US006917252B1

(12) **United States Patent**
Wyszynski

(10) **Patent No.: US 6,917,252 B1**
(45) **Date of Patent: Jul. 12, 2005**

(54) **FULLY INTEGRATED AUTOMATICALLY-TUNED RF AND IF ACTIVE BANDPASS FILTERS**

(76) Inventor: **Adam S. Wyszynski**, 1512 Highland Cir., Little Elm, TX (US) 75068-3787

(*) 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.: **10/423,923**

(22) Filed: **Apr. 28, 2003**

(51) **Int. Cl.**^{7} **H04B 3/04**

(52) **U.S. Cl.** **333/17.1**; 333/202; 455/339

6,310,512 B1	* 10/2001	Briskin et al.	....	327/552
6,356,736 B2	3/2002	Tomasz et al.		
6,374,086 B1	* 4/2002	Tolson	....	455/73
6,377,315 B1	4/2002	Carr et al.		
6,400,932 B1	* 6/2002	Oh et al.	....	455/150.1
6,404,277 B1	6/2002	Lee et al.		
6,417,727 B1	7/2002	Davis		
6,496,230 B1	12/2002	Limberg et al.		

OTHER PUBLICATIONS

Y. Tsividis, "Self–Tune Filters," Electronic Letters, vol. 17 (No. 12), pp. 406–407, (Jun., 1981).
G.A. De Veirman & R. Yamasaki, "Fully–Integrated 5 to 15 MHz Programmable Bessel Lowpass Filter," Proc. IEEE Int. Symp. Circ. Syst., p. 1155–1158, (1990).
G.A. De Veirman & R. Yamasaki, "Monolithic 10–30 MHz Tunable Bipolar Bessel Lowpass Filter," Proc. IEEE Int.

