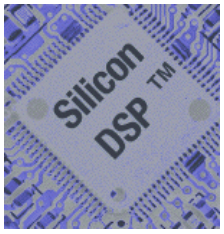
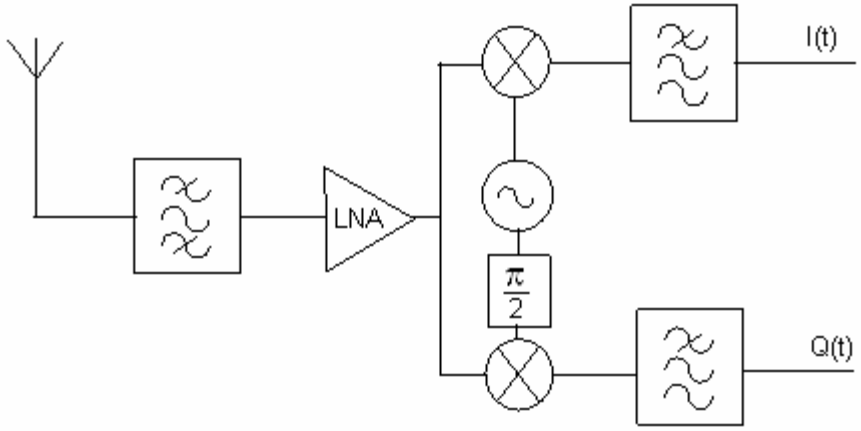
Direct Conversion Receiver

