Ultra-Wideband CMOS LNA

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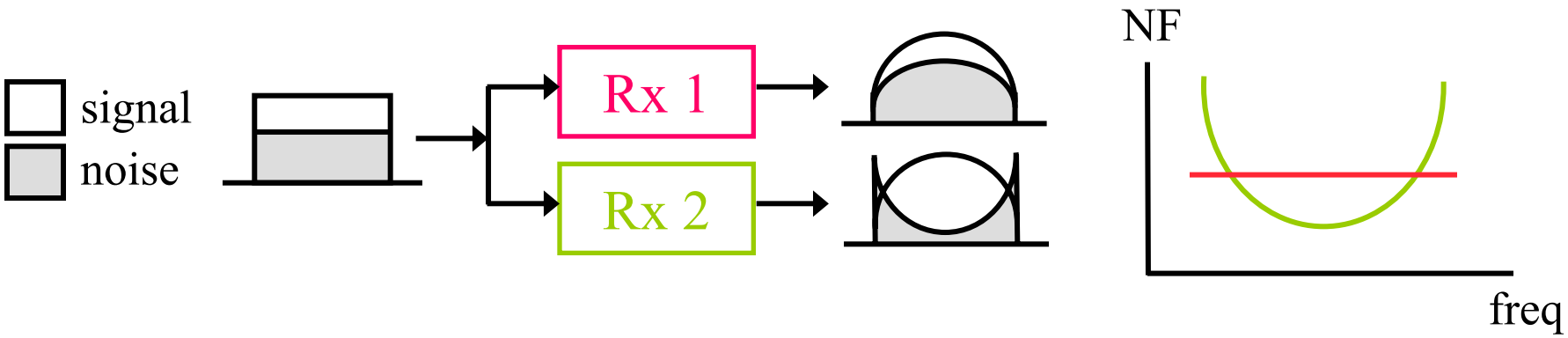
Noise Figure Revisited

- Formal definition introduced by Friis (1940s).
  - NF = (input SNR)/(output SNR).
  - Measures degradation in the SNR as signal passes through the receiving system.
- NF varies with frequency – not well defined in wideband systems.
  - Difficult to compare two receiving systems.



W. Namgoong, J. Lerdworatawee, "Noise Figure of Digital Communication Receivers -- Revisited", IEEE Trans. Circuits and Systems I – Regular Papers, 2004

Meaningful NF Metric

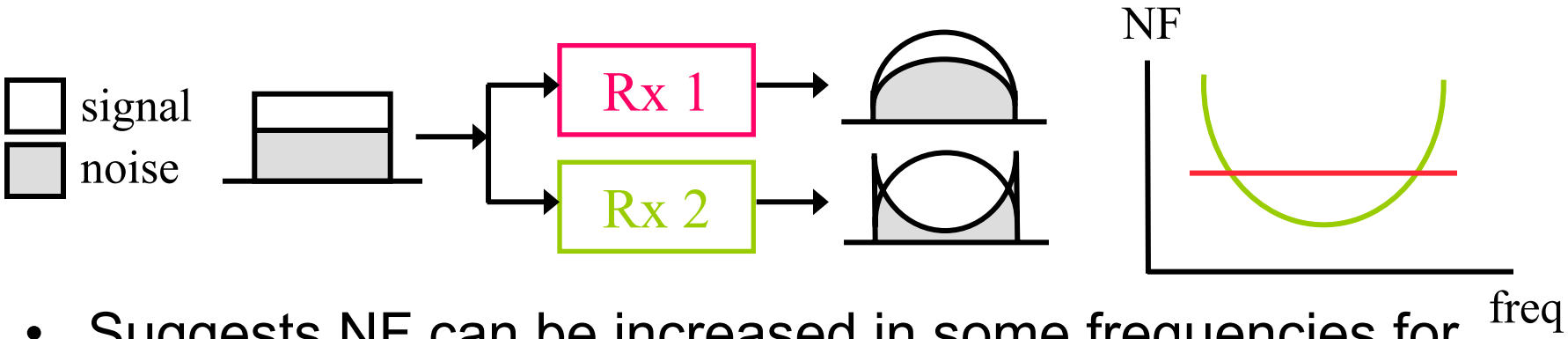
- SNR is not well defined in NF definition.
  - Assumes signal and noise spectrum are flat.
- Define SNR as the matched filter bound (MFB).
- MFB represents an upper bound on performance of data transmission systems with ISI.
  - Measures achievable performance after digital decoding.
  - MFB obtained when a noise whitened matched filter is employed to receive a single transmitted pulse.
- NF measures the degree of degradation in the achievable receiver performance.

