US006317589B1

(12) **United States Patent**
Nash

(10) **Patent No.: US 6,317,589 B1**
(45) **Date of Patent: *Nov. 13, 2001**

(54) **RADIO RECEIVER AND METHOD OF OPERATION**

(75) Inventor: **Adrian Philip Nash**, Surrey (GB)

(73) Assignee: **Nokia Mobile Phones Limited**, Espoo (FI)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/086,071**

(22) Filed: **May 28, 1998**

(30) **Foreign Application Priority Data**

Jun. 6, 1997 (GB) 9711823

(51) **Int. Cl.**[7] **H04B 1/06**

(52) **U.S. Cl.** **455/245.2**; 455/226.2; 455/240.1; 455/67.1; 375/345

(58) **Field of Search** 455/323, 226.2, 455/230, 232.1–245.2, 252, 373, 324; 375/329, 330, 346, 347; 330/278–285

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,584,710		4/1986	Hansen	455/226
4,856,027	*	8/1989	Nakamura et al.	375/327
4,922,549	*	5/1990	Johnson et al.	455/212
4,955,078	*	9/1990	Chung	455/244.1
5,052,050	*	9/1991	Collier et al.	455/296
5,481,226	*	1/1996	Parkes, Jr.	330/279
5,604,929	*	2/1997	Loper et al.	455/324
5,696,819	*	12/1997	Suizu et al.	379/390
5,848,104	*	12/1998	Ishizu	375/324
5,854,973	*	12/1998	Holtvoeth	455/245.1
5,926,749	*	7/1999	Igarashi et al.	455/127

FOREIGN PATENT DOCUMENTS

0305 603 A1		3/1989	(EP) .
411017748A	*	1/1999	(JP) .

OTHER PUBLICATIONS

"Yu Hewhu Cordic–Base VLSI Architectures for Digital Signal Processing" IEEE Signal Processing Magazine, pp. 16 to 35, Jul. 1992.

United Kingdom Search Report.

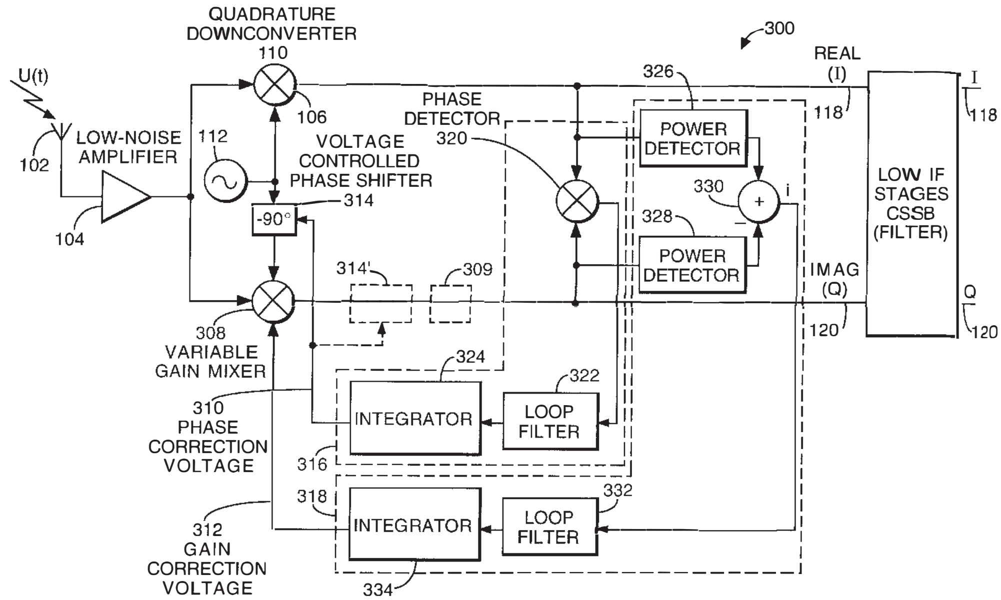
* cited by examiner

Primary Examiner—Nay Maung
Assistant Examiner—Charles Carver
(74) *Attorney, Agent, or Firm*—Perman & Green, LLP

(57) **ABSTRACT**

A gain compensation loop suitable for a quadrature receiver comprises a signal strength comparator having in-phase and quadrature signals fed to respective inputs of the signal strength comparator. The signal strength comparator outputs a signal which represents the difference in strength between the in-phase and quadrature signals. The signal output from the signal strength comparator is input to a gain adjuster which adjusts the gain of the in-phase or quadrature signal in accordance with the signal from the signal strength comparator to bring the in-phase and quadrature signals towards the same strength.