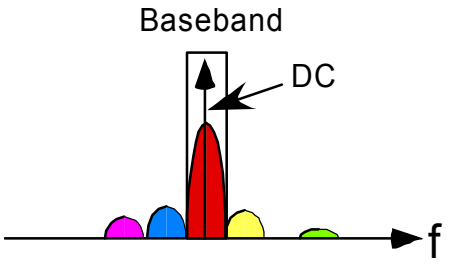
DC Offset and AGC
I/Q Imbalance

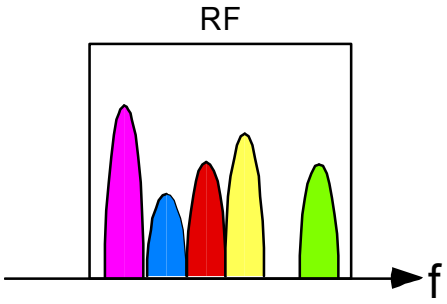


Silicon DSP Corporation

Direct Conversion Receiver



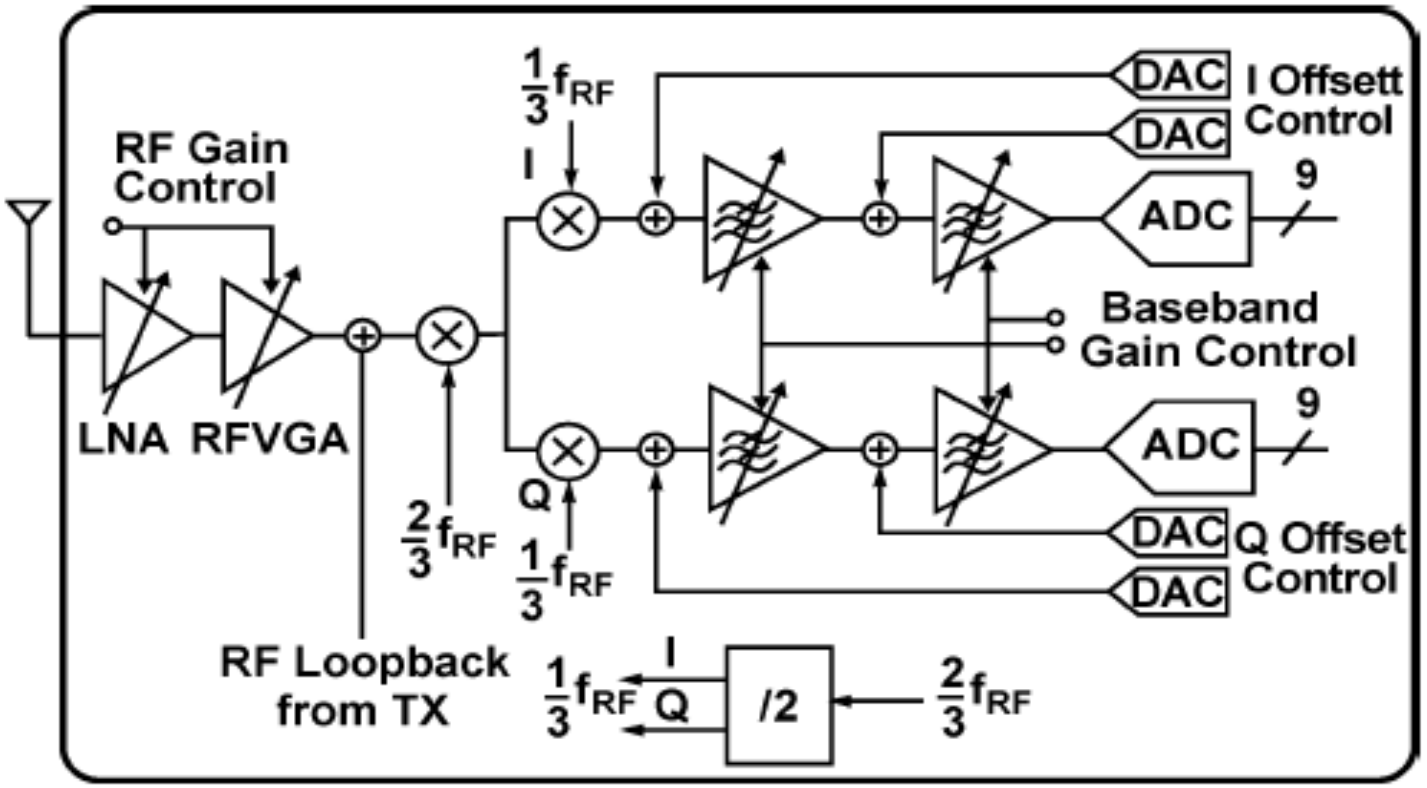




Homodyne Receiver

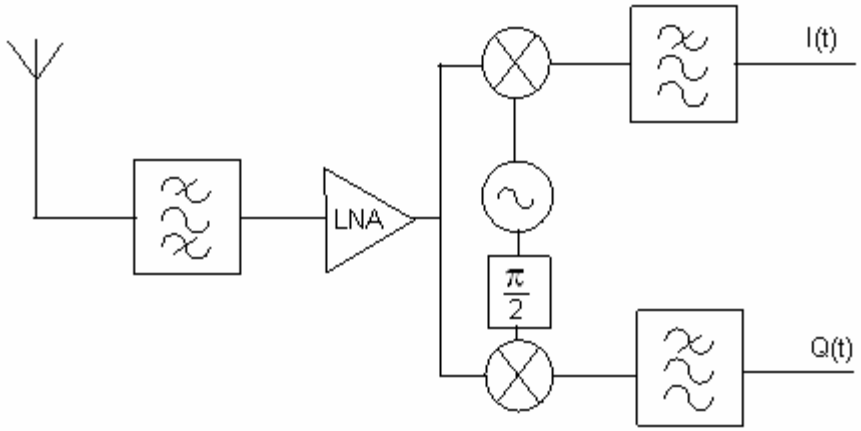
On the Direct Conversion Receiver -- A Tutorial, Ashkan Mashhour, William Domino and Norman Beamish, Conexant Systems, Microwave Journal, June 2001

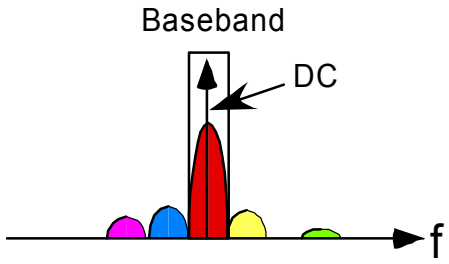
Heterodyne Receiver

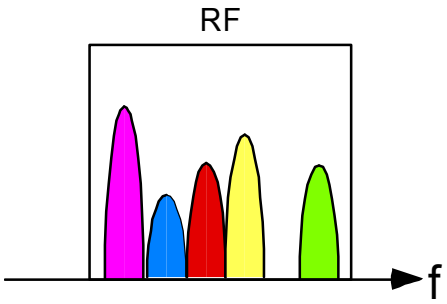


"An 802.11g WLAN SoC", Srenik S. Mehta,et. Al., IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 40, NO. 12, DECEMBER 2005

Direct Conversion Receiver



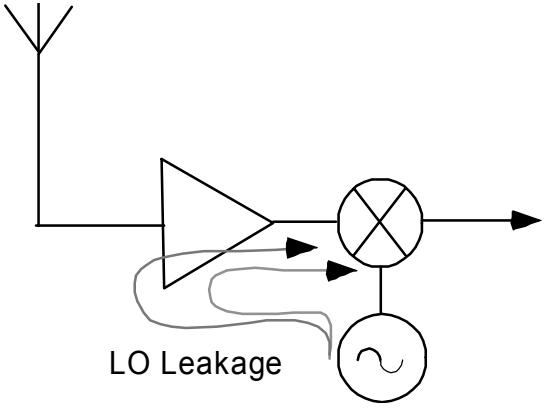


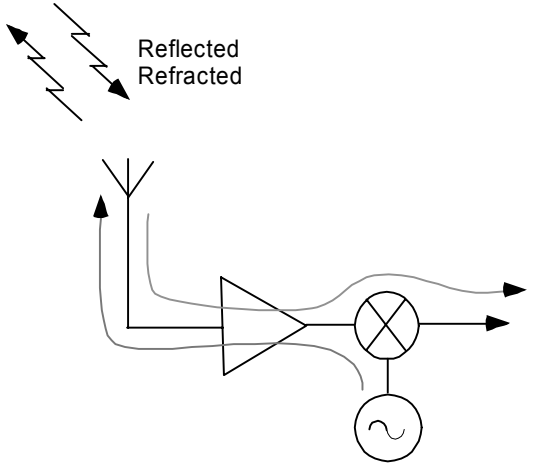


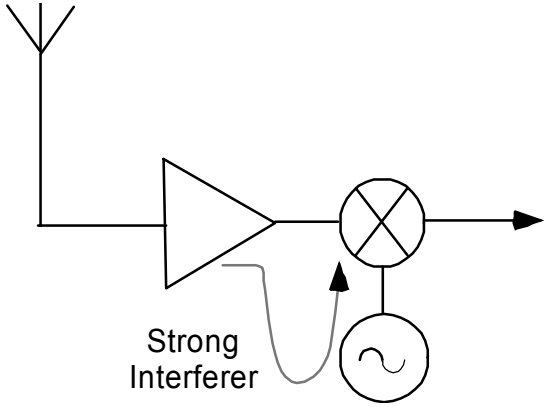
Homodyne Receiver

On the Direct Conversion Receiver -- A Tutorial, Ashkan Mashhour, William Domino and Norman Beamish, Conexant Systems, Microwave Journal, June 2001

