A 0.8-1.5 GHz Multi-Standard WCDMA Receiver with an Inter-Stage Tunable Notch Filter

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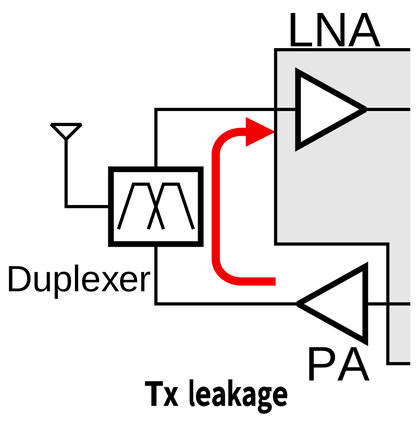
Conclusion

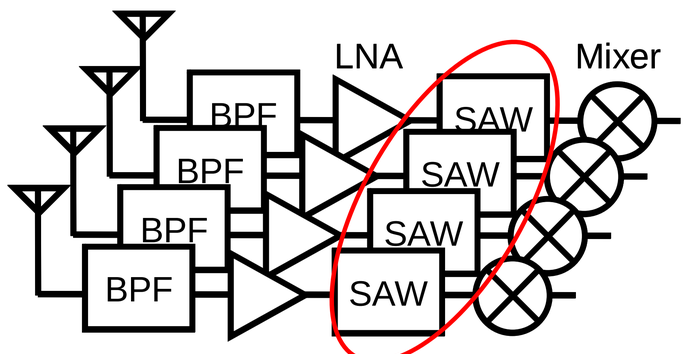
- **The tunable notch filter realizes a 49% tuning range.**
- **A 31dB conversion gain, 45dBm IIP_2, and -1dBm IIP_3 is realized by the multi-standard receiver integrating the tunable notch filter.**

1. Background

Tx leakage is a critical problem to realize the multiband WCDMA receiver.



Tx leakage



Narrow band WCDMA receivers

The present narrow-band WCDMA receivers employ an external SAW filter.

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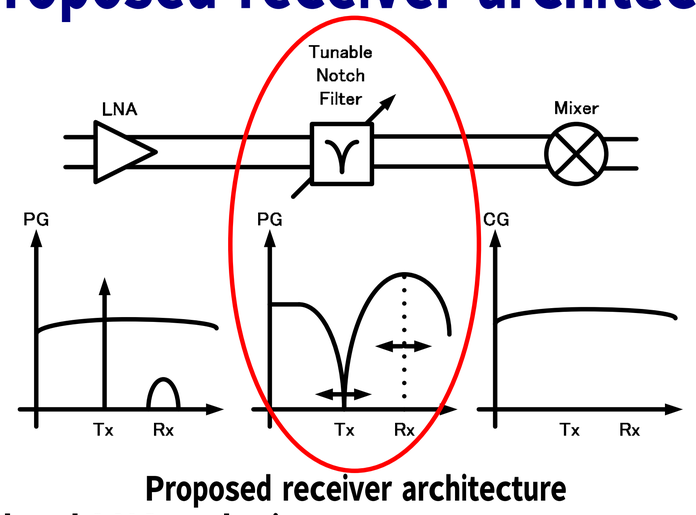
Large area, High cost

Multi-band RF frontend is needed.

2. Proposed receiver architecture



Proposed receiver architecture

- **Wideband LNA and mixer**
- **A tunable notch filter → suppress the Tx leakage**

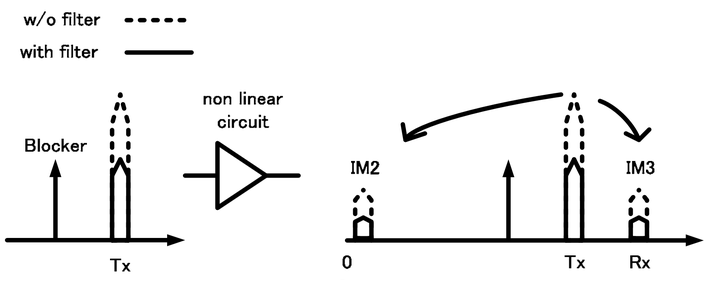
3. Linearity improvement

Without filter →
$$IIP_{3\text{wofilter}} = \frac{P_{in} + G_{Rx} - P_{IM3,Mixer}}{2} + P_{in}$$

$$IIP_{3\text{wifilter}} = \frac{P_{in} + (G_{Rx} - G_{loss,Rx}) - (P_{IM3,Mixer} - 2G_{sup,Tx})}{2} + P_{in}$$