14 Claims, 3 Drawing Sheets



INTEL 1007

Fig.1.

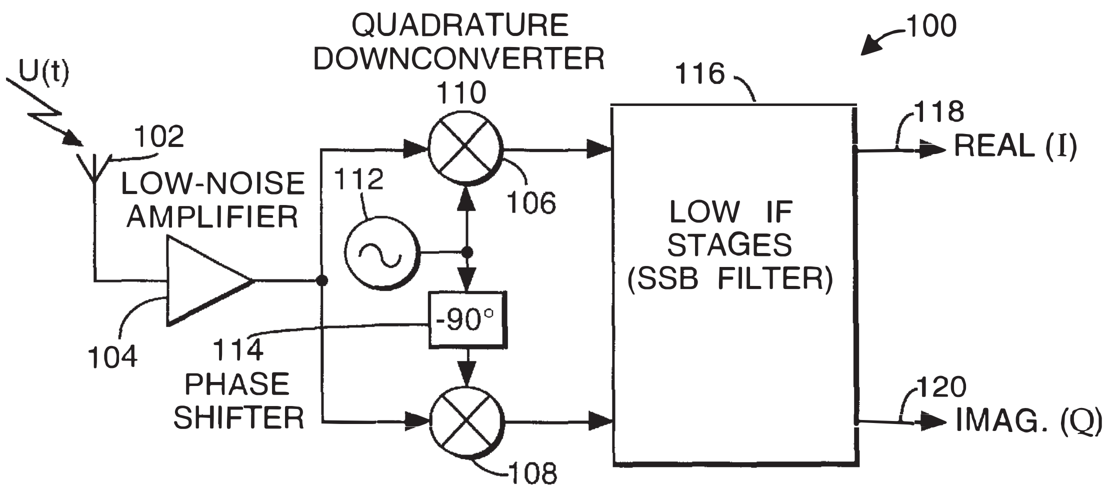

U(t)
102
LOW-NOISE
AMPLIFIER
104
QUADRATURE
DOWNCONVERTER
110
112
106
-90°
114
PHASE
SHIFTER
108
116
100
LOW IF
STAGES
(SSB FILTER)
118
REAL (I)
120
IMAG. (Q)

Fig.2.

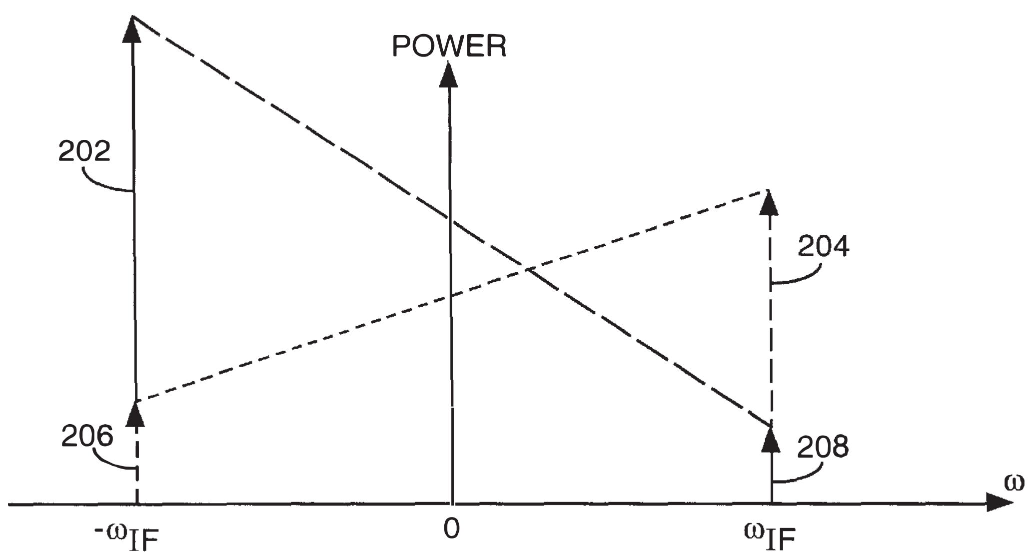

POWER
202
204
206
208
ω
-ωIF
0
ωIF

Fig.3.