DC Offset Mechanisms







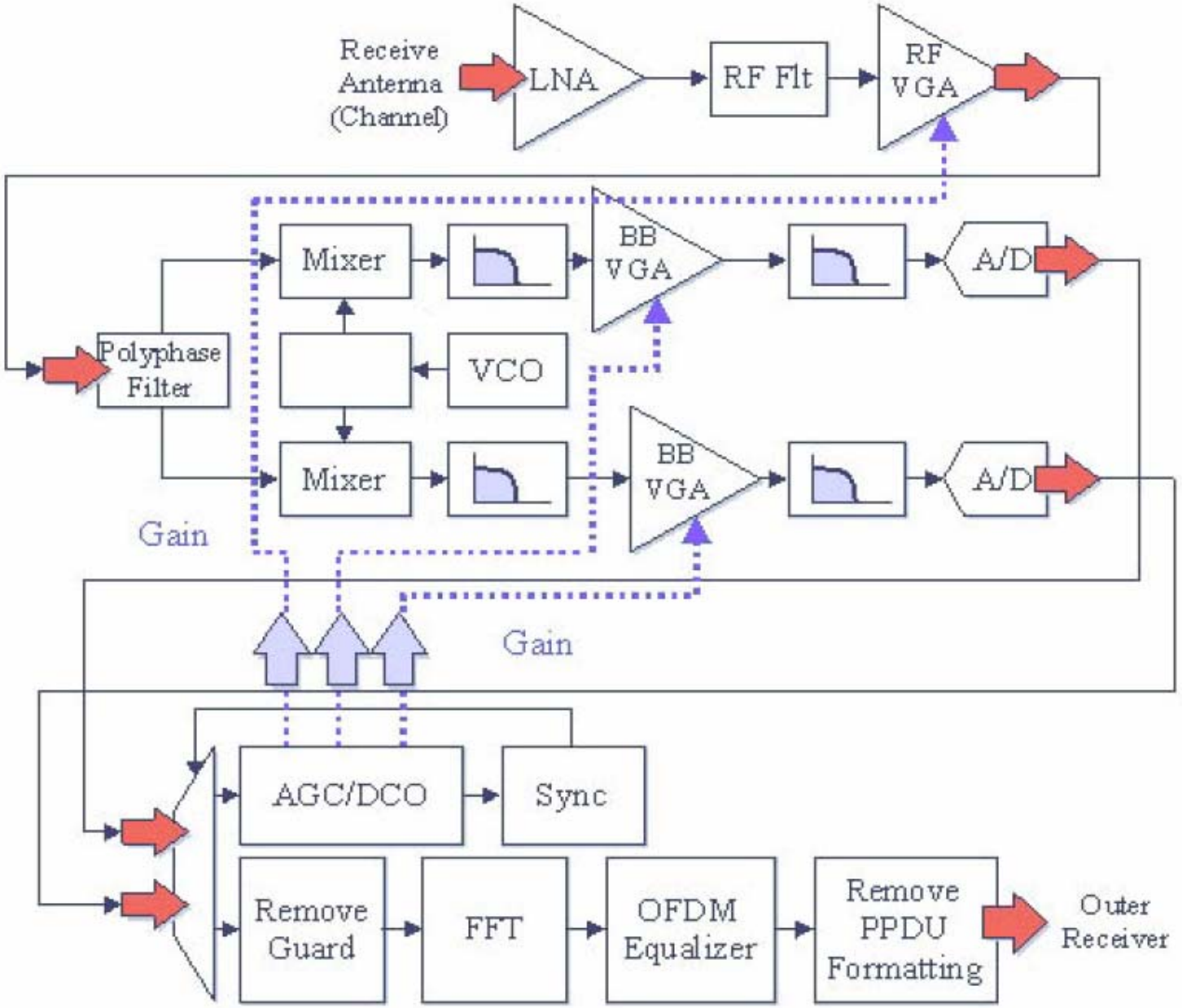
$$\overbrace{\cos 2\pi f_c t}^{\text{LO}}(\underbrace{\alpha \cos 2\pi f_c t}_{\text{LO Leakage}}) = \frac{1}{2}\alpha(1 + \cos 4\pi f_c t)$$

$$DC = \frac{1}{2}\alpha$$

On the Direct Conversion Receiver -- A Tutorial, Ashkan Mashhour, William Domino and Norman Beamish, Conexant Systems, Microwave Journal, June 2001

