US007444126B1

(12) **United States Patent**
**Wyszynski**

(10) **Patent No.: US 7,444,126 B1**
(45) **Date of Patent: Oct. 28, 2008**

(54) **SIGNAL-TO-NOISE OPTIMIZED FULLY MONOLITHIC VIDEO RECEIVER IF CHANNEL**

(75) Inventor: **Adam Stanislaw Wyszynski**, Plano, TX (US)

(73) Assignee: **Microtune (Texas), L.P.**, Plano, TX (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1658 days.

(21) Appl. No.: **08/579,072**

(22) Filed: **Dec. 22, 1995**

(51) **Int. Cl.**
***H04B 17/02*** (2006.01)

(52) **U.S. Cl.** ..... **455/136**; 455/296; 455/253.2; 455/232.1; 455/311; 455/313; 348/707; 348/14.02; 348/14.01; 348/725; 348/726

(58) **Field of Classification Search** ..... 455/296, 455/253.2, 232, 311, 313, 341, 334, 566, 455/14; 348/14, 707, 725, 726
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,289,088 | A | 11/1966 | Berger | 325/408 |
| 3,673,499 | A * | 6/1972 | Avins et al. | 455/334 |
| 3,921,077 | A | 11/1975 | Suzuki | 325/477 |
| 4,031,469 | A | 6/1977 | Johnson | 325/363 |
| 4,081,837 | A * | 3/1978 | Tada et al. | 455/296 |
| 4,087,750 | A * | 5/1978 | Allen et al. | 455/296 |
| 4,236,254 | A * | 11/1980 | Augustin et al. | 455/311 |
| 4,271,433 | A * | 6/1981 | Theriault | 348/731 |
| 4,326,297 | A * | 4/1982 | Sato et al. | 455/311 |
| 4,344,128 | A * | 8/1982 | Frye | 700/78 |
| 4,406,019 | A | 9/1983 | Ide et al. | 455/245 |
| 4,466,133 | A | 8/1984 | Price | 455/303 |
| 4,581,643 | A | 4/1986 | Carlson | |
| 4,606,075 | A * | 8/1986 | Eastmond | 455/234.2 |
| 4,726,072 | A | 2/1988 | Yamashita et al. | |
| 4,742,566 | A | 5/1988 | Nordholt et al. | |
| 4,856,084 | A * | 8/1989 | Richards, Jr. | 455/311 |
| 4,979,230 | A | 12/1990 | Marz | |
| 4,984,292 | A | 1/1991 | Millen | 455/40 |
| 5,038,404 | A | 8/1991 | Marz | |
| 5,060,297 | A | 10/1991 | Ma et al. | |
| 5,140,198 | A | 8/1992 | Atherly et al. | |
| 5,200,826 | A | 4/1993 | Seong | |
| 5,287,558 | A | 2/1994 | Hansen | 455/296 |
| 5,311,318 | A | 5/1994 | Dobrovolny | |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| JP | 5167469 | * 7/1993 | | 455/234.1 |

OTHER PUBLICATIONS

"The New IEEE Standard Dictionary of Electrical and Electronics Terms", pp. 90, 500, 1306, Jan. 1993.*

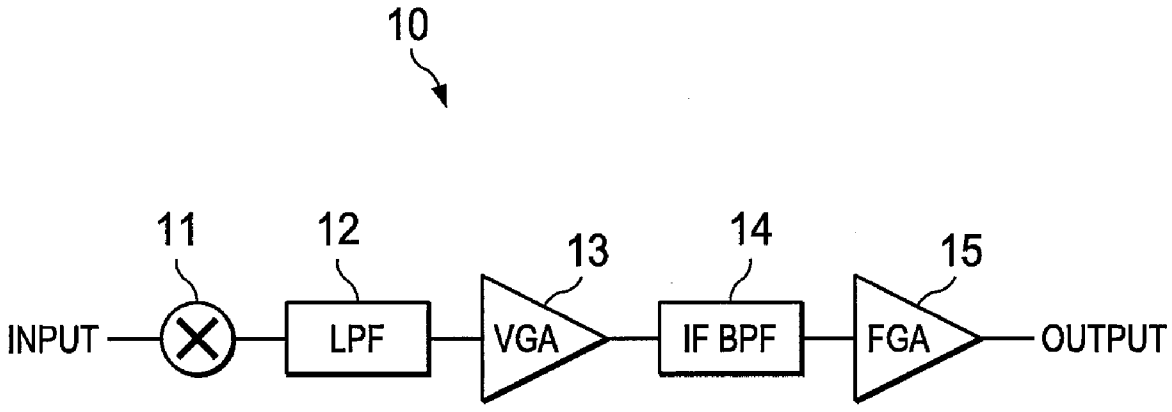
(Continued)

