US006230000B1

(12) United States Patent
Tayloe

(10) Patent No.: US 6,230,000 B1
(45) Date of Patent: May 8, 2001

(54) **PRODUCT DETECTOR AND METHOD THEREFOR**

(75) Inventor: **Daniel Richard Tayloe**, Phoenix, AZ (US)

(73) Assignee: **Motorola Inc.**, Schaumburg, IL (US)

(*) Notice: 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.: **09/173,030**

(22) Filed: **Oct. 15, 1998**

(51) **Int. Cl.**[7] **H04B 1/26**; H04B 1/00

(52) **U.S. Cl.** **455/323**; 455/303; 455/304; 455/313

(58) **Field of Search** 455/302, 303, 455/304, 324, 338, 339, 313, 318, 323; 375/323, 329, 332; 327/113, 45; 329/304

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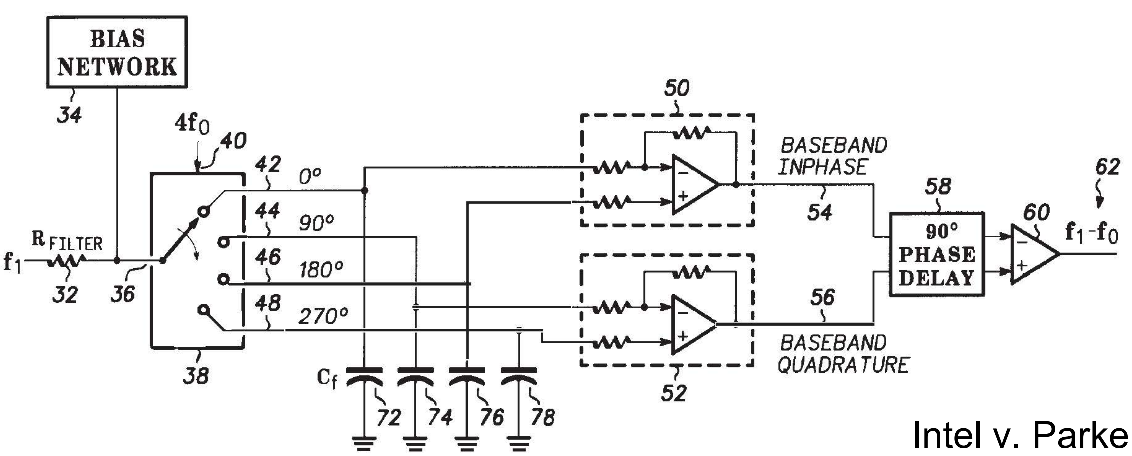
Primary Examiner—Dwayne Bost
Assistant Examiner—Raymond B. Persino
(74) *Attorney, Agent, or Firm*—Dana B. LeMoine; Timothy J. Lorenz; Frank J. Bogacz

(57) **ABSTRACT**

A product detector for converting a signal to baseband includes a commutating switch which serves to sample an RF waveform four times per period at the RF frequency. The samples are integrated over time to produce an average voltage at 0 degrees, 90 degrees, 180 degrees and 270 degrees. The average voltage at 0 degrees is the baseband in-phase signal, and the average voltage at 90 degrees is the baseband quadrature signal. Alternatively, to increase gain, the 0 degree average can be differentially summed with the 180 degree average to form the baseband in-phase signal, and the 90 degree average can be differentially summed with the 270 degree average to produce the baseband quadrature signal.