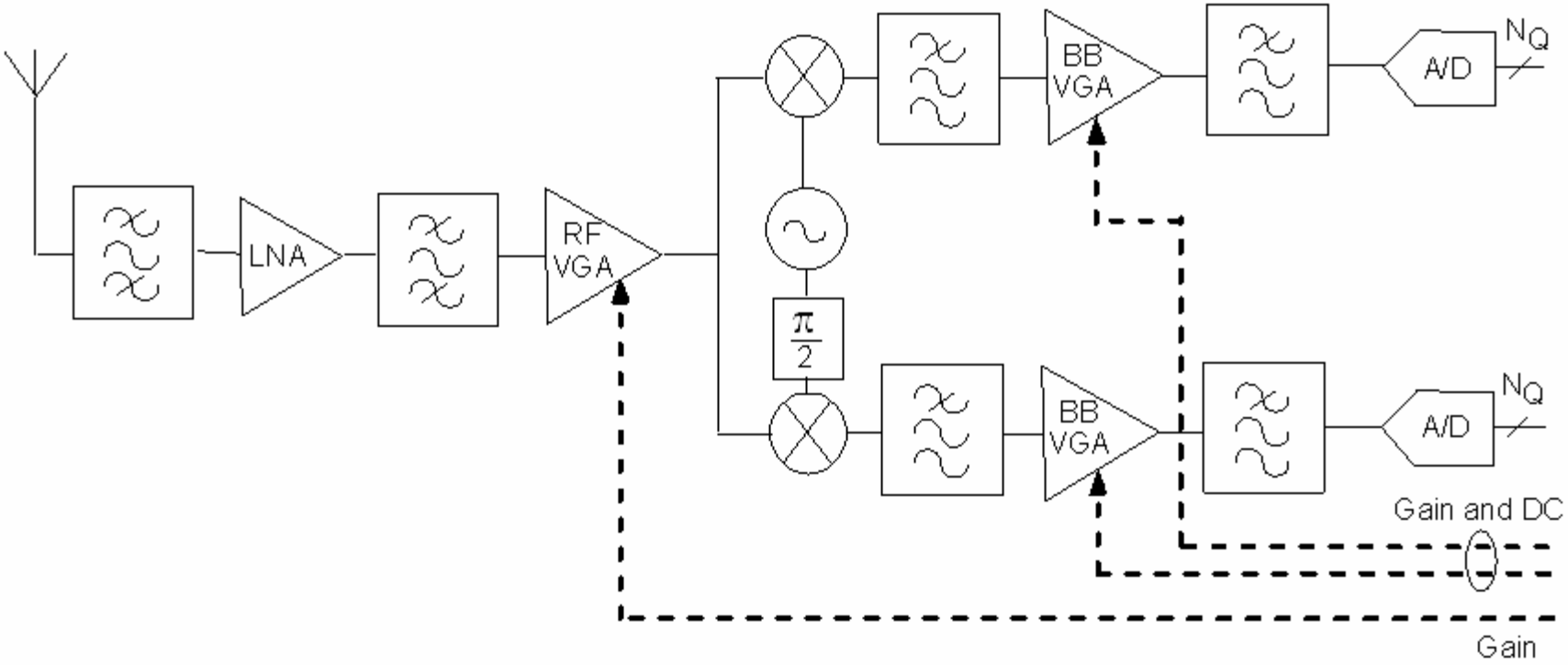
Automatic Gain Control

Direct Conversion Receiver



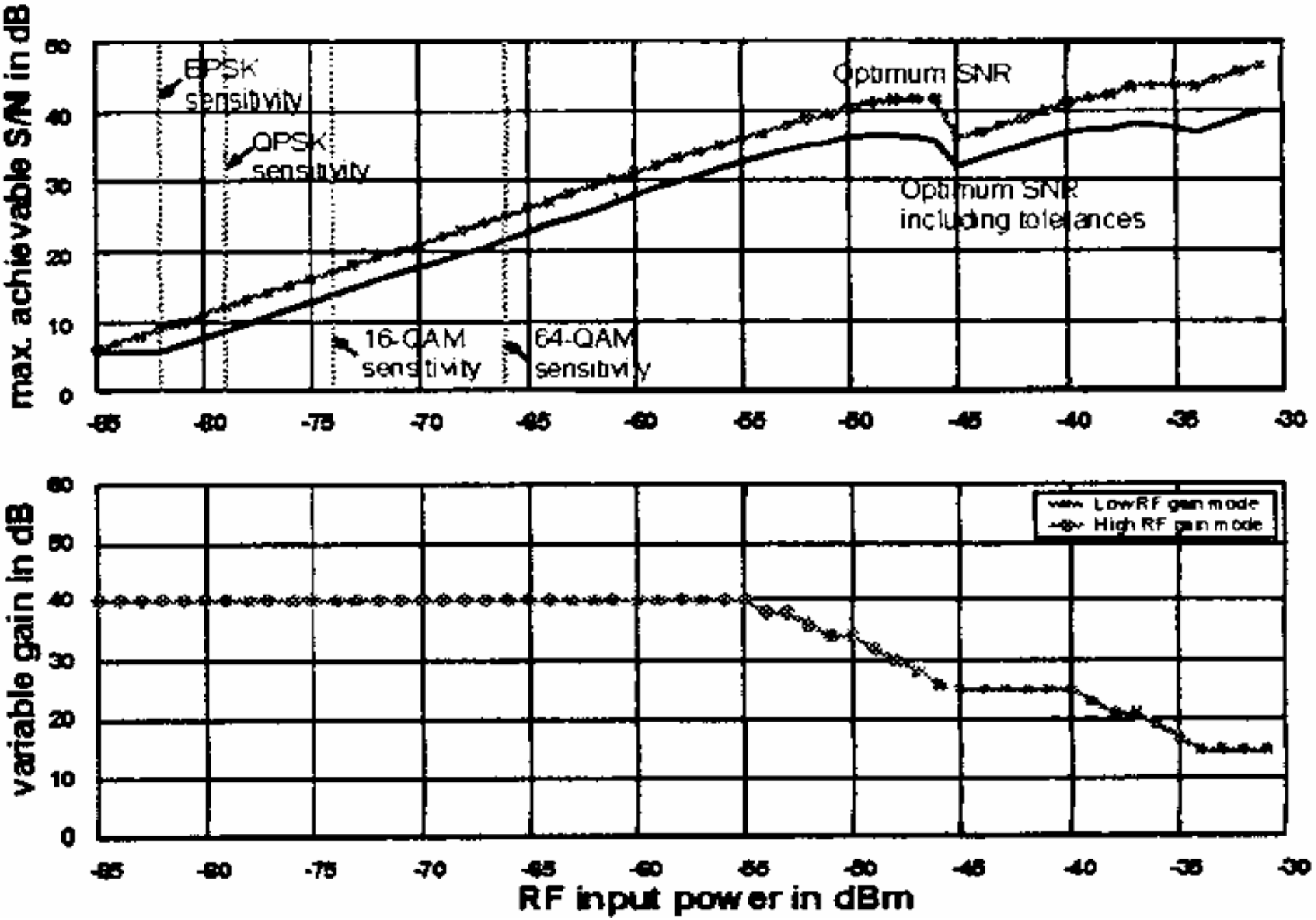
Reference:
OFDM-WLAN Receiver Performance Improvement using Digital Compensation Techniques
Wolgang Eberle, Jan Tubbax, Boris Come, Stephane Donnay, Hugo De Man, Georges Gielen, IMEC and KU Leuven, IEEE, 2002