*Primary Examiner*—Nay Maung
*Assistant Examiner*—Richard Chan
(74) *Attorney, Agent, or Firm*—Fulbright & Jaworski L.L.P.

(57) **ABSTRACT**

In a video IF channel the gain of the circuit is achieved ahead of the IF filter and the output of the filter, including its noise, need only be amplified a relatively small amount, thus preserving an acceptable signal to noise ratio. In one embodiment, a variable gain amplifier is used as the first stage amplifier and a fixed gain amplifier is used for the output stage.

**12 Claims, 1 Drawing Sheet**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,321,852 | A | | 6/1994 | Seong |
| 5,361,395 | A | * | 11/1994 | Yamamoto ..... 455/234.1 |
| 5,390,346 | A | | 2/1995 | Marz |
| 5,428,824 | A | * | 6/1995 | Kasai ..... 455/78 |
| 5,428,836 | A | | 6/1995 | Sanecki et al. |
| 5,491,507 | A | * | 2/1996 | Umezawa et al. ..... 348/14 |
| 5,555,275 | A | * | 9/1996 | Oshima ..... 375/261 |
| 5,555,550 | A | * | 9/1996 | Kaschke ..... 455/566 |
| 5,563,545 | A | | 10/1996 | Scheinberg |

OTHER PUBLICATIONS

Millman et al. , "Microelectronics", p. 172, 1987.*

Meyer, Robert G. "A 1-GHz BiCMOS RF Front-End IC." IEEE Journal of Solid-State Circuits; vol. 29 No. 3 (Mar. 1994): 350-355.

Kinget, Peter and Michiel Steyaert. "A 1 GHz CMOS Upconversion Mixer". IEEE Custom Integrated Circuits Conference. (1996) 197-200.

Crols, Jan, and Michel S. J. Steyaert. "A 1.5 GHz Highly Linear CMOS Downconversion Mixer." IEEE Journal of Solid-State Circuits. vol. 30 No. 7 (Jul. 1995). 736-742.

Kuhn, William B., William Stephenson, and Aicha Elshabini-Riad. "A 200 MHz CMOS Q-Enhanced LC Bandpass Filter." IEEE Journal of Solid-State Circuits. vol. 31 No. 8 (Aug. 1996). 1112-1122.

Razavi, Behzad, Kwing F. Lee, Ran-Hong Yan, and Robert G. Swartz. "A 3-GHz 25-mW CMOs Phase-Locked Loop." 1994 Symposium on VLSI Circuits Digest of Technical Papers. (1994). 131-132.

McGinn, Mike. "An Advanced I.F. Amplifier & AFT System Suitable for HDTV." IEEE Transactions on Consumer Electronics. vol. 36 No. 3 (Aug. 1990) 407-414.

Okanobu, Taiwa, Hitoshi Tomiyama, and Hiroshi Arimoto. "Advanced Low Voltage Single Chip Radio IC." IEEE Transactions on Consumer Electronics . vol. 38 No. 3. (Aug. 1992) 465-475.

Crols, Jan, and Michiel Steyaert. "An Analog Integrated Polyphase Filter for a High Performance Low-IF Receiver." 1995 Symposium on VLSI Circuits Digest Of Technical Papers. (1995) 87-88.

Anadigics, Inc. CATV/TV/Cable Modem Upconverter MMIC. Warren NJ (Apr. 22, 1998).

Anadigics Inc. VHF/UHF CATV/TV Tuner Dowconverter. Warren, NJ. (Apr. 22, 1998).