Effective Noise Figure

- The effective NF becomes

$$F_{eff} \approx \frac{1}{\frac{1}{N}\sum_{l=0}^{N-1}\frac{1}{F(f_l)}}$$

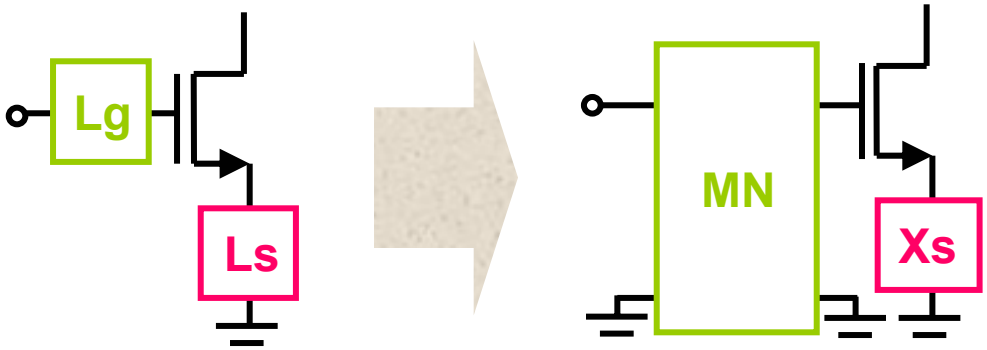
- Effective NF is the harmonic mean of spot NF.
  - Dominated by low NF values (or high SNR values).



- Suggests NF can be increased in some frequencies for implementation benefits with little loss in overall performance.

Wideband LNA with Source Degeneration

- LNA with source inductive degeneration commonly used in narrowband systems.
  - Can achieve very low NF.
- Generalize this LNA topology using arbitrary Xs and general input matching network for wideband systems.
  - Optimize transistor parameters (bias and W) and Xs to minimize NF subject to power matching constraint



J. Lerdworatawee, W. Namgoong, "Wideband LNA Design Based on Source Degeneration Topology", IEEE Trans. Circuits and Systems I – Regular Papers, 2005.

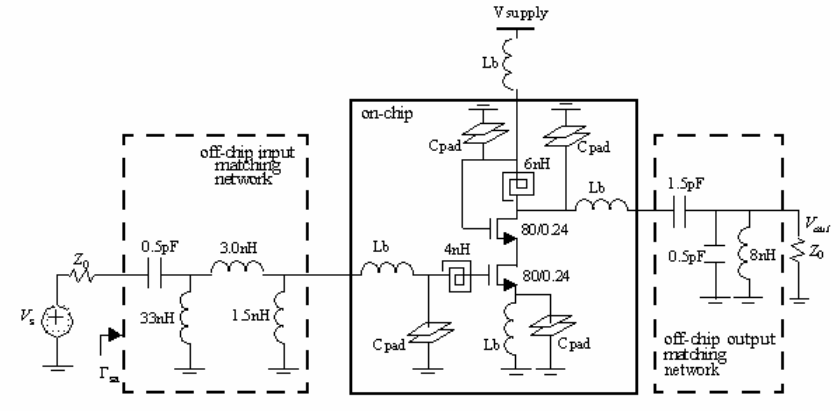
Analysis Results

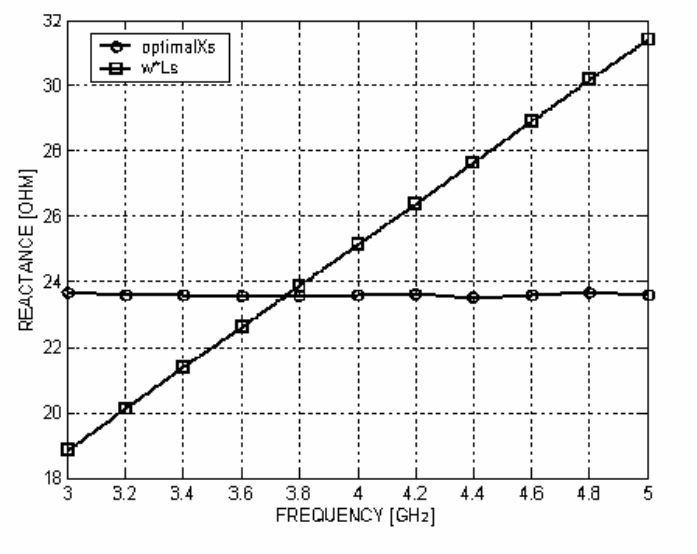
- The minimum NF is a function of bias voltage and the product of W and Xs.

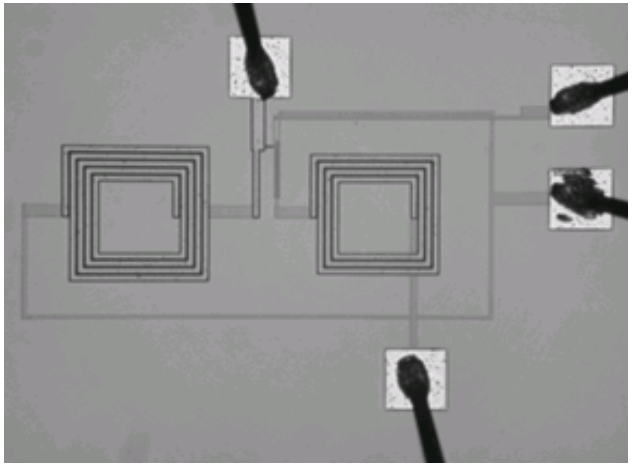
  →Minimum NF can be achieved at each frequency over any frequency band of interest.
- Higher W increase gain at the cost of power consumption.
- Result applies uniquely to CMOS, as the analysis is based on the quasi-static MOSFET model.