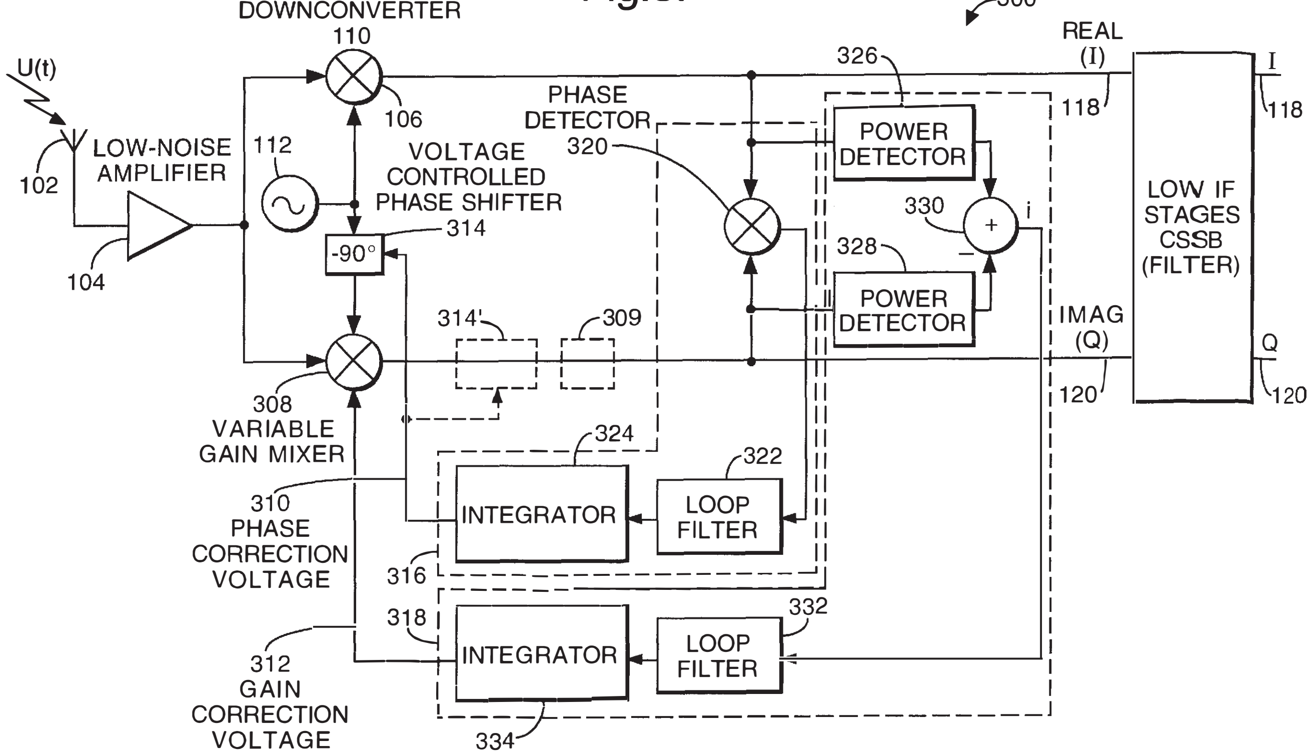

300
QUADRATURE DOWNCONVERTER
110
U(t)
102
LOW-NOISE AMPLIFIER
104
112
106
VOLTAGE CONTROLLED PHASE SHIFTER
314
-90°
314'
309
308
VARIABLE GAIN MIXER
310
PHASE CORRECTION VOLTAGE
312
GAIN CORRECTION VOLTAGE
PHASE DETECTOR
320
324
322
INTEGRATOR
LOOP FILTER
316
318
INTEGRATOR
LOOP FILTER
332
334
326
POWER DETECTOR
330
+
−
i
328
POWER DETECTOR
REAL
(I)
118
IMAG
(Q)
120
LOW IF STAGES CSSB (FILTER)
I
118
Q
120

Fig.4A.

