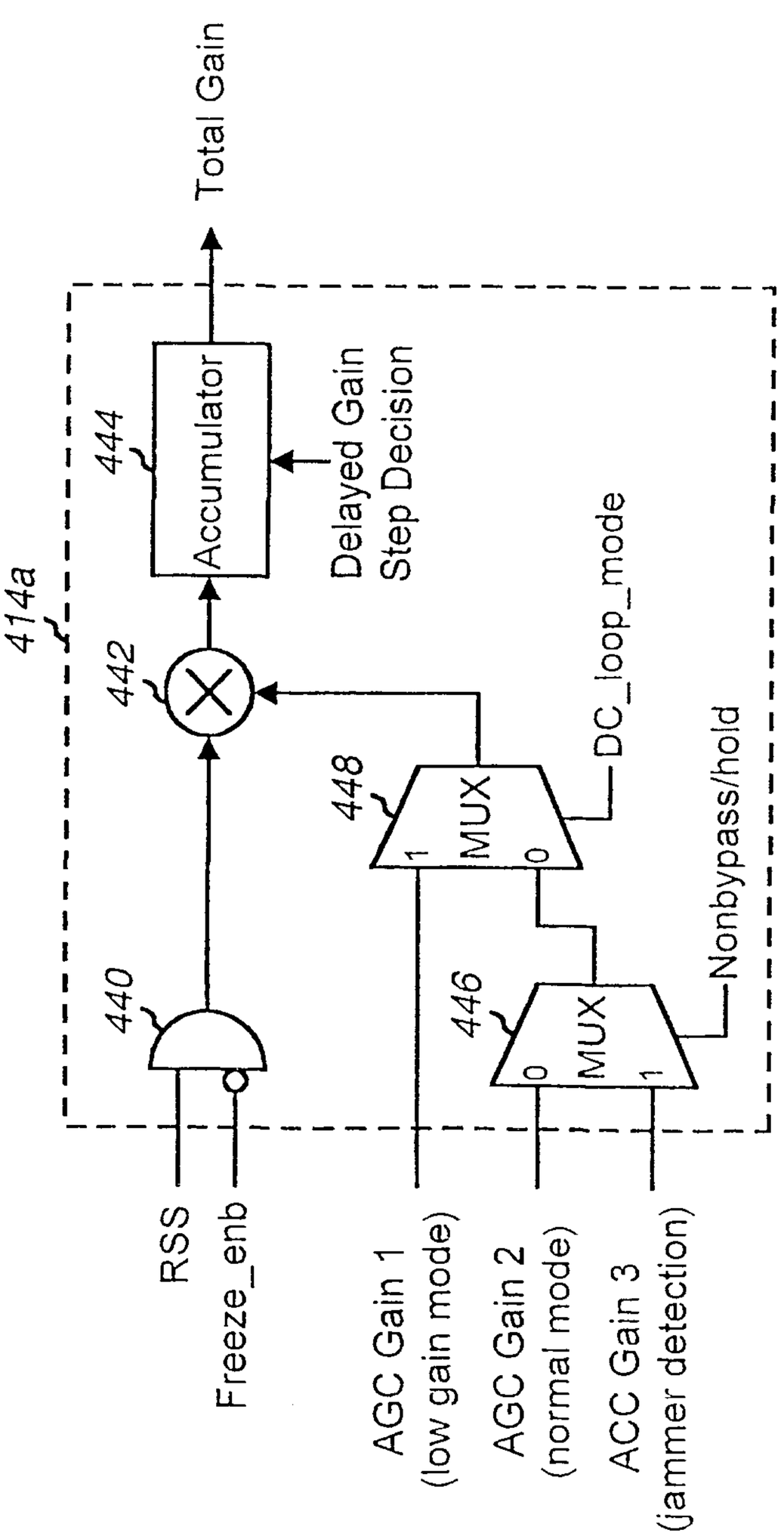

414a
442
444
Accumulator
Total Gain
Delayed Gain
Step Decision
440
448
MUX
446
MUX
DC_loop_mode
Nonbypass/hold
RSS
Freeze_enb
AGC Gain 1
(low gain mode)
AGC Gain 2
(normal mode)
ACC Gain 3
(jammer detection)