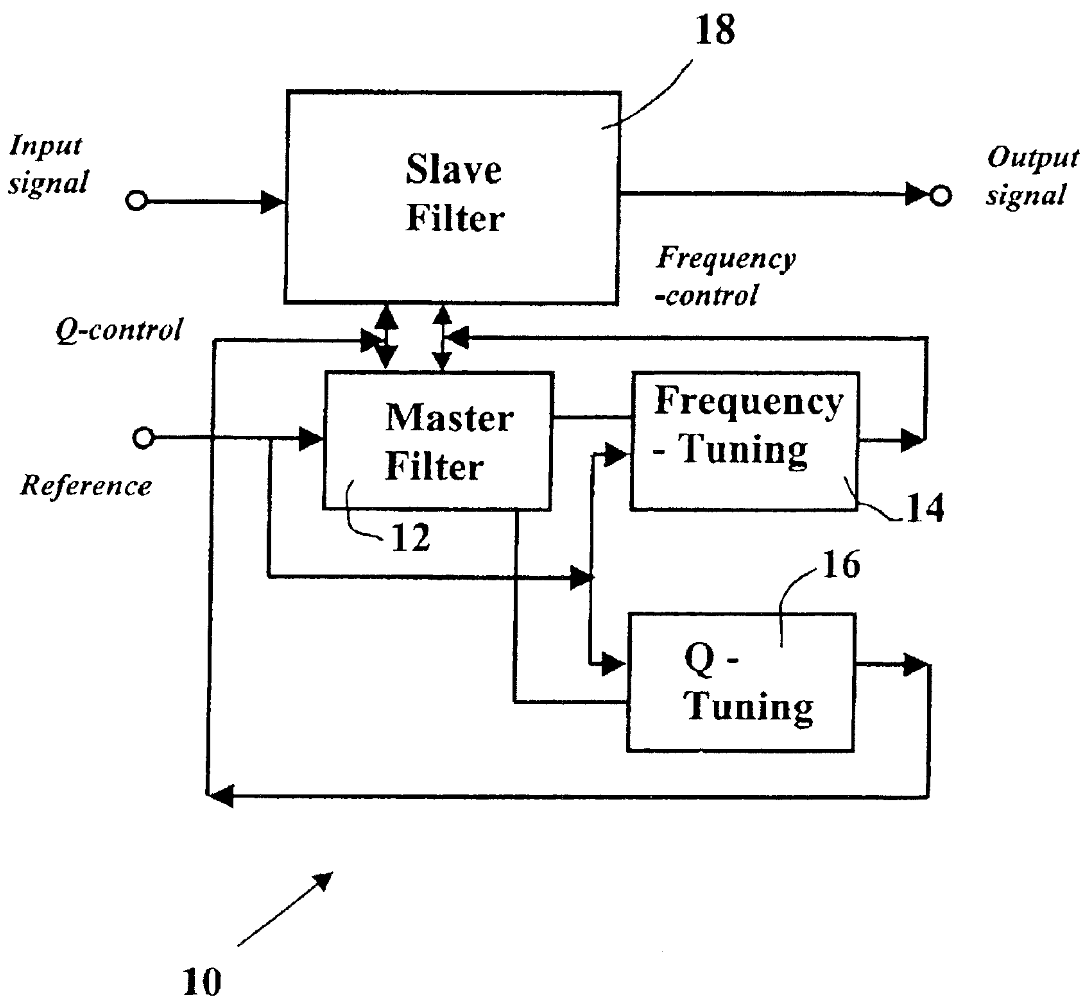

Figure 1

Prior Art

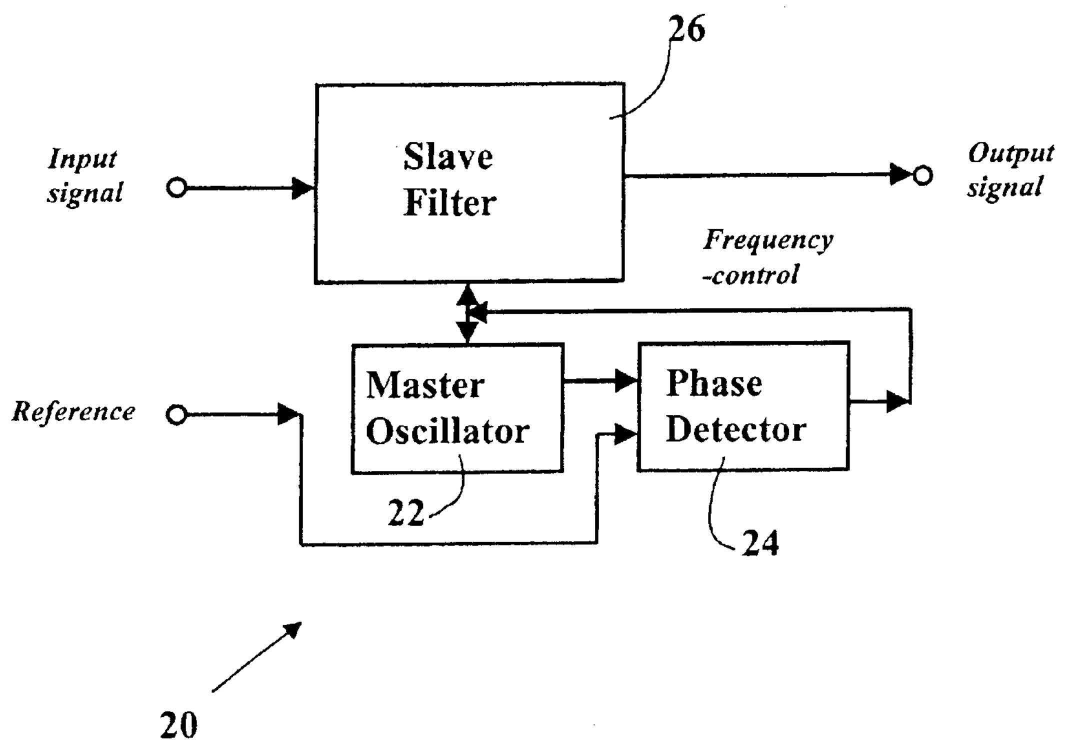

Figure 2

Prior Art

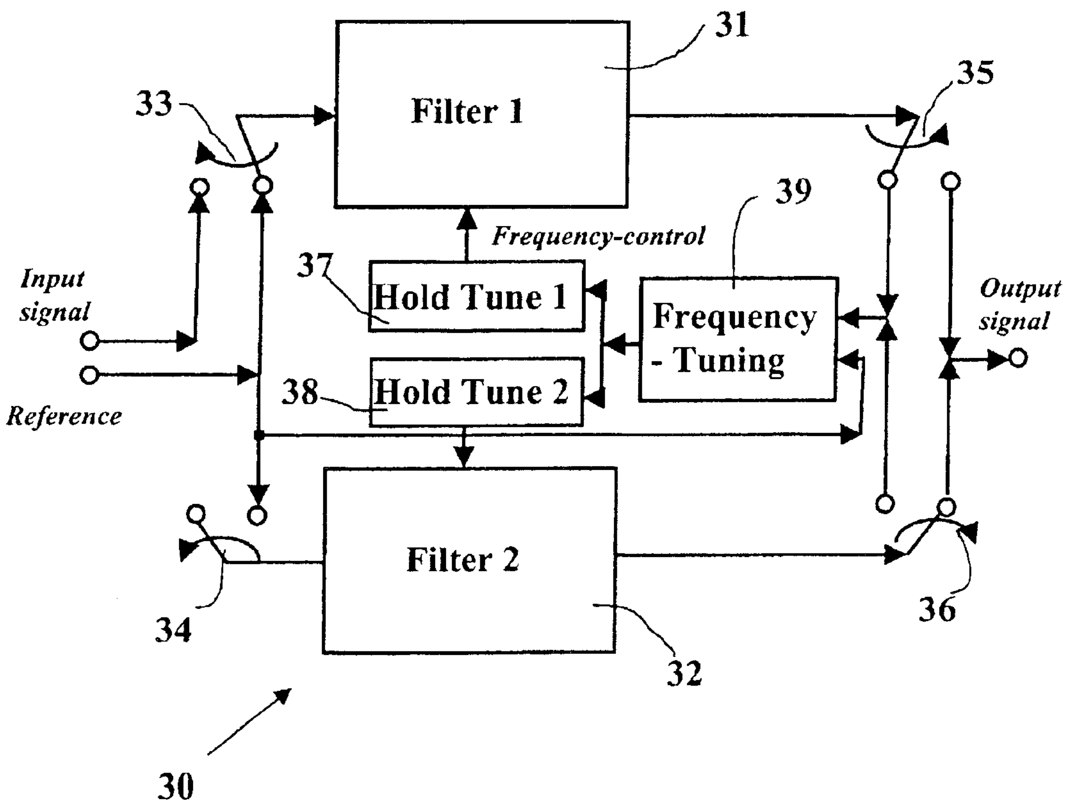