14 Claims, 3 Drawing Sheets



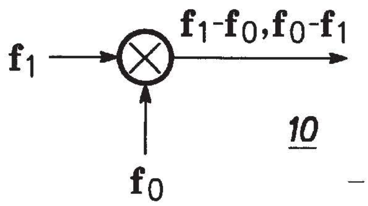


FIG. 1
- PRIOR ART -

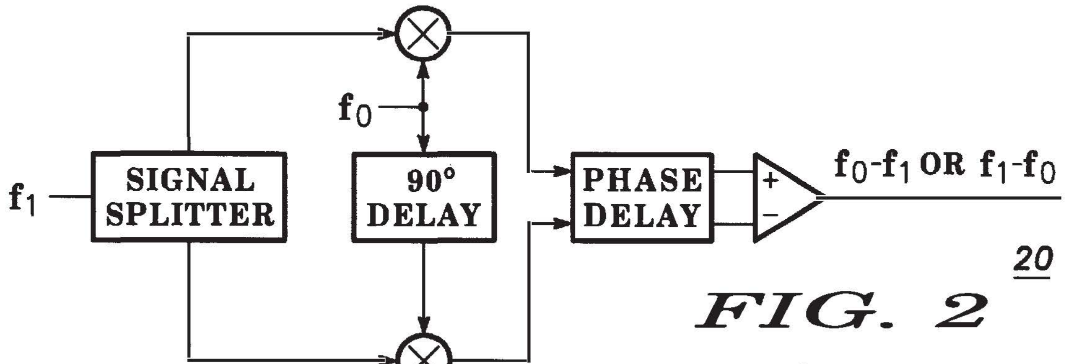


FIG. 2
- PRIOR ART -

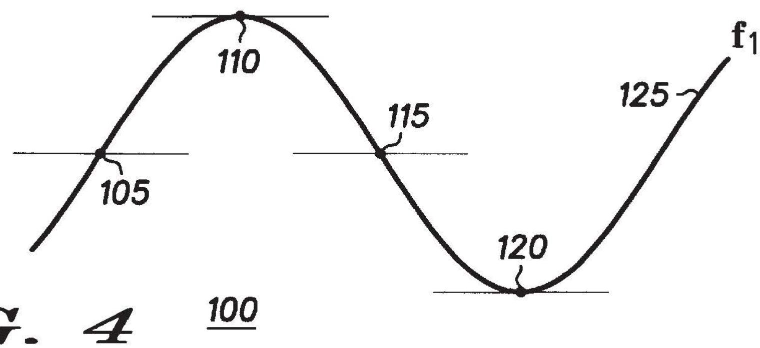


FIG. 4

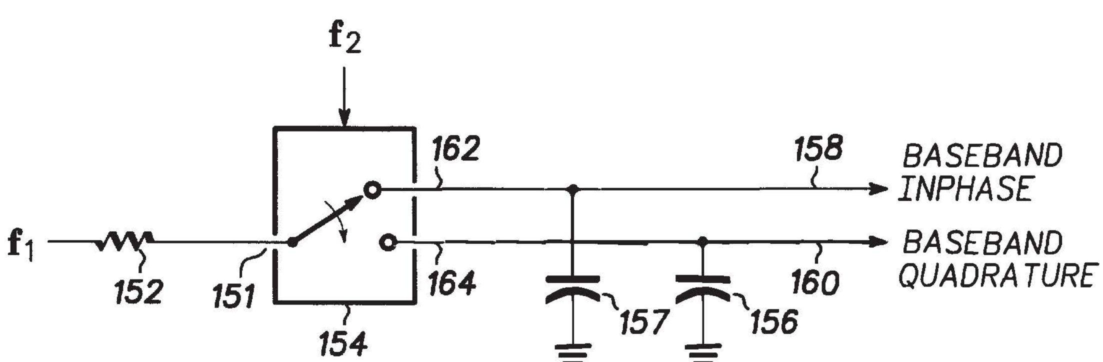
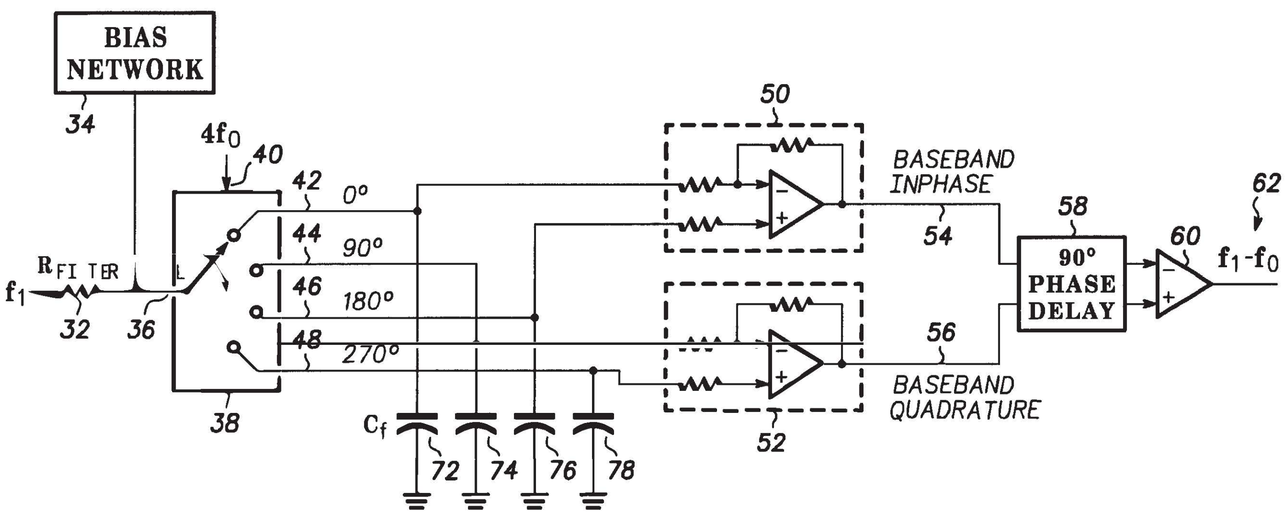