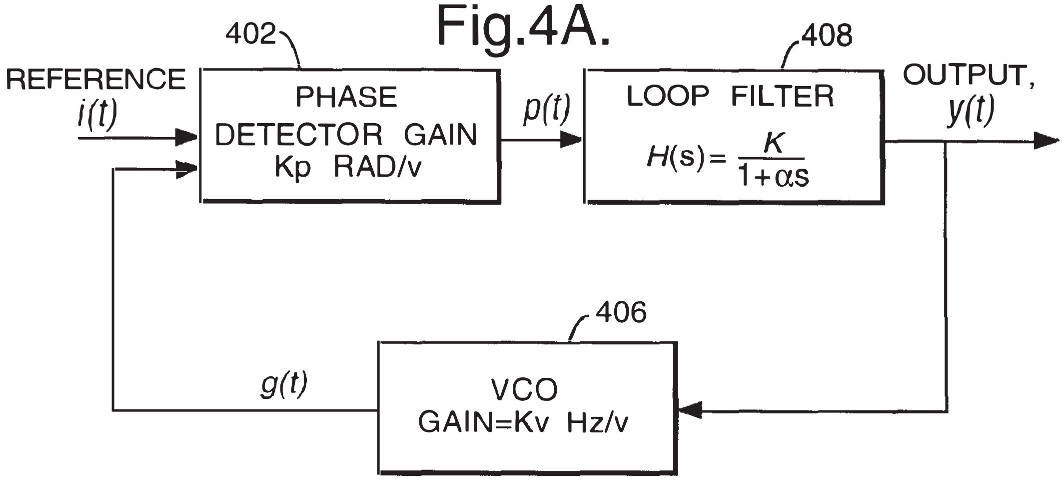


Fig.4B.

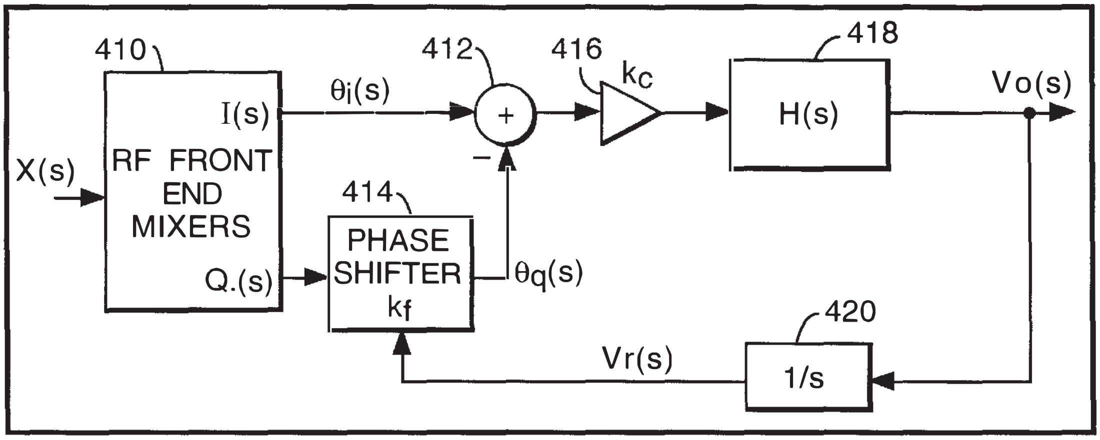
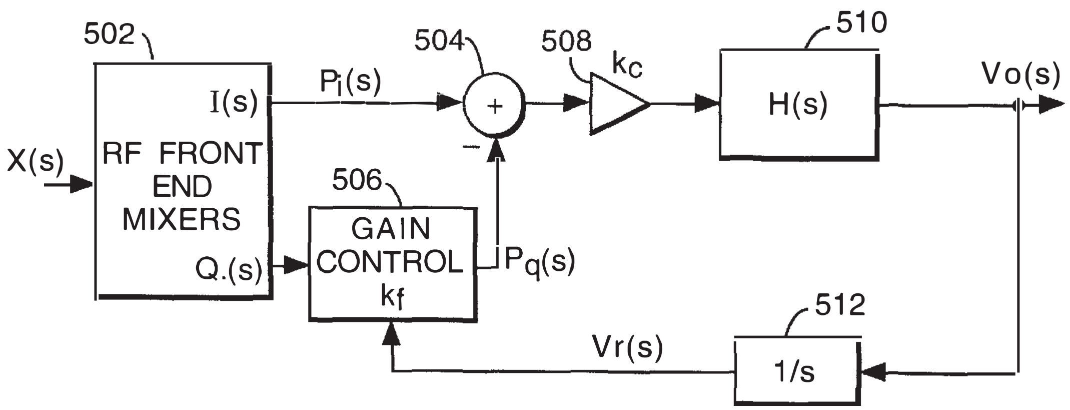


Fig.5.



RADIO RECEIVER AND METHOD OF OPERATION

BACKGROUND OF THE INVENTION

The present invention relates to a radio receiver, in particular but not exclusively, to a gain compensation loop for a quadrature receiver.

The current trend in receiver technology is to reduce weight, volume, power consumption and cost. This is particularly important for receivers in portable apparatus such as radio telephones. This has resulted in receiver architecture designs in which there are no or few discrete radio frequency (RF) and intermediate frequency (IF) filters in the receiver front end.