Figure 3

Prior Art

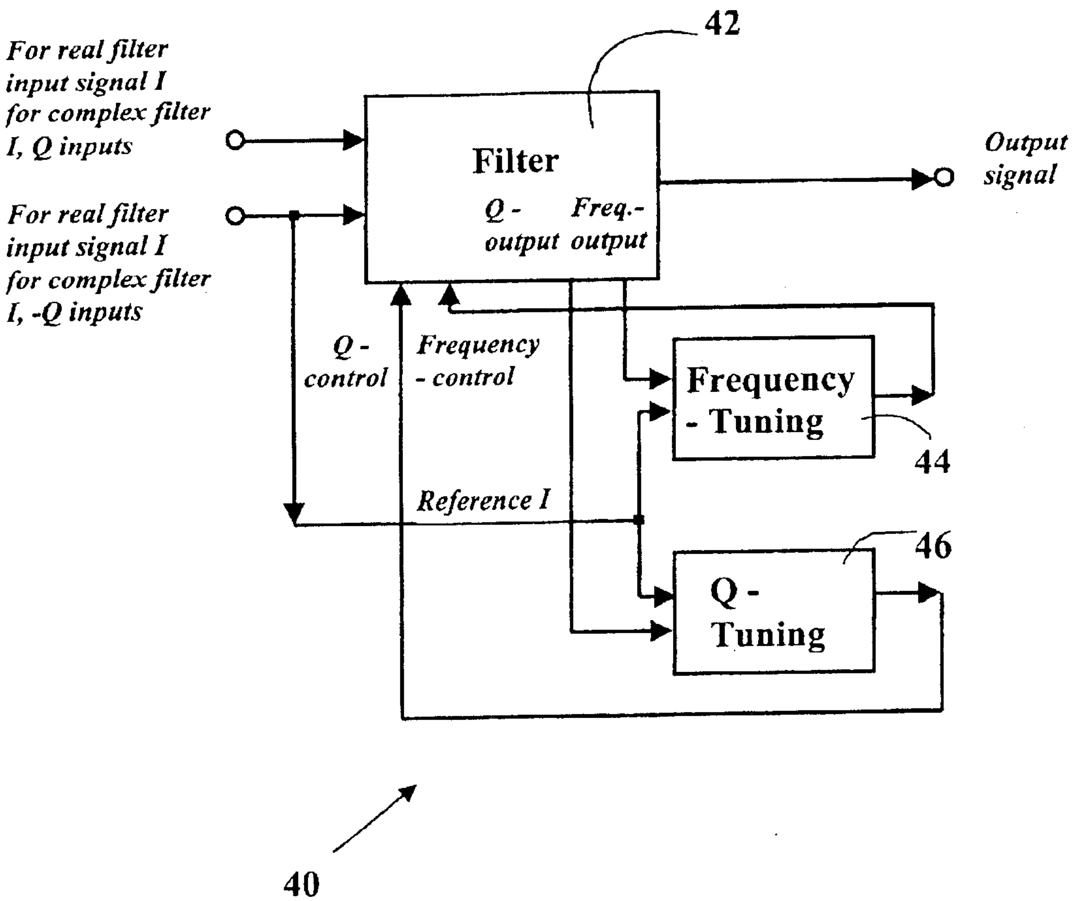
42
For real filter
input signal I
for complex filter
I, Q inputs
Filter
Q -
output
Freq.-
output
Output
signal
For real filter
input signal I
for complex filter
I, -Q inputs
Q -
control
Frequency
- control
Frequency
- Tuning
44
Reference I
46
Q -
Tuning
40