FIG. 5 150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40
42
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44
90°
46
180°
48
270°
R_{FILTER}
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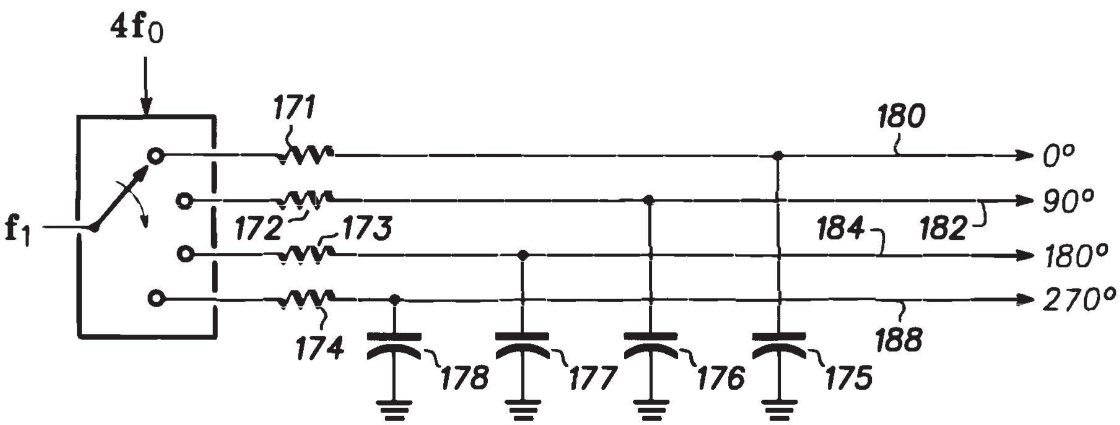
32
36
38
C_f
72
74
76
78
50
52
BASEBAND INPHASE
54
56
BASEBAND QUADRATURE
58
90° PHASE DELAY
60
62
f_1-f_0