Anadigics, Inc. Anagics Technical Brief. Upconverter MMIC for CATV Preliminary. Warren, NJ. (Jan. 11, 1994).

Racanelli, Marco et al. "RF BiCMOS Technology for Highly Integrated Wireless Systems." 1999 IEEE RFIC Symposium. (1999).

Kimura, Katsuji. "A Bipolar Four-Quadrant Analog Quarter-Square Multiplier Consisting of Unbalanced Emitter-Coupled Pairs and Expansions of Its Input Ranges." IEEE Journal of Solid-State Circuits. vol. 29 No. 1 (Jan. 1994) 46-55.

Archer, John, and John Granlund, and Robert E. Mauzy. "A Broad-Band UHF Mixer Exhibiting High Image Rejection over a Multidecade Baseband Frequency Range." IEEE Journal of Solid-State Circuits, vol. SC-16 No. 4 (Aug. 1981) 385-392.

Boutin, Noel. "Complex Signals: Part 1" RF Featured Technology. (Dec. 1989). 27-75.

"Double-balanced mixer and oscillator" Phillips Semiconductors. (Nov. 7, 1997). 1-11.

Gilbert, Barrie. "Demystifying the Mixer" Analog Devices Inc. (Apr. 1994). 1-58.

Kuhn, William B. "Design of Monolithically Integrated Radio Transceivers" Kansas State University. 1996 /RC/.

Sato, Akihiro, et al. "Development of an Adjustment Free Audio Tuner IC" IEEE Transactions on Consumer Electronics, vol. 42 No. 3. (Aug. 1996). 328-334.

Scheinberg, N., et al., "A GaAs Up Converter Interated Circuit for a Double Conversion Cable TV "Set-Top" Tuner" International Conference on Consumer Electronics. (Jun. 1993). 108-109.

Maier, G.M., et al. "Double Conversion Tuner a Must for the Future?" IEEE Transaction on Consumer Electronics, vol. 38, No. 3. (Aug. 1992). 384-388.

Moloney, Daniel M., et al. "Expanded Bandwidth Requirements in CATV Applications." NCTA Technical Papers. (1992). 200-206.

Gilbert, Barrie and Baines, Rupert. "Fundamentals of Active Mixers" Applied Microwave and Wireless. (1995). 10-27.

Muller, J-E., et al. "A Double-Conversion Broad Band TV Tuner with GaAs ICs." GaAs IC Symposium Technical Digest. (1984). 97-98.

Nakatsuka, T., et al. , "Low Distortion and Low Noise Oscillator Mixer for CATV Converters." GaAs Symposium Technical Digest. (1988). 161-164.

Brady, Vernon, et al. "Development of a Monolithic FET Ka-Band Single Side Band UFConverter and Image Reject Downconverter." GaAs Symposium Technical Digest (Oct. 1989) 189-192.

Ablassmeier, Ulrich, et al. "GaAs FET Upconverter for TV Tuner" IEEE Transactions on Electron Devides, vol. ED-27, No. 6. (Jun. 1980). 1156-1159.

Maas, Stephen A. "A GaAs MESFET Mixer with Very Low Intermodulation" IEEE Transactions on Microwave Theory and Techniques, vol. MTT-35, No. 4. (Apr. 1987). 425-429.

Pratt, William J. "High Linearity HBT Amplifier Targets Multicarrier Systems" RF Design. (Mar. 1996). 47-54.

Pandula, Louis. "Image Reect and Image Canceling Mixers" RF Design. (Apr. 1995). 60-65.

Leffel, Michael. "Intermodulation Distortion in a Multi-Signal Environment" RF Design (Jun. 1995). 78-84.

Meyer, Robert G. "Intermodulation in High-Frequency Bipolar Transistor Integrated-Circuit Mixers." IEEE Journal of Solid-State Circuits, vol. SC-21, No. 4. (Aug. 1986). 534-537.

Giles, Martin. "The LM 1823: A High Quality TV Video I.F. Amplifier and Synchronous Detector for Cable Receivers." National Semiconductor Corporation. (Mar. 1985). 1-16.