Figure 4

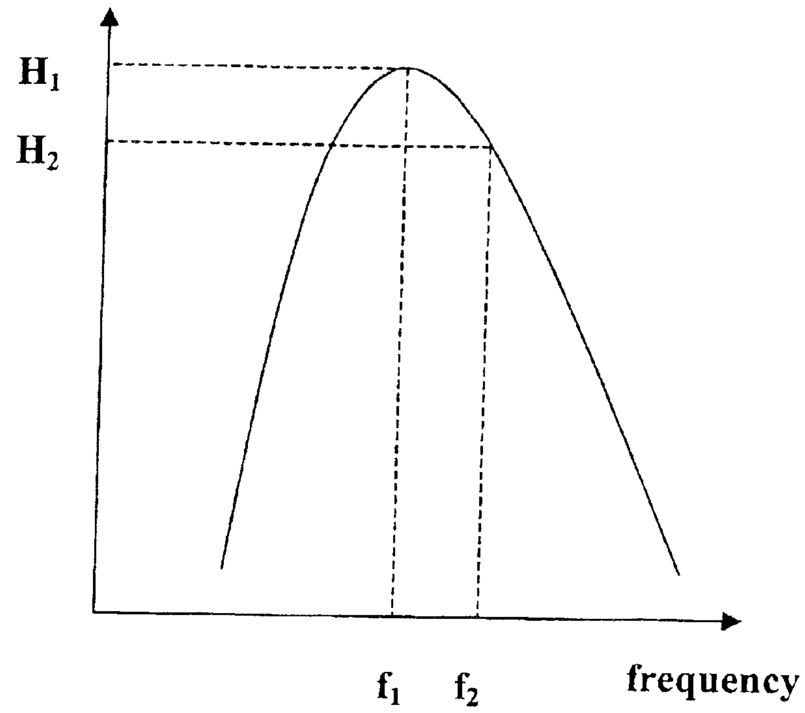

Figure 5a

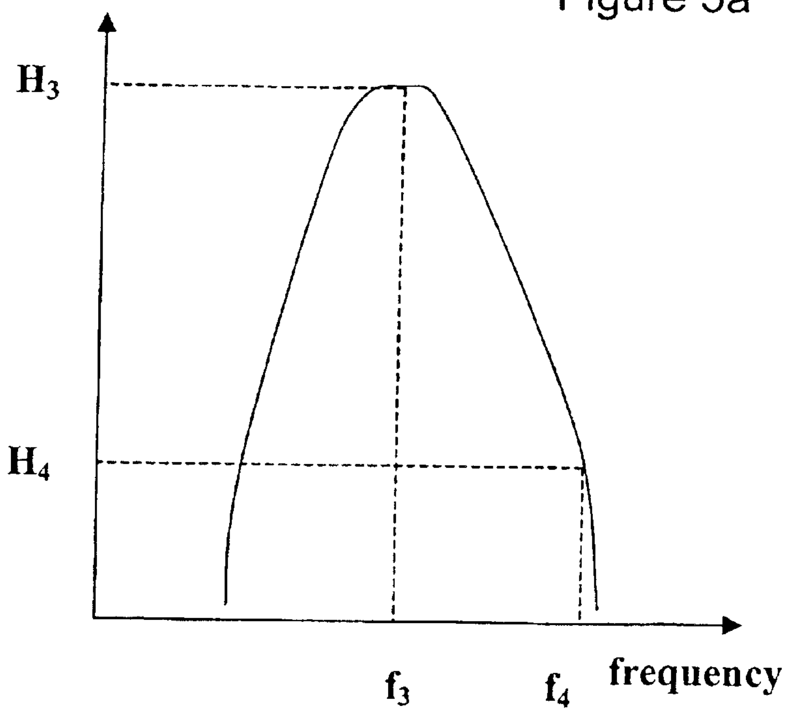

Figure 5b

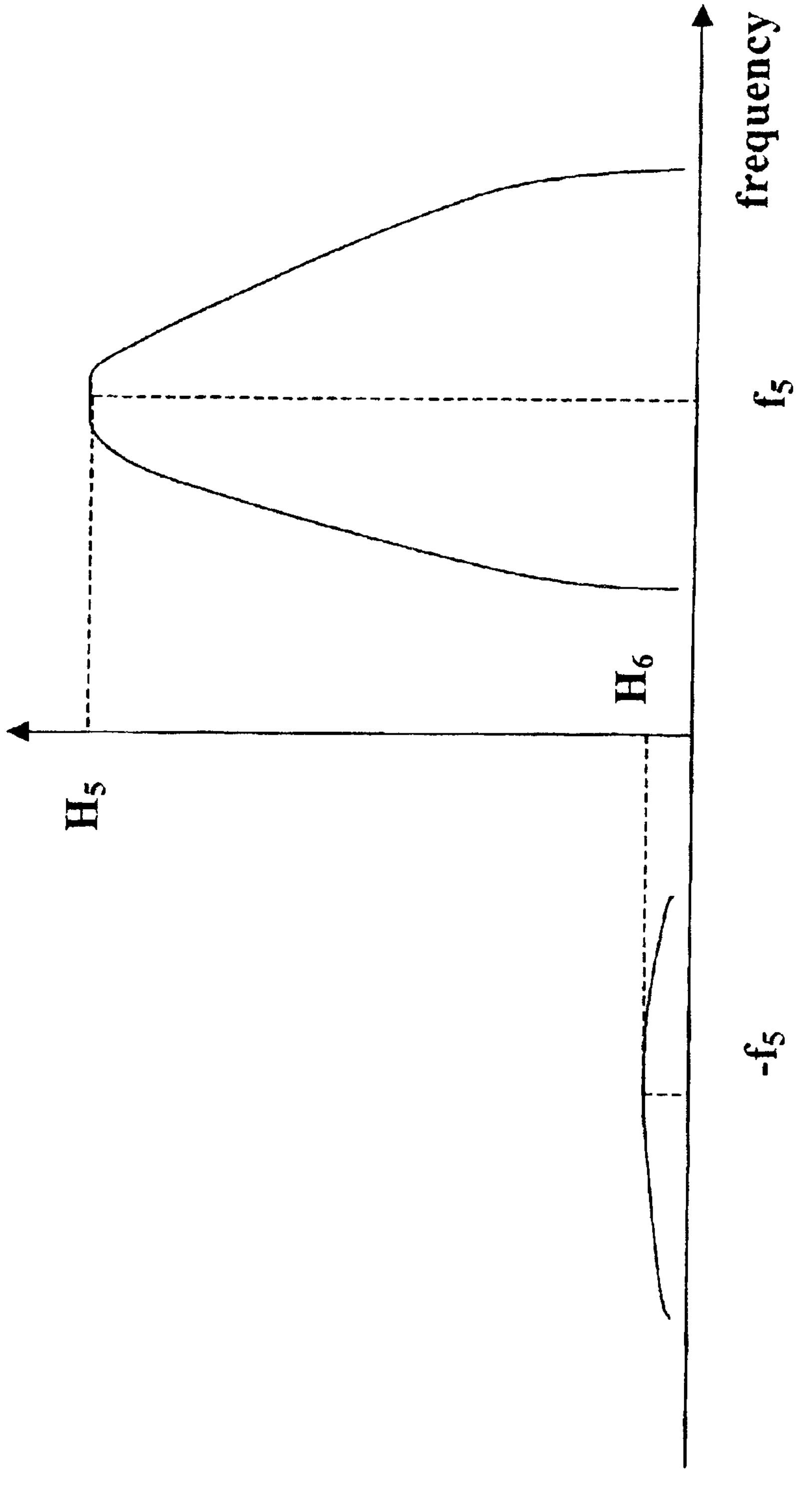

Figure 6a

FULLY INTEGRATED AUTOMATICALLY-TUNED RF AND IF ACTIVE BANDPASS FILTERS

TECHNICAL FIELD OF THE INVENTION

The present invention relates to fully-integrated continuous-time active band-pass filters and their automatic frequency- and Q-tuning systems.

BACKGROUND OF THE INVENTION

Nearly all practical transceivers require some form of filtering. Up to the date, in majority of cases, these radio-frequency (RF) and intermediate-frequency (IF) filters are realized off-chip as ceramic or surface-acoustic wave (SAW) devices.

A first reason for slow progress in integration RF and IF filters is their rather modest noise and distortion performance. This can be alleviated by a careful overall system design by taking into account the filter short comings and by purposely reducing their requirements while simultaneously offsetting their reduced performance with superior performance of preceding and following high-quality blocks.

A second reason for slow progress in integration RF and IF filters is that these filters require circuitry for adjusting

tortion. Suppose that the reference frequency it is Δf away from the desired channel carrier. Give the attenuation characteristic of the IF BP filter Δf separation should be chosen such that the IF BP filter attenuates the reference of the RF BP filter by at least 40 dB;

hence at the output the signal and the reference differ at least by 55 dB, which is better than the reference feed-through of a typical M-S scheme;