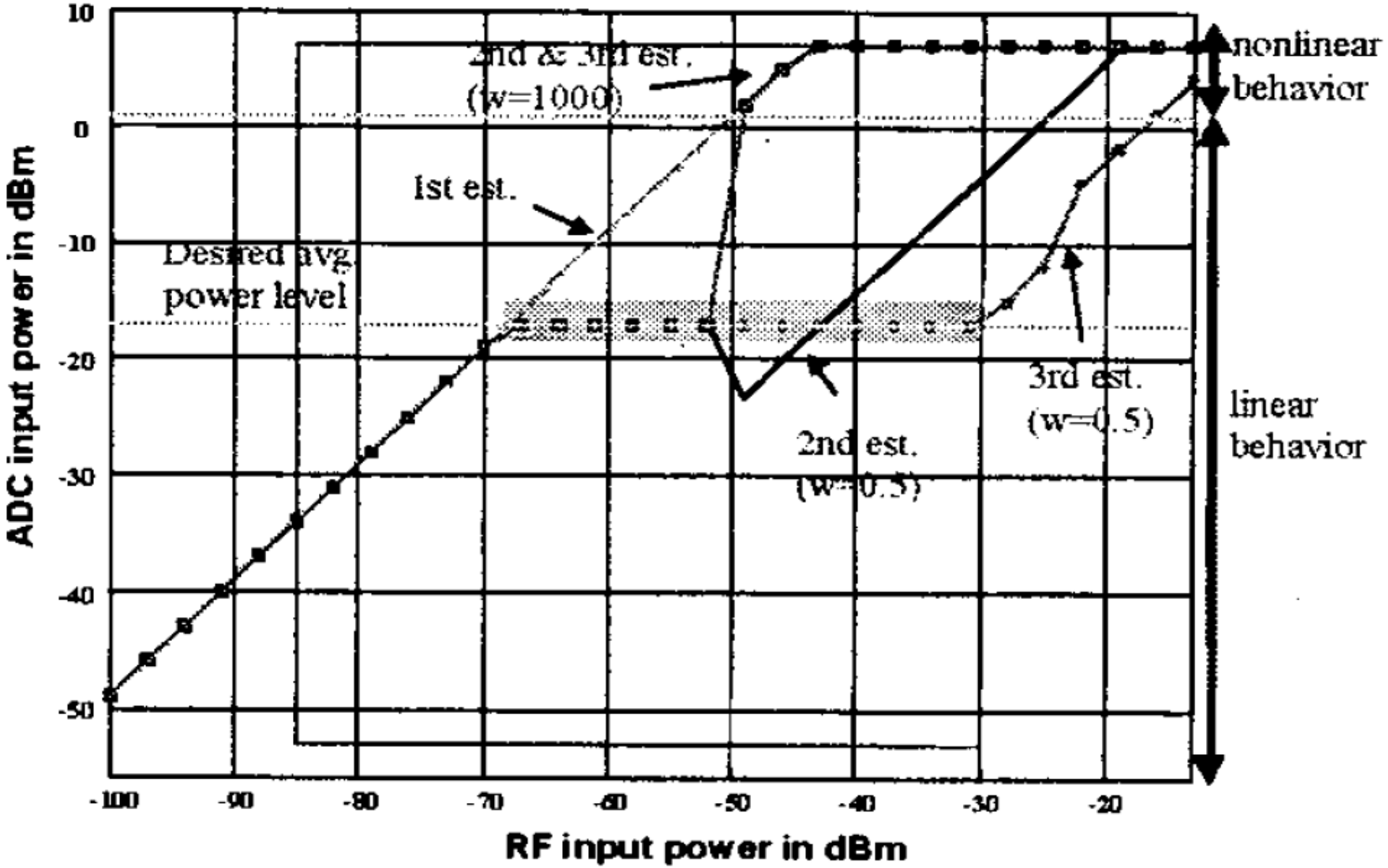
AGC

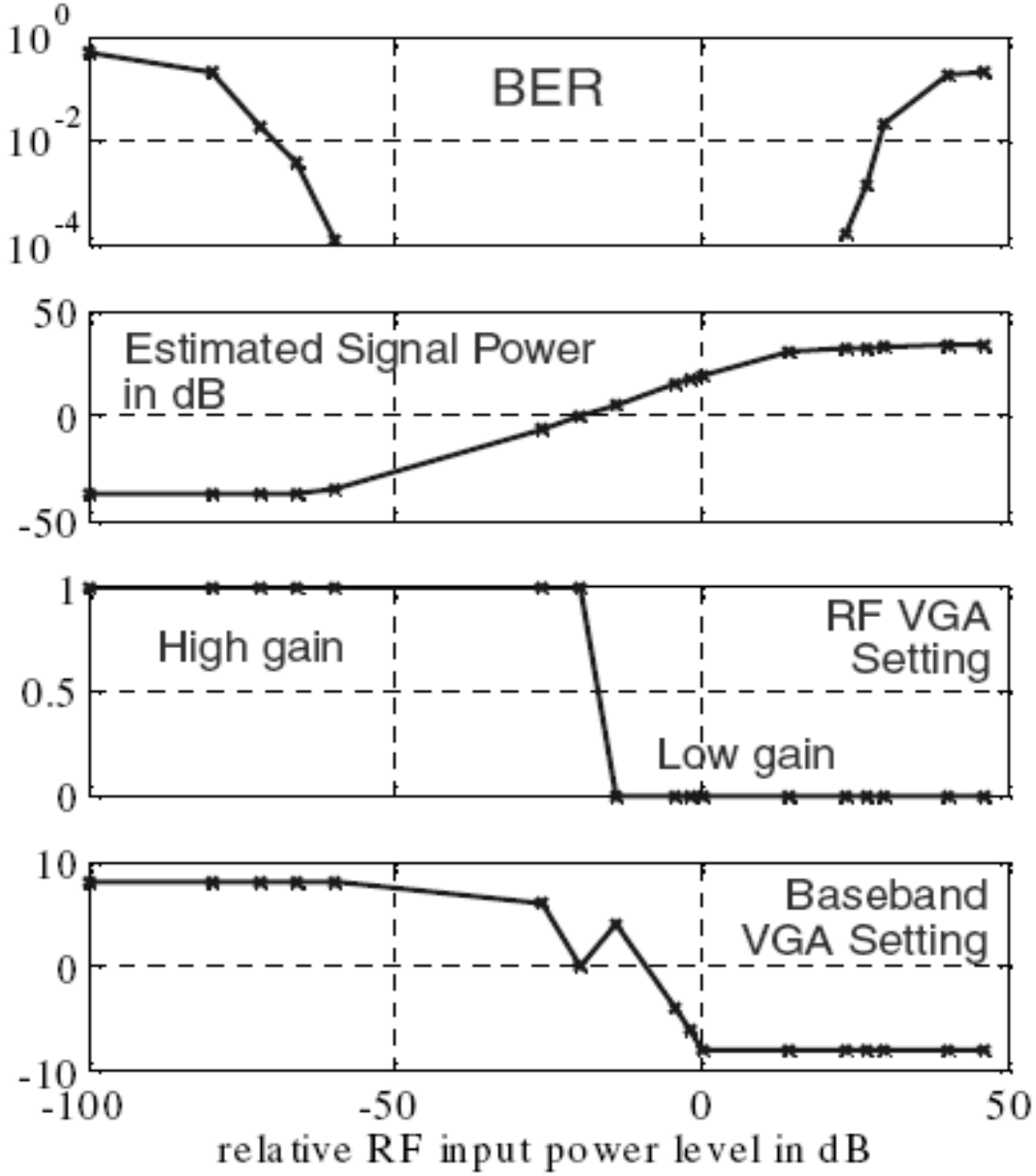


Baseband VGA : -8 to +8 dB gain range in 2 dB steps

Reference:
OFDM-WLAN Receiver Performance Improvement using Digital Compensation Techniques
Wolgang Eberle, Jan Tubbax, Boris Come, Stephane Donnay, Hugo De Man, Georges Gielen, IMEC and KU Leuven, IEEE, 2002