Svelto, F., et al. "A Low-Voltage Topology After CMOS RF Mixers." IEEE Transactions on Consumer Electronics., vol. 45, No. 2 (May 1999). 299-309.

Otaka, Shoji, et al. "A Low Local Input Power 1.9 GHz Si-Bipolar Quadrature Modulator without Any Adjustment." Bipolar/BiCMOS Circuits and Technology Meeting. (1994). 171-174.

Gilbert, Barrie. "The MICROMIXER: A highly Linear Variant of the Gilbert Mixer using a bisymmetric Class-AB Input Stage" IEEE Journal of Solid-State Circuits, vol. 32, No. 9, (Sep. 1997). 1412-1423.

Ducourant, Thierry, et al. "A 3 Chip GaAs Double Conversion TV Tuner System with 70 db Image Rejection." Monolithic Circuits Symposium Digest of Papers. (1988). 87-90.

Torji, K., et al. "monolithic Integrated VHF TV Tuner." IEEE Transactions on Consumer Electronics, vol. CE-26. (May 1980). 180-189.

Altes, Stephen K., et al. "Monolithic RC All-Pass Networks with Constant-Phase-Difference Outputs." IEEE Transactions on Microwave Theory and Techniques, vol. MTT-34, No. 12. (Dec. 1986). 1533-1537.

MC13143: Ultra Low Power DC-2.4 GHz Linear Mixer. Motorola, Inc. Issue 2. (1996). 1-8.

HP 8516A and HP 8562A/B Portable Spectrum Analyzers. Hewlett-Packard. (Jul. 1989).

MC44302: Advanced Multi-Standard TV Video/Sound IF. Motorola, Inc. (Jun. 17, 1994).

"NCTA Reccomended Practices for Measurements on Cable Television Systems." National Cable Television Association. 2nd Ed. (1993). 1-13.

Maier, Gerd M. "New System Approach to TV Tuner Design." IEEE Transactions on Consumer Electronics, vol. 36, No. 3. (Aug. 1990). 403-406.

Charbon, Edoardo, et al. "A Performance-Driven Routeer for RF and Microwave Analog Circuit Design." Department of Electrical Engineering and Computer Sciences, University of California, Berkeley. 1992.

Koullias,Iconomos, A., et al. "A 900MHz Transceiver Chip Set for Dual-Mode Cellular Mobile Terminals." IEEE International Solid-State Circuits Conference. (1993). 140-141.

McDonald, Mark D. "A 2.5GHz BiCMOS Image-Reject Front-End" IEEE International Solid-State Circuits Conference. (1993). 144-145.

Lovelace, David, et al. "Silicon Upconverter RF IC Simplifies Cable Modem Designs" Microwaves & RF (Mar. 1997). 136-142.

Lovelace, David, et al. "Innovative Simulator Models Silicon Upconverter RF IC" Microwaves & RF. (Apr. 1997). 106-109.

Farmer, James O. "Specifications for Tuner Design for use in Cable Ready Television Receivers and VCRs." IEEE Transactions on Consumer Electronics, vol. 36, No. 3,. (Aug. 1990). 660-668.

Abidi, Asad A. "Direct-Conversion Radio Transceivers for Digital Communications." IEEE International Solid-State Circuits Conference. (1995). 186-187; 363-364.

Kokozinski, Rainer, et al. "Microwave Wideband Amplifiers In Bulk-CMOS/SIMOX Technologies." IEEE International Solid-State Circuits Conference. (1995). 146-147; 188-189.

Kimura, Katsuji. "The Ultra-Multi-Tanh Technique for Bipolar Linear Transconductance Amplifiers." IEEE Transactions on Circuits and Systems-1: Fundamental Theory and Applications. vol. 44, No. 4. (Apr. 1997). 288-302.

Al-Hashimi, Bashir. "Understand the Fundamentals of Passive Video Filters." Microwaves & RF. (May 1996). 171-178.

Long, John R., et al. "A Low-Voltage Silicon Bipolar RF Front-End for PCN Receiver Applications." IEEE International Solid-State Circuits Conference. (1995). 104-105; 140-141.