the reference of the IF BP filter is rejected by its appropriate conditioning with respect to the main signal and the complex nature of the IF BP filter. The expected attenuation of the IF BP filter reference is at least 55 dB.

DESCRIPTION OF THE PRIOR ART

The architecture of a classical Master-Slave (M-S) tuning scheme such as one described in U.S. Pat. No. 3,997,856 is illustrated in FIG. **1**, and is identified by the numeral **10**. Note that only a frequency-tuning scheme is presented in U.S. Pat. No. 3,997,856. The Q-tuning scheme is not disclosed in that patent. The frequency-control part consists of a Master filter (or Master oscillator) **12** followed by the frequency-tuning circuit **14** that similarly to U.S. Pat. No. 3,997,856 may consist of a phase-detector, a low-pass filter and a differential amplifier. These blocks are not drawn separately here for the sake of simplicity. The Q-control part when the first of filters **31** and **32** has its input connected to the input signal the other one is tuned and then their roles are interchanged. The outputs of filters **31** and **32** are switched using switches **35** and **36**. The frequency reference is applied to the frequency-tuning circuit **39** that generates control signals via hold circuits **37** and **38** for tuning the one of the filters **31** and **32** that is not processing the input signal. The critical difficulty of this scheme is switching the filters on and off the signal such that transients are avoided. As far as