30 *FIG. 3*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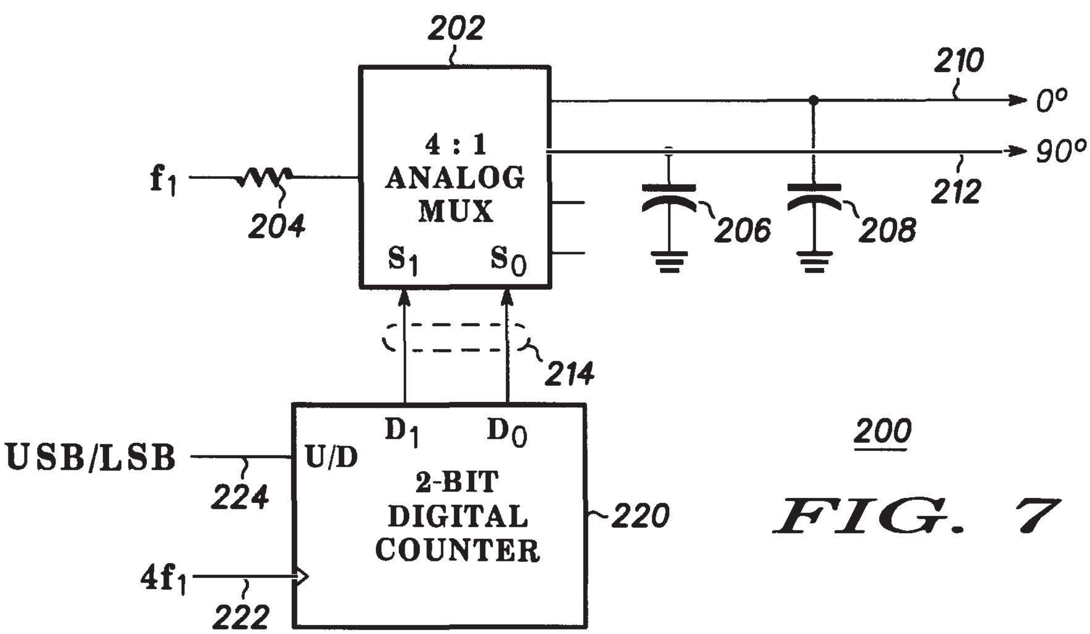
180
0°
90°
f_1
172
173
184
182
180°
270°
174
188
178
177
176
175
170

FIG. 6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MUX
90°
f_1
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204
206
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S$_1$
S$_0$
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D$_1$
D$_0$
200
USB/LSB
U/D
2-BIT
DIGITAL
COUNTER
224
220
4f$_1$
222

FIG. 7

PRODUCT DETECTOR AND METHOD THEREFOR

FIELD OF THE INVENTION

This invention relates in general to radio receivers and, in particular, to the converting of signals in frequency.

BACKGROUND OF THE INVENTION

Direct conversion receivers are desirable in part because they convert signals of interest directly to baseband (or near zero hertz) from a radio frequency (RF) or an intermediate frequency (IF). Simple direct conversion receivers, such as receiver **10** shown in FIG. **1**, suffer from multiple drawbacks. The RF signal f_1 is mixed with the local oscillator signal f_0, and the signal of interest f_1-f_0 is produced at baseband at the output. Unfortunately, superimposed on the signal of interest is the image f_0-f_1. The "image problem" of simple direct conversion receivers is well known in the art of receiver design, the solution to which has been the subject of scholarly study for decades.

Image reject mixers, such as mixer **20** in FIG. **2**, have been developed in response to the image problem suffered by simple direct conversion receivers. The operation of image reject mixers, including the mathematical basis upon which they operate, is described in detail in "High-Performance, Single-Signal Direct-Conversion Receivers" by Rick Campbell, published in the January, 1993 issue of QST magazine. Image reject mixers utilize two local oscillator signals, each differing from the other by 90 degrees in phase. Image reject mixers also require the use of two separate mixer elements. Image reject receivers represent a complex and expensive solution to the image problem of direct conversion receivers.

Both simple direct conversion receivers and image reject mixers nominally exhibit a loss of 6 dB because half of the signal is converted to f_0+f_1, the sum of the RF frequency and the local oscillator frequency, and then discarded. In practice, the loss is often greater than 6 dB because conventional mixers are typically implemented with diodes which exhibits a finite amount of loss themselves. Typical conversion loss in prior art image reject mixers is 7–8 dB.