Sabin, William E. & Edgar O. Schoenike. "Single -Sideband Systems & Circuits." McGraw Hill Book Company. New York. (1987). 88-134, 181-213.

* cited by examiner

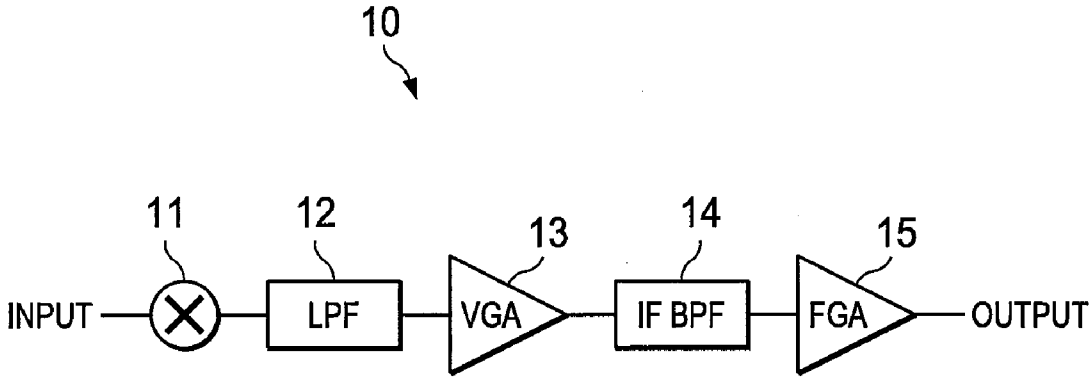



FIG. 1

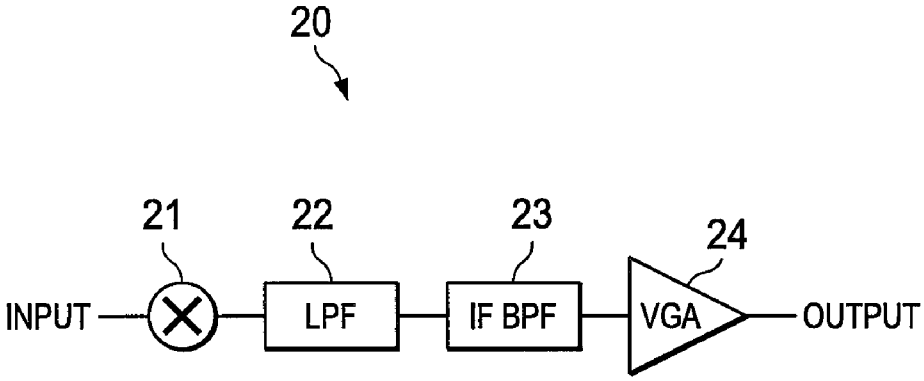



FIG. 2
(PRIOR ART)

# SIGNAL-TO-NOISE OPTIMIZED FULLY MONOLITHIC VIDEO RECEIVER IF CHANNEL

## TECHNICAL FIELD OF THE INVENTION

This invention relates to a video-receiver IF channel, and more particularly, to partitioning the gains in the IF channel so that the signal-to-noise ratio is optimized in a fully monolithic video receiver.

## BACKGROUND OF THE INVENTION

If a video-receiver is to be fully integrated, then a monolithic filter must be used, as opposed to a partially integrated



## SUMMARY OF THE INVENTION

In accordance with the present invention, a modified configuration of a fully-monolithic active IF channel is provided. The system consists of two amplifiers, a VGA (a variable gain amplifier), and an FGA (a fixed gain amplifier), as well as two filters. A low-pass filter precedes the VGA, and an intermediate frequency band-pass filter follows the VGA and precedes the FGA.

In order to achieve an optimum S/N ratio condition, a filter should always operate with the maximum possible input signal. Therefore, a VGA precedes the IF band-pass filter, which is then followed by an FGA. In such a configuration, the maximum possible gain is applied by the VGA in front of the filter, so that only a portion of the gain, that of the FGA after the filter, amplifies its noise. Additionally, the input referred

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic representation of the fully-monolithic IF channel video-receiver according to the present invention.