With filter →
$$IIP_{3\text{wifilter}} = IIP_{3\text{wofilter}} + \left(G_{sup,Tx} - \frac{G_{loss,Rx}}{2}\right)$$

The notch filter can improve the receiver linearity.



IM3 and IM2

4. Notch filter

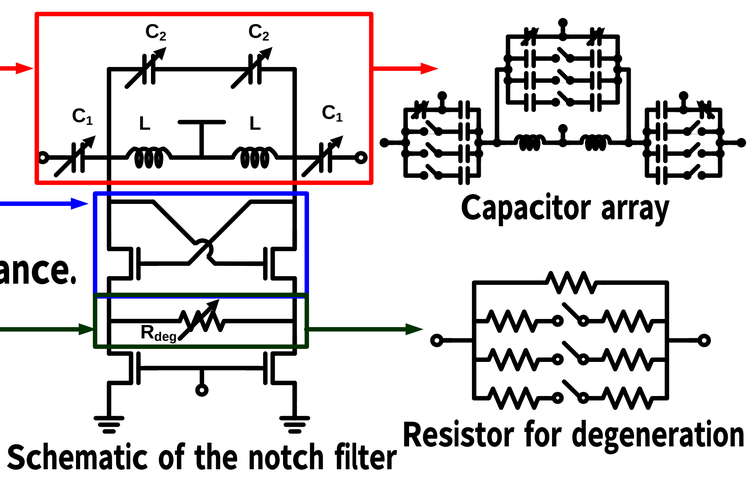
The impedance of the resonator

$$Z_N = j\frac{\omega(C_1 + C_2) - 1/\omega L}{\omega C_1(1/\omega L - \omega C_2)}$$

$$f_{zero} = \frac{1}{2\pi\sqrt{L(C_1 + C_2)}}$$ **Tx frequency**

$$f_{pole} = \frac{1}{2\pi\sqrt{LC_2}}$$ **Rx frequency**

- **Resonator**
  -a varactor and capacitor bank realize wide tuning range.
- **Q-enhancement**
  -a cross-coupled transistor pair compensates the parasitic conductance.
- **Source degeneration**
  -switched resistance improves the linearity of the filter



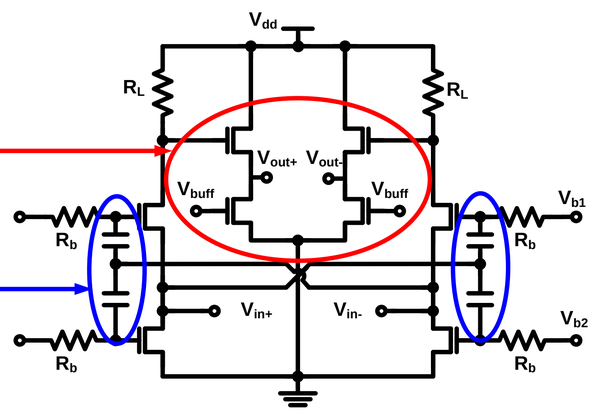
Capacitor array

Resistor for degeneration

Schematic of the notch filter

5. Low noise amplifier

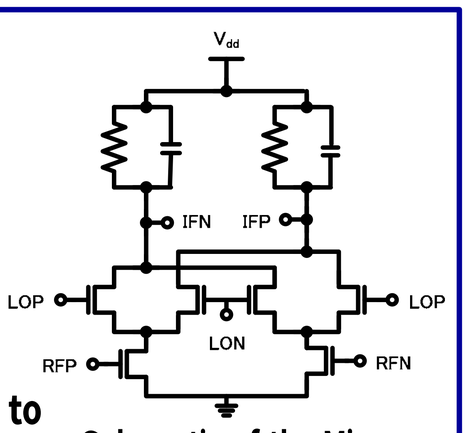
- **The source follower buffer is connected to make the power gain high at the output node**
- **The capacitive cross-couple contributes to cancel the noise generated at the common-gate transistor**