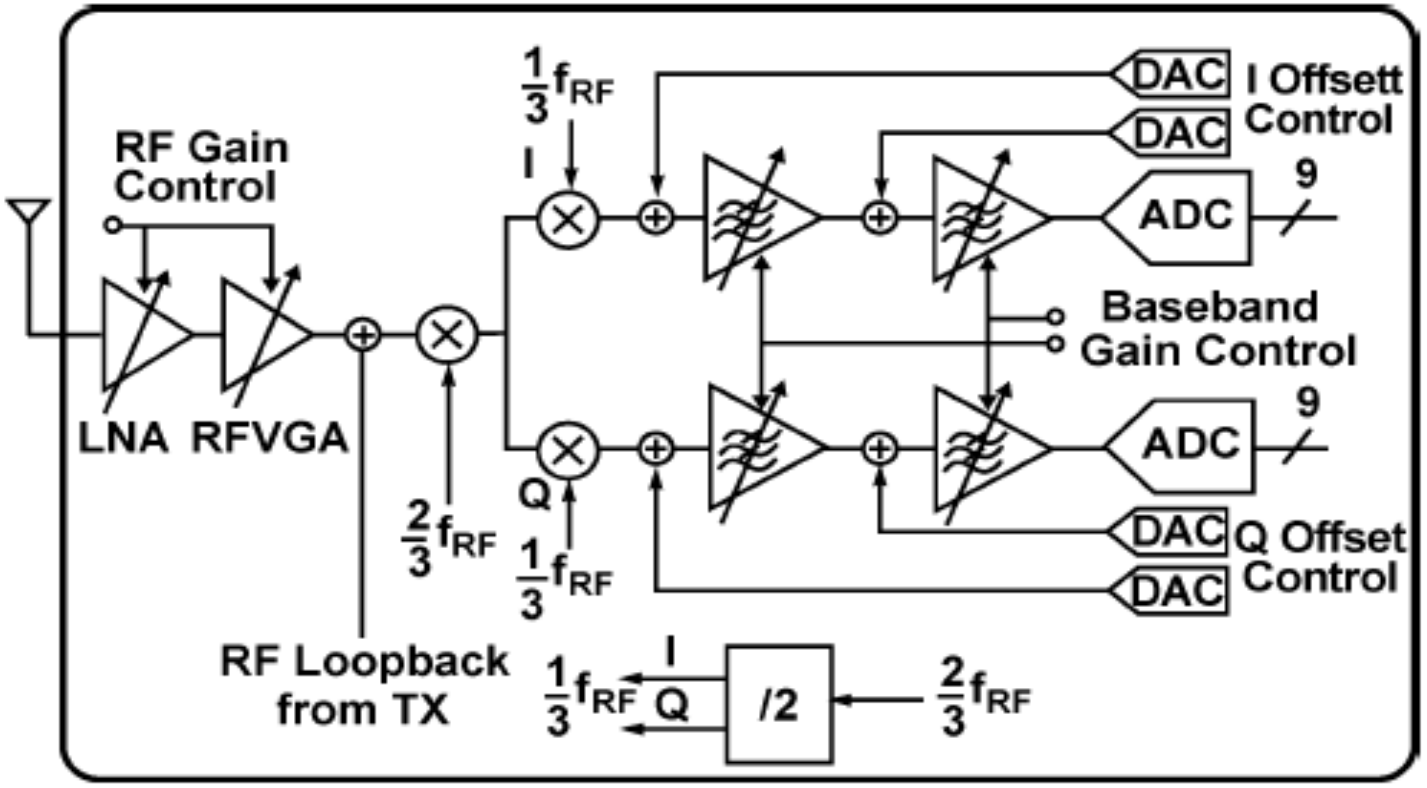

max. achievable S/N in dB
BPSK sensitivity
QPSK sensitivity
16-QAM sensitivity
64-QAM sensitivity
Optimum SNR
Optimum SNR including tolerances
0
10
20
30
40
-85
-80
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
variable gain in dB
Low RF gain mode
High RF gain mode
RF input power in dBm


10
0
-10
-20
-30
-40
-50
-100
-90
-80
-70
-60
-50
-40
-30
-20
ADC input power in dBm
RF input power in dBm
2nd & 3rd est.
(w=1000)
1st est.
Desired avg.
power level
2nd est.
(w=0.5)
3rd est.
(w=0.5)
nonlinear
behavior
linear
behavior



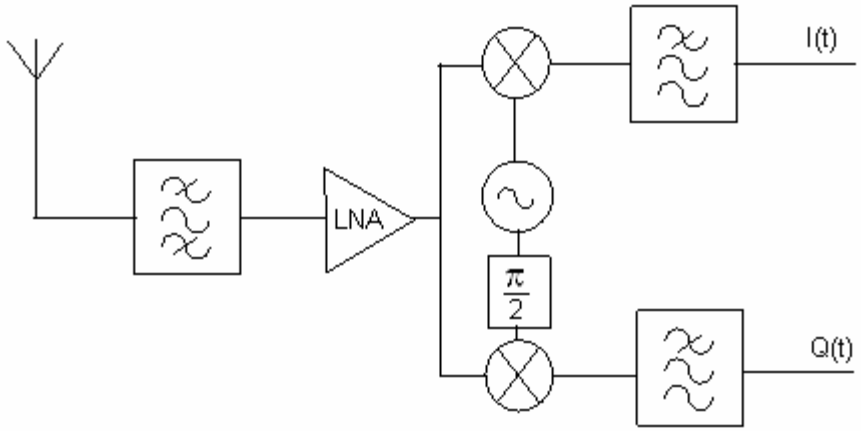
"Behavioral Modeling and Simulation of a Mixed Analog/Digital Automatic Gain Control Loop in a 5 GHz WLAN Receiver" Wolfgang Eberle,, Gerd Vandersteen, Piet Wambacq, Stéphane Donnay,Georges Gielen, Hugo De Man, IMEC, *Proceedings of the Design,Automation and Test in Europe Conference and Exhibition* , 2003