Wideband LNA in 0.25um CMOS

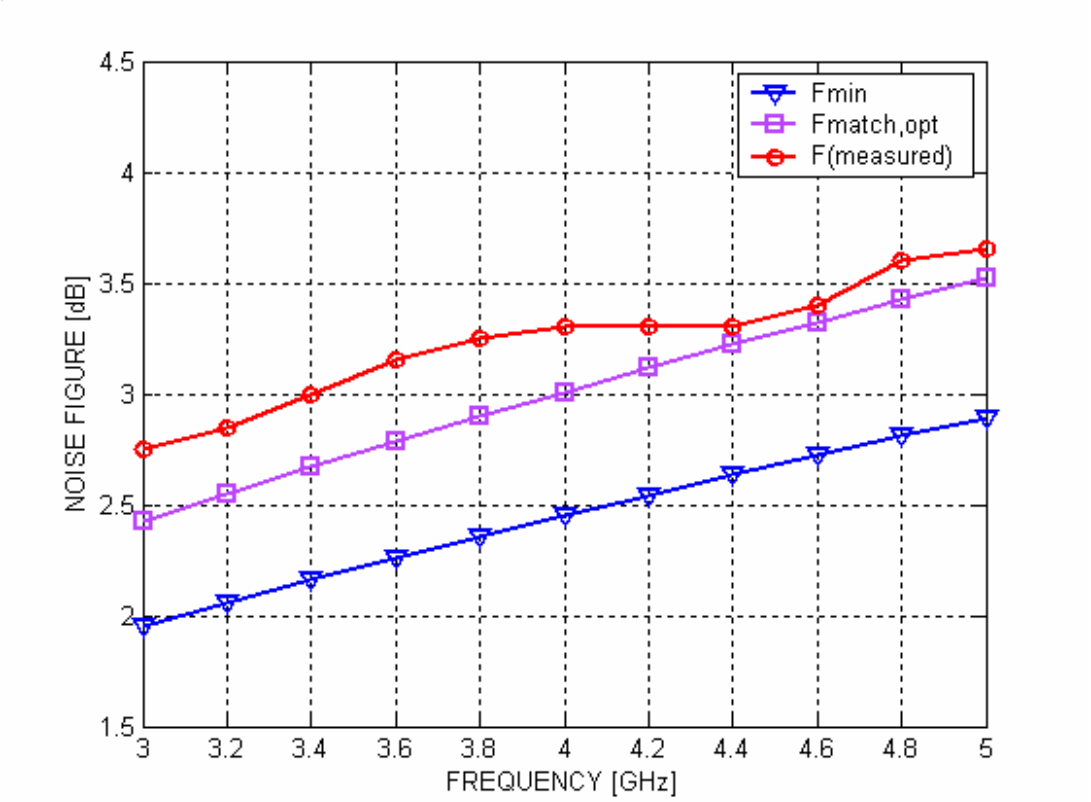
- Target frequency range: 3 – 5 GHz
- A single inductor realized by bonding wire can approximate the optimal Xs
- Matching network is implemented partially off-chip.







NF Measurement Results



- Measured NF agrees closely with experimental results (< 0.5dB).

LNA Performance Comparison

	This work (2005)	Gharpurey (2005)	Kim (2005)	Bevilacqua (2004)	Anderson (2003)
Frequency (GHz)	3 ~ 5	2 ~ 5.2	3 ~ 6	3 ~ 10	3 ~ 5
S11 (dB)	-9.5 ~ -15	<-9	<-9	-10 ~ -17	-8 ~ -14
NF (dB)	2.7 ~ 3.7	4.7 ~ 5.7	2.3 ~ 6	4 ~ 9.6	4 ~ 5
Effective NF (dB)	3	5.1	3.8	6	4.5
Gain (dB)	7	16	9.8	9.2	13
Power (mW)	20	38	12.6	9	75
Technology	0.25um CMOS	0.13um CMOS	0.18um CMOS	0.18um CMOS	0.18um CMOS

S. Anderson, et. al., "Wideband LNA for a multistandard wireless receiver in 0.18um CMOS," ESSCIRC, pp. 655-658, 2003.
A. Bevilacqua et. al., "An ultra-wideband CMOS LNA for 3.1to 10.6GHz wireless receiver," ISSCC, pp. 382-383, 2004.
A. Ismail and A. A. Abidi, "A 3-10 GHz LNA with wideband LC-ladder matching network," JSSC, no. 12, Dec. 2004, pp. 2269-2277.
C. –W. Kim et al, "An ultra-wideband CMOS LNA for 3-5GHz UWB systems," JSSC, no. 2, Feb. 2005, pp. 544-547.
R. Gharpurey, "A broadband low noise front-end amplifier for ultra wideband in 0.13um CMOS", JSSC, no. 9, Sept 2005, pp. 1983-1986