An example of a receiver architecture having few discrete RF and IF filters is a single conversion low-IF architecture for a quadrature receiver. Single conversion low-IF architectures typically produce an image signal which is very close to the wanted signal. Such image signals are termed "in-band" image signals, and may be filtered out using a single sideband filter. However, a portion of the image signal appears at the wanted signal frequency as cross-talk if there is an imbalance between the phase and/or gain of respective quadrature signals. It is desirable for such cross-talk to be reduced or rejected. Typically, a quadrature receiver front end can only achieve about 30dB of image-to-signal cross-talk rejection, which is often insufficient for many applications such as radio telephones.

A solution to the problem of cross-talk is to use a double-quadrature mixer architecture. However, such an architecture requires 90° phase shifts on both the local oscillator and RF ports coupled to four mixers. Providing at least one of the ports (e.g. the local oscillator) is phase and amplitude balanced, any imbalance at the other port (e.g. the RF port) results in a spurious product at a frequency given by the sum of the RF and local oscillator frequencies. This can be easily filtered out using an RF bandpass filter before the mixers.

A drawback of the above approach is that four mixers are required resulting in relatively high power consumption. Additionally, a relatively bulky RF 90° hybrid coupler is also required together with quadrature balance on the local oscillator port.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a gain compensation loop for a quadrature receiver adapted to generate first and second quadrature signals from a received signal, the gain compensation loop comprising : a signal strength comparator for receiving the first and second signals and adapted to output a third signal indicative of a difference in signal strength between the first and second signals; and gain adjusting means for adjusting the strength of the first signal in accordance with the third signal thereby bringing the first and second signals towards the same strength.

According to a second aspect of the invention there is provided a method for gain compensation in a quadrature receiver adapted to generate first and second quadrature signals from a received signal, the method comprising the steps of: comparing the signal strength of the first signal with the signal strength of the second signal; deriving a third signal indicative of a difference in strength between the first and second signals; and adjusting the strength of the first signal in accordance with the third signal.

Preferred embodiments in accordance with first and second aspects of the invention have the advantage that the strength of the first and second signals may be brought towards a balance by appropriate control of the gain adjusting means. Thereby image cross-talk may be reduced. This obviates the need for image rejection filters in the RF front end of the receiver which results in lower weight, volume, loss and cost for such receivers.

In a preferred embodiment the gain adjusting means is disposed in the radio frequency front end of a quadrature receiver which has the advantage that any image rejecting filters in the intermediate frequency region of the receiver are less likely to be overdriven by a strong image signal.

Preferably, the gain adjusting means comprises variable gain mixer, which is suitably one of the mixers in the quadrature receiver.

Optionally, the gain adjusting means is disposed after the radio frequency front end and is operable for signals at an intermediate frequency of a quadrature receiver. Such an intermediate frequency may be zero Hertz (0 Hz) for a gain compensation loop in a direct conversion receiver, for example.

Suitably, the gain adjusting means and/or gain comparator comprise an appropriately conditioned digital signal processor, which advantageously is environmentally independent and does not require external components. Alternatively, the gain adjusting means comprises an amplifier.

The gain compensation loop may comprise a loop filter having an input for receiving the third signal and an output for providing a control signal to the gain adjusting means, thereby providing for tracking a dynamic gain or signal strength imbalance between first and second signals.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments in accordance with the invention will now be described, by way of example only, and with reference to the accompanying drawings, in which:

FIG. **1** is a schematic diagram of a quadrature single-conversion RF front end;

FIG. **2** shows a schematic representation of wanted and image signals, and image crosstalk;

FIG. **3** is a schematic diagram of a quadrature receiver in accordance with an embodiment of the present invention;

FIG. **4A** is a schematic diagram of a conventional phase locked loop;

FIG. **4B** is a schematic diagram of a phase compensation loop in accordance with an embodiment of the present invention; and

FIG. **5** is a schematic diagram of a gain compensation loop.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a schematic diagram for a quadrature single-conversion receiver RF front end **100**. A radio frequency signal v(t), such as an AM or FM modulated signal, is received by antenna **102**. The received signal v(t) is amplified by low-noise amplifier **104** and the amplified signal is input to mixers **106** and **108** by a power splitter. The mixers **106** and **108** form part of quadrature down-converter **110**. The signal LO output from local oscillator **112** has a frequency which is very close to the carrier frequency, fc, of the received signal v(t). The LO signal is fed directly into

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.