DC Compensation



"An 802.11g WLAN SoC", Srenik S. Mehta,et. Al.,IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 36, NO. 11, NOVEMBER 2001

I/Q Mismatch

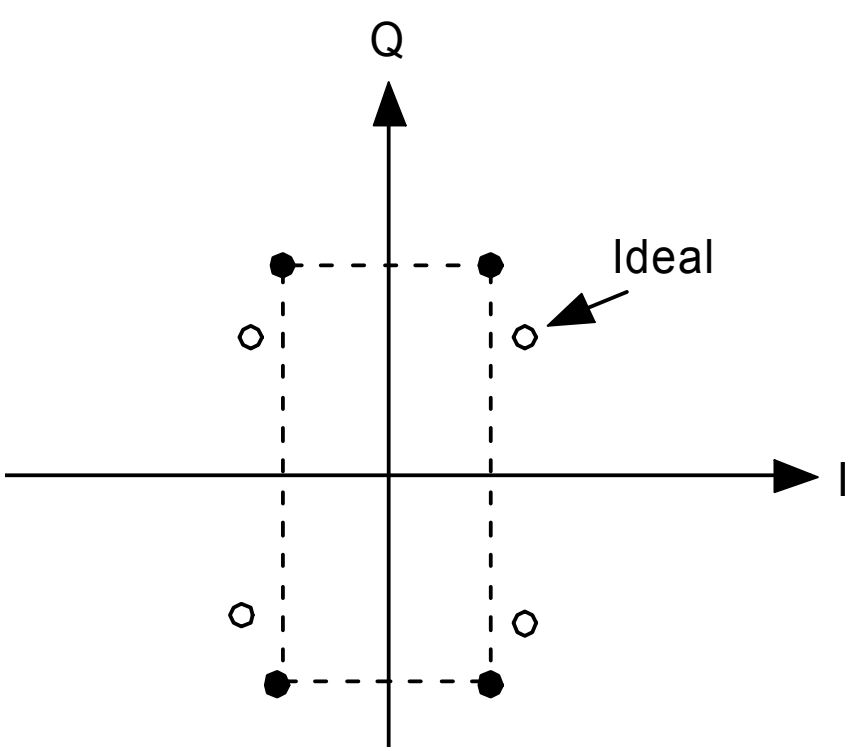


$$x_{LO,I}(t) = 2(1 + \frac{\epsilon}{2})\cos(\omega_c t + \frac{\theta}{2})$$

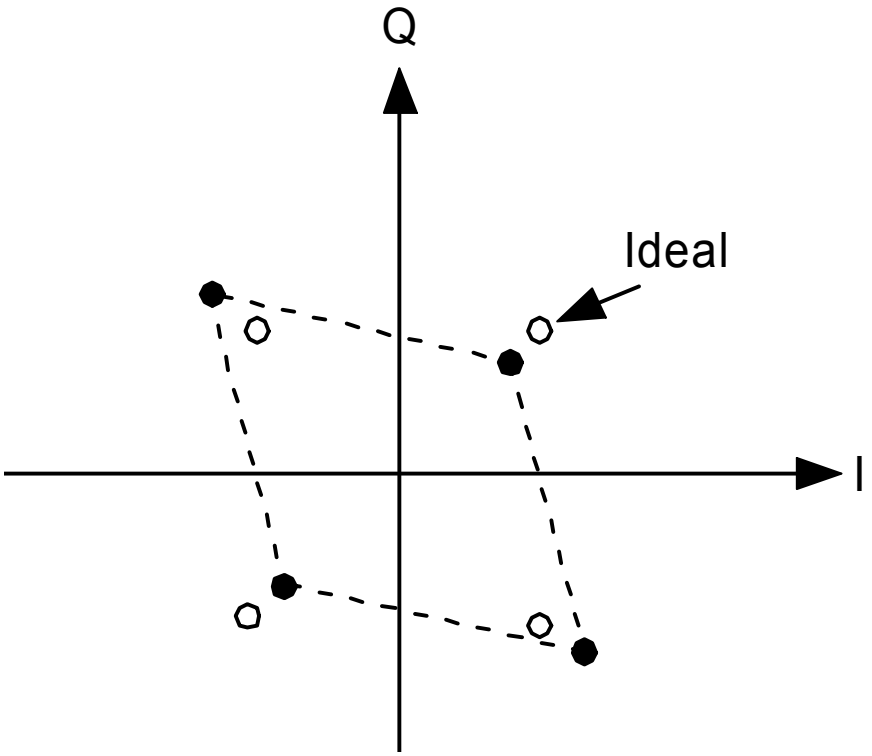
$$x_{LO,Q}(t) = 2(1 - \frac{\epsilon}{2})\sin(\omega_c t - \frac{\theta}{2})$$

$$x_{BB,I}(t) = a(1 + \frac{\epsilon}{2})\cos\frac{\theta}{2} - b(1 + \frac{\epsilon}{2})\sin\frac{\theta}{2}$$

$$x_{BB,Q}(t) = -a(1 - \frac{\epsilon}{2})\sin\frac{\theta}{2} + b(1 - \frac{\epsilon}{2})\cos\frac{\theta}{2}$$