FIG. 4B

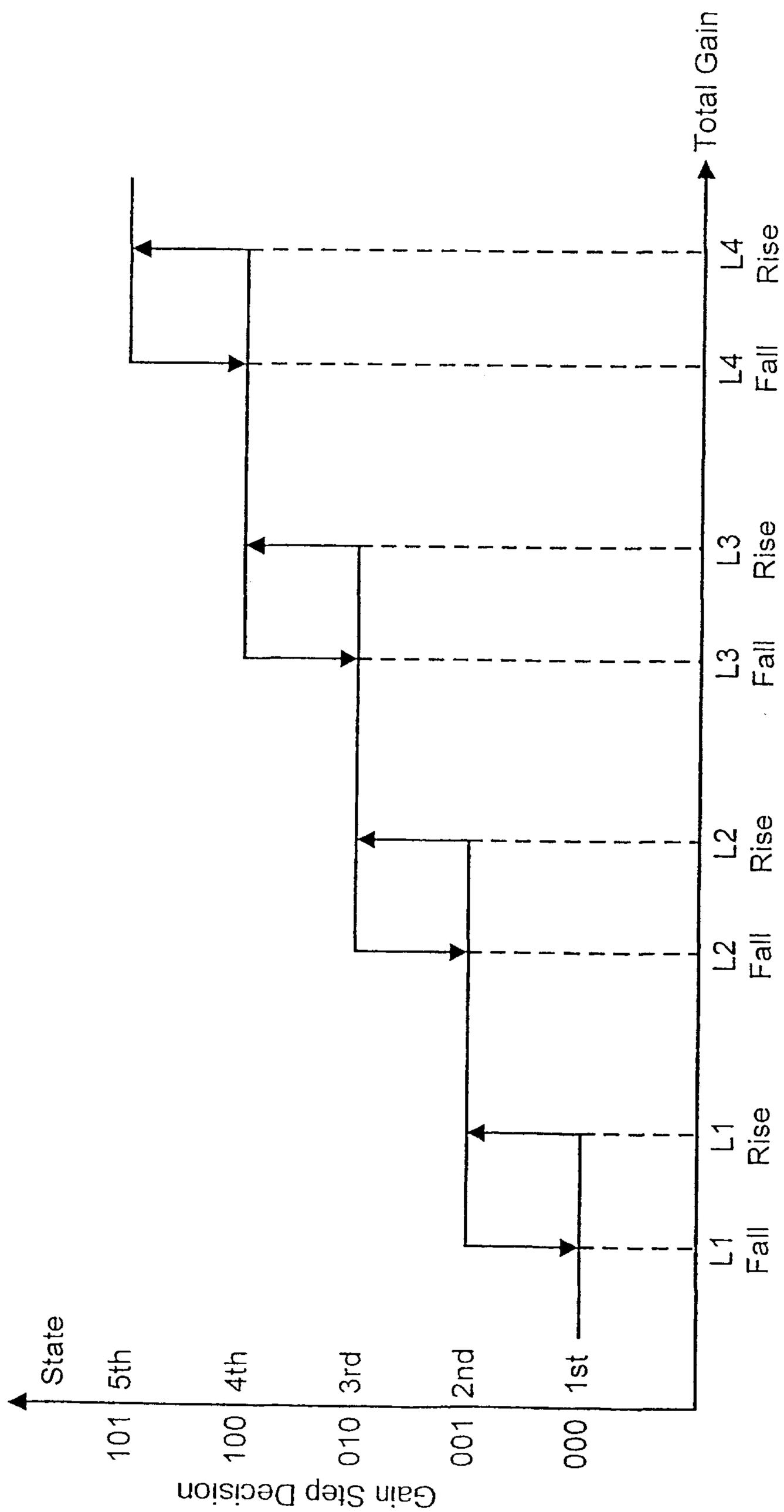
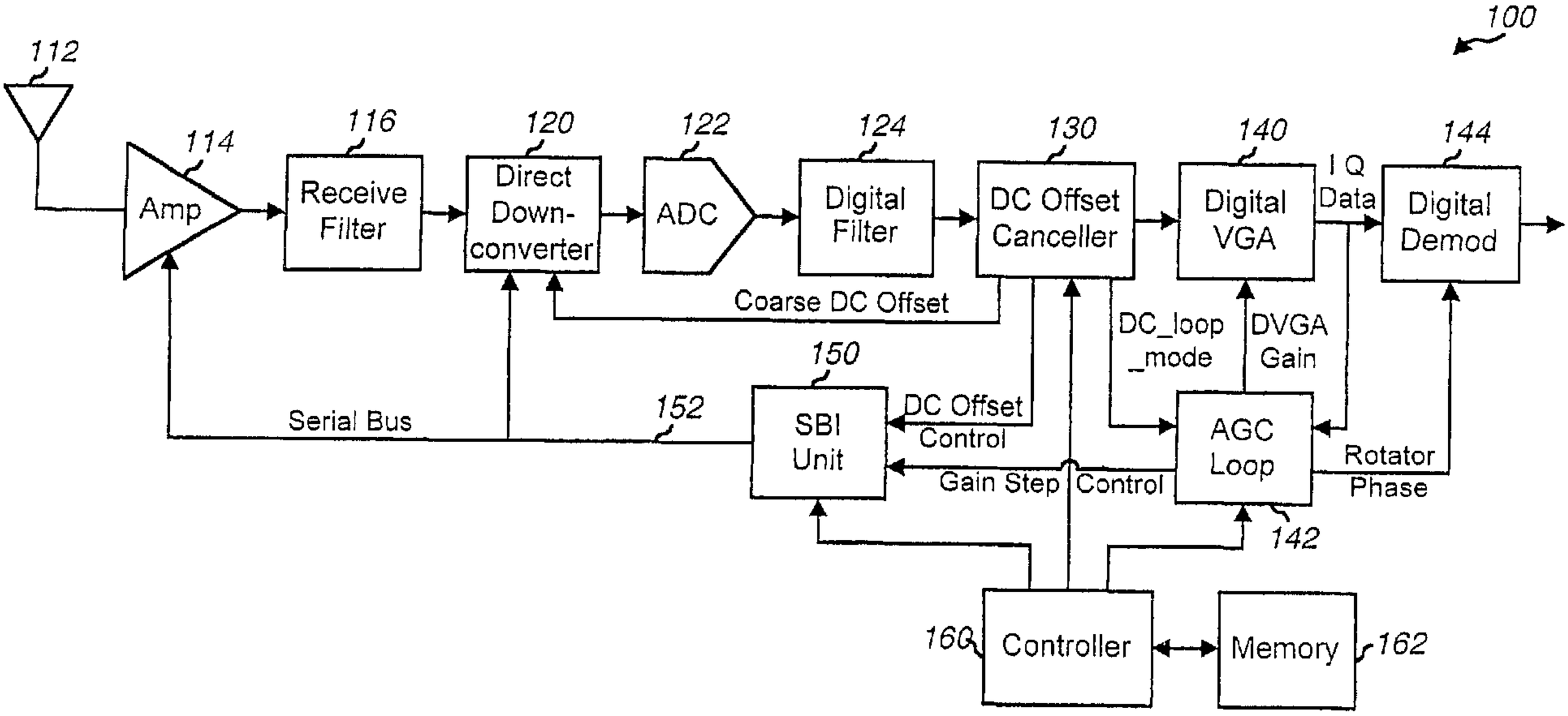

Total Gain
L4 Rise
L4 Fall
L3 Rise
L3 Fall
L2 Rise
L2 Fall
L1 Rise
L1 Fall
State
5th
4th
3rd
2nd
1st
101
100
010
001
000
Gain Step Decision

FIG. 4C


100
112
114
Amp
116
Receive Filter
120
Direct Down-converter
122
ADC
124
Digital Filter
130
DC Offset Canceller
140
Digital VGA
I Q Data
144
Digital Demod
Coarse DC Offset
DC_loop _mode
DVGA Gain
150
Serial Bus
152
SBI Unit
DC Offset Control
Gain Step Control
AGC Loop
Rotator Phase
142
160
Controller
Memory
162