What is needed is a low-loss method and apparatus for simply and inexpensively overcoming the image problem of direct conversion receivers.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a prior art direct conversion receiver;

FIG. **2** shows a prior art image reject mixer;

FIG. **3** shows a direct conversion receiver in accordance with a preferred embodiment of the present invention;

FIG. **4** shows a waveform in accordance with a preferred embodiment of the present invention;

FIG. **5** shows a product detector in accordance with a preferred embodiment of the present invention;

FIG. **6** shows a product detector in accordance with an alternate embodiment of the present invention; and

FIG. **7** shows a product detector in accordance with an alternate embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

The method and apparatus of the present invention represent a simple and inexpensive product detector which facilitates the conversion of a signal to baseband without the unwanted image from interfering. A commutating switch is

used in combination with capacitors to integrate portions of the input signal. The in-phase and quadrature signals that result represent the signal of interest at baseband.

Turning now to the drawings in which like reference characters indicate corresponding elements throughout the several views, attention is first directed to FIG. **3**. FIG. **3** shows a direct conversion receiver in accordance with a preferred embodiment of the present invention. Direct conversion receiver **30** includes resistor **32**, bias network **34**, commutating switch **38**, capacitors **72**, **74**, **76**, and **78**, summing amplifiers **50** and **52**, phase delay **58**, and summing amplifier **60**.

In operation, an RF or IF signal f_1 is received at resistor **32**. Resistor **32**, as is more fully discussed below, forms a filter when taken in combination with capacitors **72–78**. After passing through resistor **32**, the input signal is received by commutating switch **38** at input **36**. Commutating switch **38** switches input **36** to outputs **42**, **44**, **46**, and **48**. The rate at which commutating switch **38** operates is controlled by a signal present at control input **40**. In the preferred embodiment as shown in FIG. **3**, the control signal input to control input **40** is substantially equal to four times the local oscillator frequency that would exist in a simple direct conversion receiver. As a result, input **36** is switched to each of the four outputs substantially once during each period of the input signal f_1.

In a preferred embodiment, commutating switch **38** remains closed at each of the four outputs for substantially 90 degrees at the frequency of the input signal. In alternate embodiments, commutating switch **38** remains closed at each of the four outputs for less than 90 degrees.

During the time that commutating switch **38** connects input **36** to output **42**, charge builds up on capacitor **72**. Likewise, during the time commutating switch **38** connects input **36** to output **44**, charge builds up on capacitor **74**. The same principle holds true for capacitors **76** and **78** when commutating switch **38** connects input **36** to outputs **46** and **48** respectively. As commutating switch **38** cycles through the four outputs, capacitors **72–78** charge to voltage values substantially equal to the average value of the input signal during their respective quadrants. Each of the capacitors functions as a separate integrator, each integrating a separate quarter wave of the input signal. This principle is described more fully with respect to FIG. **4** below.

Output **42** represents the average value of the input signal during the first quarter wave of the period, and is termed the 0 degree output. Output **44** represents the average value of the input signal during the second quarter wave of the period, and is termed the 90 degree output. Output **46** represents the average value of the input signal during the third quarter wave of the period, and is termed the 180 degree output. Output **48** represents the average value of the input signal during the fourth quarter wave of the period, and is termed the 270 degree output.

The outputs of commutating switch **38** are input to summing amplifiers **50** and **52**. Summing amplifier **50** differentially sums the 0 degree output and the 180 degree output, thereby producing baseband in-phase signal **54**. Summing amplifier **52** differentially sums the 90 degree output and the 270 degree output, thereby producing baseband quadrature signal **56**. Baseband in-phase signal **54** and baseband quadrature signal **56** are input to phase delay **58** which shifts the phase of baseband quadrature signal **56** by 90 degrees relative to baseband in-phase signal **54**. The resulting signals are then summed by summing amplifier **60** to produce the signal of interest **62**.

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