higher accuracy than that of M-S scheme. Its tuning accu-

FIG. **7** is a block diagram of the fully integrated heterodyne receiver using the present automatically tuned BP filters.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the FIG. **4**, the present automatically-tuned filter system is illustrated, and is generally identified by the numeral **40**. The input signal enters the filter circuit **42**, one of the filter outputs is connected to the frequency-tuning

block **46**. The output of the frequency tuning block **44** is

FIG. 7 illustrates a fully integrated heterodyne receiver **70** using the present filters **74** and **77**. The signal from the antenna enters the input of the low-noise amplifier (LNA) circuit **72**, the output of which is connected to filter **74**. The output of filter **74** is then connected to the two inputs of the complex mixer circuit **76**, which consists of two identical mixers fed by identical input signals and two LO signals shifted by 90 degrees (LO I and LO Q). The complex mixer has two outputs I and Q. They enter two inputs of filter **77**. The I and Q outputs of filter **77** are connected to the input of the variable gain amplifier (VGA) circuit **78**.

I claim:

1. A tuning system for continuous-time filters comprising:

an active real band-pass filter for receiving an input signal and for generating an output signal in a signal path;

a first tuning system connected to said active real band-pass filter for receiving an output signal from said active real band-pass filter and for generating a reference signal applied to said active real band-pass filter for tuning said active real band-pass filter while said active real band-pass filter is simultaneously operating on said input signal;

an active complex band-pass filter connected in said signal path for receiving an input signal on said signal path and for generating an output signal; and

a second tuning system connected to said active complex band-pass filter for receiving an output signal from said active complex band-pass filter and for generating a reference signal applied to said active complex band-pass filter for tuning said active complex band-pass filter while said active complex band-pass filter is simultaneously operating on said input signal on said signal path.

2. The tuning system of claim **1** wherein said first tuning system includes a frequency-tuning system.

3. The tuning system of claim **1** wherein said first tuning system including a Q-tuning system.

4. The tuning system of claim **1** wherein said second tuning system includes a frequency-tuning system.

5. The tuning system of claim **1** wherein said second tuning system includes a Q-tuning system.

6. The tuning system of claim **1** wherein said filters are fabricated in monolithic technology selected from the group consisting of silicon CMOS, BiCMOS and bipolar processes.

7. The tuning system of claim **1** wherein said real band-pass filter is an on-chip active device, and said complex band-pass filter is an on-chip active device.

8. The tuning system of claim **1** wherein said first tuning system adjusts a center-frequency of said active real band-pass filter with respect to a reference frequency, and said second tuning system adjusts a magnitude, and thereby its Q-factor of said active complex band-pass filter with respect to a reference amplitude.

9. The tuning system of claim **1** wherein said real band-pass filter has a symmetrical frequency response for positive and negative frequencies, and said complex band-pass filter has a non-symmetrical frequency response for positive and negative frequencies.

10. The tuning system of claim **1** wherein said real band-pass filter is tunable by changing its center frequency and its bandwidth, and said complex band-pass filter is tunable by changing its center frequency and its bandwidth.

11. The tuning system of claim **1** wherein said real band-pass filter can be implemented in an active filter design technique selected from the group consisting of Q-enhanced LC design and gm—C design, and said complex band-pass filter can be implemented in an active filter design technique selected from the group consisting of an active R—C design, MOSFET—C design, and gm—C design.

12. The tuning system of claim **1** wherein, said real band-pass filter is tuned with said reference signal falling in said real band-pass filter pass-band.

13. The tuning system of claim **1** wherein, said complex band-pass filter is tuned with said reference signal falling in said complex band-pass filter pass-band.

* * * * *