FIG. **2** is a schematic representation of a prior art discrete video-receiver.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Before beginning a discussion of the operation of the invention, it might be well to review the prior art discrete circuits in relation to FIG. **2**.

FIG. **2** describes the classical arrangement for an IF channel. It consists of mixer **21**, which is then connected to low-pass filter **22**. The output signal from LPF **22** is then passed through an IF band-pass filter **23**. Because the channel is discrete, and the IF filter is either an LC Network with some discrete amplifiers or a SAW (surface acoustic wave) filter, the noise through this IF filter is minimal. After the IF filter, the signal enters variable gain amplifier (VGA) **24**, which can have a maximum gain as high as 10,000.

then the remaining components can be decided upon. If the IF stage can take the full gain, the output amplifier would not be required.

In one preferred embodiment, if the distortion level is chosen at 1%, and this is achieved for 200 mV input signal to the IF filter, then the output signal of VGA **13** should never exceed 200 mV. Otherwise, distortion greater than 1% would be introduced into the IF filter.

Note, that while a single substrate is contemplated, the monolithic device can have more than one substrate. Also note that, while video is discussed, this concept could be used with any IF communication channel.

The present invention, therefore, is well adapted to carry out the objects and obtain the ends and advantages mentioned as well as others inherent therein. While presently preferred embodiments of the invention have been given for the purpose of disclosure, numerous changes in the details of construction and arrangement of parts will be readily apparent to those skilled in the art and which are encompassed within the spirit of the invention and the scope of the appended claims.

What is claimed is:

**1**. A system for processing radio frequency (RF) signals comprising:

an input to said circuit for receiving an RF signal;

a mixer having an input connected to said RF signal input;

a first filter having an input connected to an output of said mixer, wherein said first filter is a low-pass filter;

a first amplifier having an input connected to an output of said first filter, wherein said first amplifier operates to amplify an output signal from said first filter to a maximum level acceptable as an input to said second filter to avoid distortion of said RF signal;

a second filter having an input connected to an output of said first amplifier; and

a second amplifier having an input connected to an output of said second filter, and an output connected to an output of said circuit;

wherein said mixer, said first and second filters and said first and second amplifiers are constructed on a single integrated circuit substrate.

**2**. The system as claimed in claim **1**, wherein said first

fourth signal includes processing said third signal through an intermediate-frequency, band-pass filter.

**7**. A method of processing RF signals as recited in claim **6**, wherein said step of amplifying said fourth signal to generate a fifth signal includes amplifying said fourth signal by a fixed gain amplifier (FGA).

**8**. The circuit of claim **1** wherein said RF signal is a video signal.

**9**. The method of claim **5** wherein said amplifying to a fixed level step amplifies said second signal to a specific level that is a maximum level acceptable as an input to a filter to avoid distortion of said RF signal.

**10**. The method of claim **9** wherein said RF signal is a video signal.

**11**. A radio frequency (RF) signal processing circuit comprising:

a mixer coupled to an RF signal input;

a variable gain amplifier coupled to said mixer, wherein said variable gain amplifier amplifies IF signals received from said mixer to a particular signal level, said particular signal level corresponding to the maximum signal level that can be accepted by a filter without distorting said RF signal·

[redacted]

an amplifier coupled to an output of said filter;

wherein said mixer, said filter, and said amplifiers are physically located on a single integrated circuit substrate.

**12**. The method of processing an RF signal comprising the steps of:

inputting said RF signal to a mixer;

mixing said RF signal to create an intermediate frequency (IF) signal;

filtering said IF signal to remove high frequency signals, thereby creating a first filtered IF signal;

amplifying said first filtered IF signal to a selected signal level, thereby generating an amplified, first filtered IF signal, said selected signal level corresponding to the maximum level acceptable as an input to a band-pass filter to avoid distortion of said signal;

filtering said amplified, first filtered IF signal in said band-pass filter, wherein said band-pass filter attenuates signals having frequencies above and below an IF frequency band, thereby generating a second filtered IF signal; and

amplifying said second filtered IF signal;

wherein said mixing step, said filtering steps, and said

[redacted]