Schematic of the LNA

6. Mixer

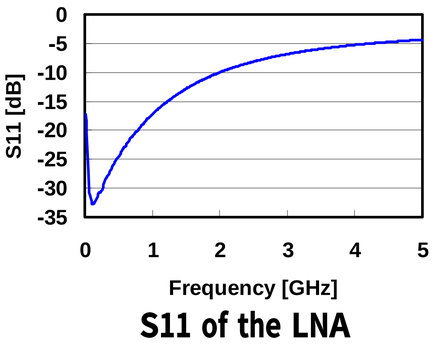
- **The mixer employs a double balanced Gilbert cell topology for high IIP2.**
- **The output has low pass characteristics resulting from a RC filter.**
- **The cut-off frequency is designed to be 10MHz.**



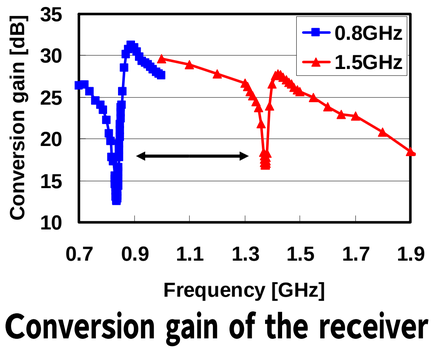
Schematic of the Mixer

7. Measurement results

- **The tunable notch filter realizes 49% tuning range.**
- **IIP_2 is 45dBm, and IIP_3 is -1dBm at 0.8GHz.**
- **The simulated NF is 6 to 6.2dB around the entire frequency range.**
- **The total power consumption is 121mW.**



S11 of the LNA

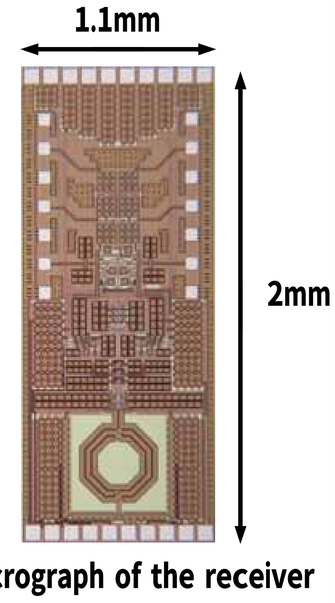


Conversion gain of the receiver

Performance summery

Reference	Freq.[GHz]	NF[dB]	Gain[dB]	IIP_3[dBm]	IIP_2[dBm]	Pdc[mW]	Topology	Band
[1]	2.1/1.9/0.8	2.8	102	-2	65	101.5-175	Notch filter	Multi band
[2]	2.1	3.1	30	-12	>39	12	LNA+Mixer	Narrow
[3]	2.1	5.5	30.5	5.3	58	33.6	IM3cancel	Narrow
[4]	2.1	4.9	96.5	-7.4	>38.8	83.7	LNA+Mixer	Narrow
[5]	1.8	2.9	37	-7	63	75	Dual mode	Multi band
This Work	0.8	6(sim)	31	-1	>45	121	Notch filter	Tunable & Multi band
	1.5	6.2(sim)	28	-4	>37	114		

[1]B. Tenbroek, *et al*., ISSCC 2008 [2]Y. Feng, *et al*., JSSC 2009 [3]E. Keehr *et al*., ISSCC 2008 [4]M. Tamura, *et al*., RFIC 2005 [5]N. K. Yanduru, *et al*., RFIC 2006



Micrograph of the receiver