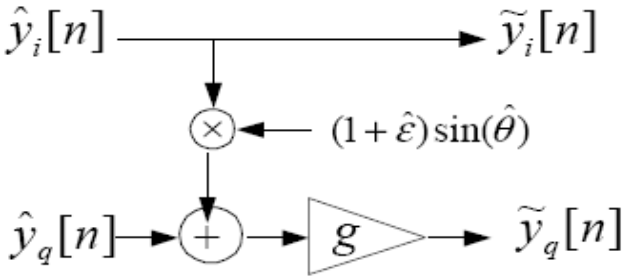


Gain Error

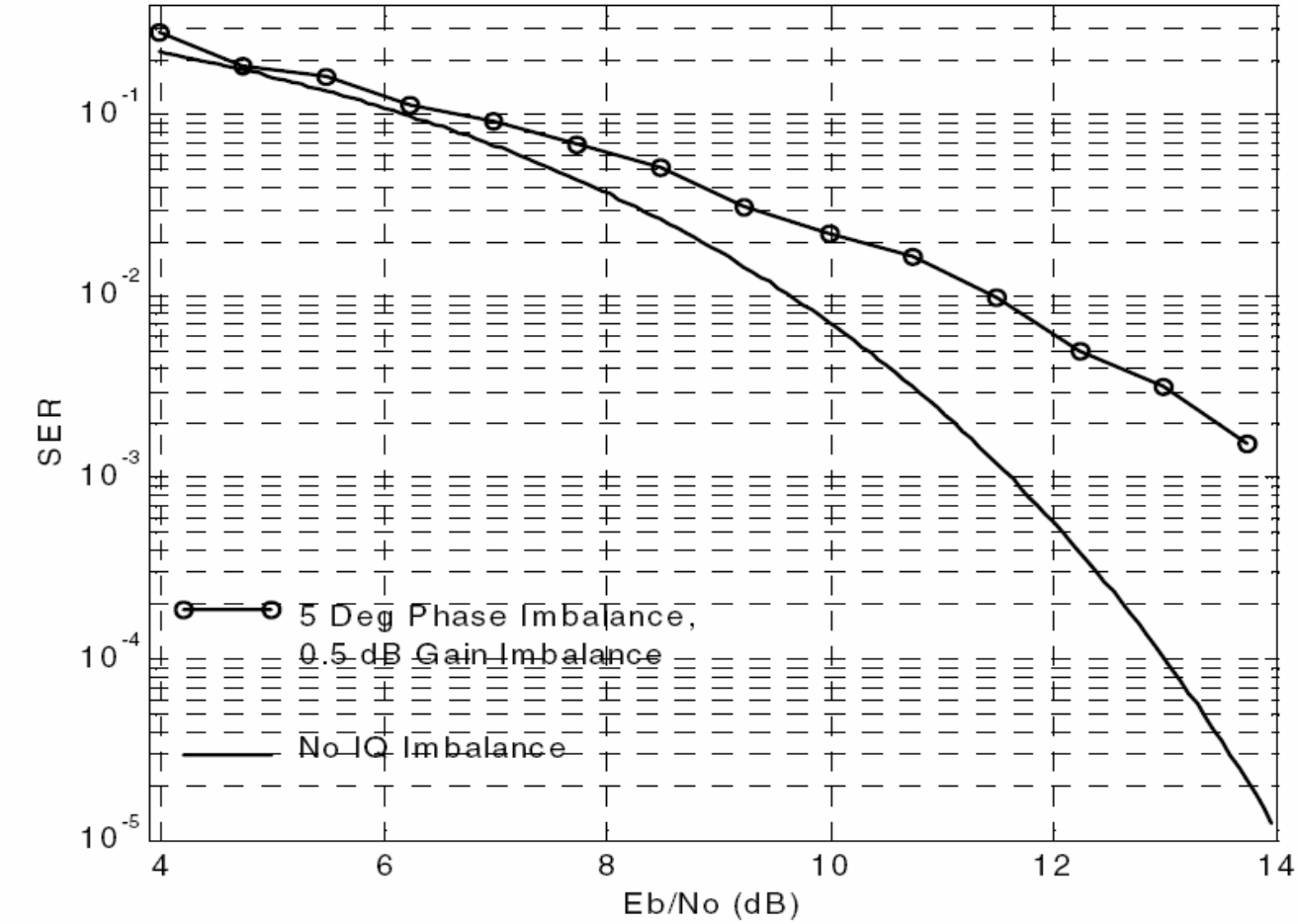


Phase Error

RF Microelectronics, Behzad Razavi, Prentice Hall, 1998



$$g = \frac{1}{(1+\hat{\epsilon})\cos\hat{\theta}}$$

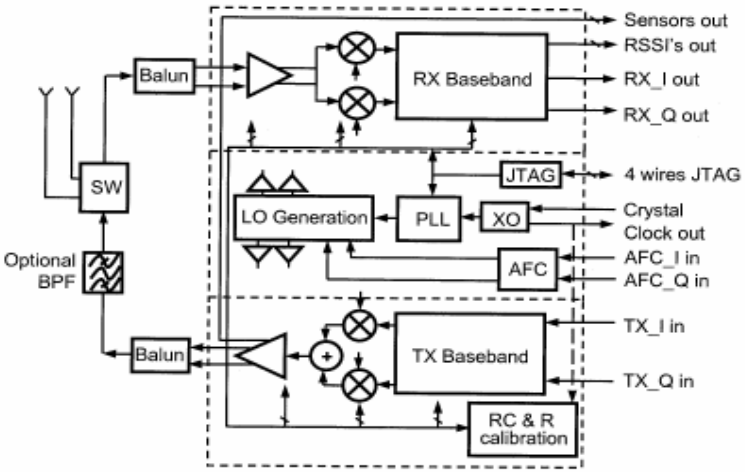


SER: Symbol Error Rate

"Calibration of IQ Imbalance in OFDM Transceivers", H. Shafiee, S. Fouladifard, 2003 IEEE

TABLE I
SUMMARY OF TRANSCEIVER PERFORMANCE

	Measured	Unit
Frequency Band	5.15 – 5.35	GHz
RX NF	4	dB
RX Sensitivity (6Mbps)	-93.7 ± 0.9	dBm
RX Sensitivity (54Mbps)	-73.9 ± 1.2	dBm
RX IIP3	-4.8	dBm
RX IIP2	> 30	dBm
RX Gain Range	15 to 93	dB
TX Power Range	-30 to +18.7	dBm
TX Psat	+23	dBm
TX P-1dB	+19	dBm
Vdd	1.8	V
Vdd_PA	3.3	V
Phase Noise @ 30KHz	-100	dBc/Hz
RX Power Consumption	150	mW
TX Power Consumption	380 (15dBm OFDM output)	mW
ESD	> ±2.5 on all pins	KV
Technology	0.18um 1P5M CMOS	
Die Size	11.7 (including padring)	mm^2



A 5-GHz Direct-Conversion CMOS Transceiver Utilizing Automatic Frequency Control for theIEEE 802.11a Wireless LAN Standard
Arya R. Behzad,IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 38, NO. 12, DECEMBER 2003