



ESSCIRC '04 workshop on Multi-mode multi-band re-configurable systems for 3rd enhanced generation mobile phones

A reconfigurable 4- GHz VCO for 3G multimode
transceivers

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Motivation (1/2)

- Application : multimode 3G transceivers
- Frame : IST project MuMoR
- Objective : design a VCO with reconfigurability features
- Targeted modes :
 - UMTS W- CDMA FDD and TDD, RX & TX



Motivation (2/2)

➤ VCO features :

- fully on- chip integrated.
- includes all the auxilliary blocks => get real- world data.
- immunity to substrate and supply noise : architecture choice.
- wide frequency tuning range : switched capacitors.
- low power : automatic amplitude control (AAC) loop.



Specifications (1/2)

➤ MuMoR specifications

Parameter	Mode	RX		TX		Unit
		Value		Value		
		Min.	Max.	Min.	Max.	
Freq.	TDD band1	3800	3840	3800	3840	MHz
	TDD band2	4040	4050	4040	4050	MHz
	FDD	4220	4340	3840	3960	MHz
Noise @ 3 MHz	All				-120	dBc/Hz
Noise @ 5 MHz	All		-97			dBc/Hz
Noise @ 10 MHz	All		-107			dBc/Hz
Noise @ 12.5 MHz	All				-123	dBc/Hz
Noise @ 15 MHz	All		-119			dBc/Hz
Noise @ 20 MHz	All				-145	dBc/Hz
Noise @ 85 MHz	All				-148	dBc/Hz
Pushing	All		5			MHz/V
Supply voltage	All	2.7	2.9			V
Temperature	All	-20	+85			°C





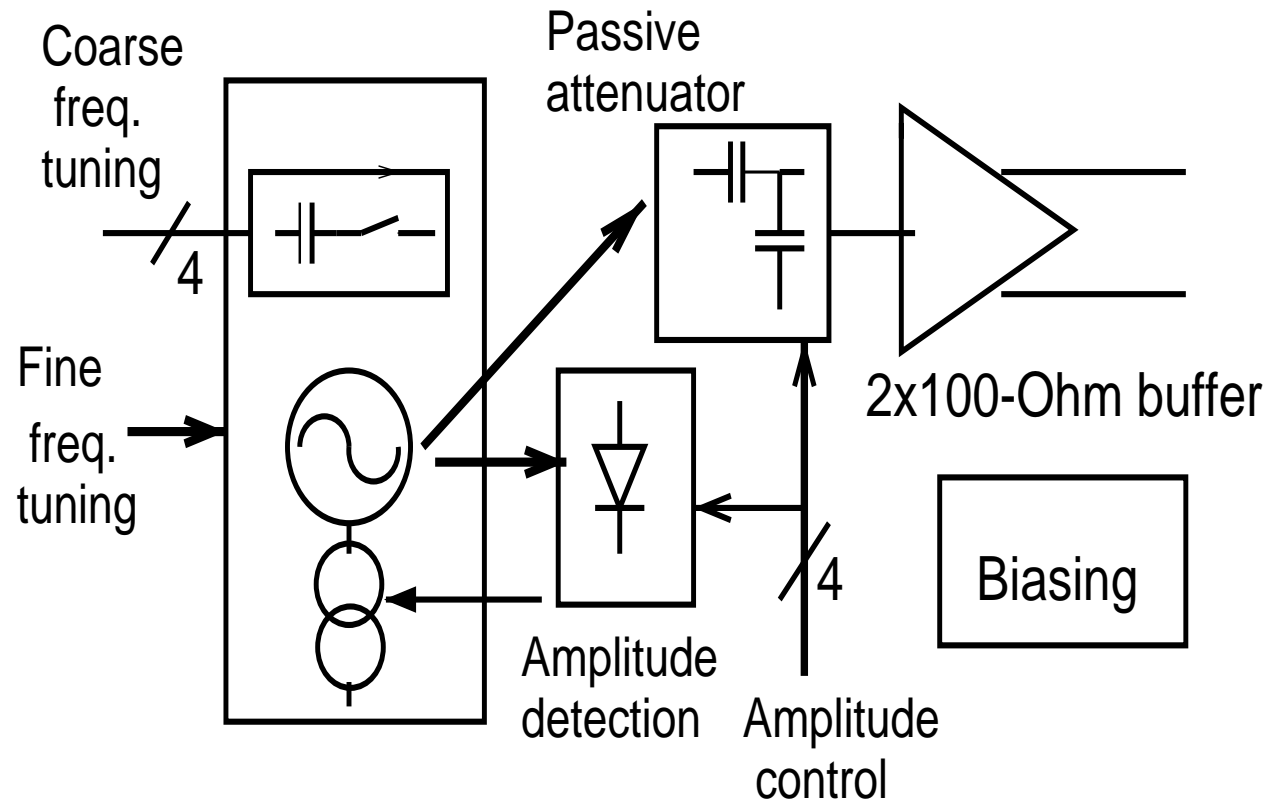
Specifications (2/2)

- VCO runs at twice the frequency.
- RX can be optimized for low power.
- TX must be optimized for low phase noise.
- TDD range (one VCO) :
3800- 4050 MHz
- FDD range (two VCOs):
3840- 3960 and 4220- 4340 MHz



Overall architecture

- coarse frequency tuning to switch between modes.
- amplitude control to keep power as low as possible.
- output level maintained constant to ease integration in system- on- chip.

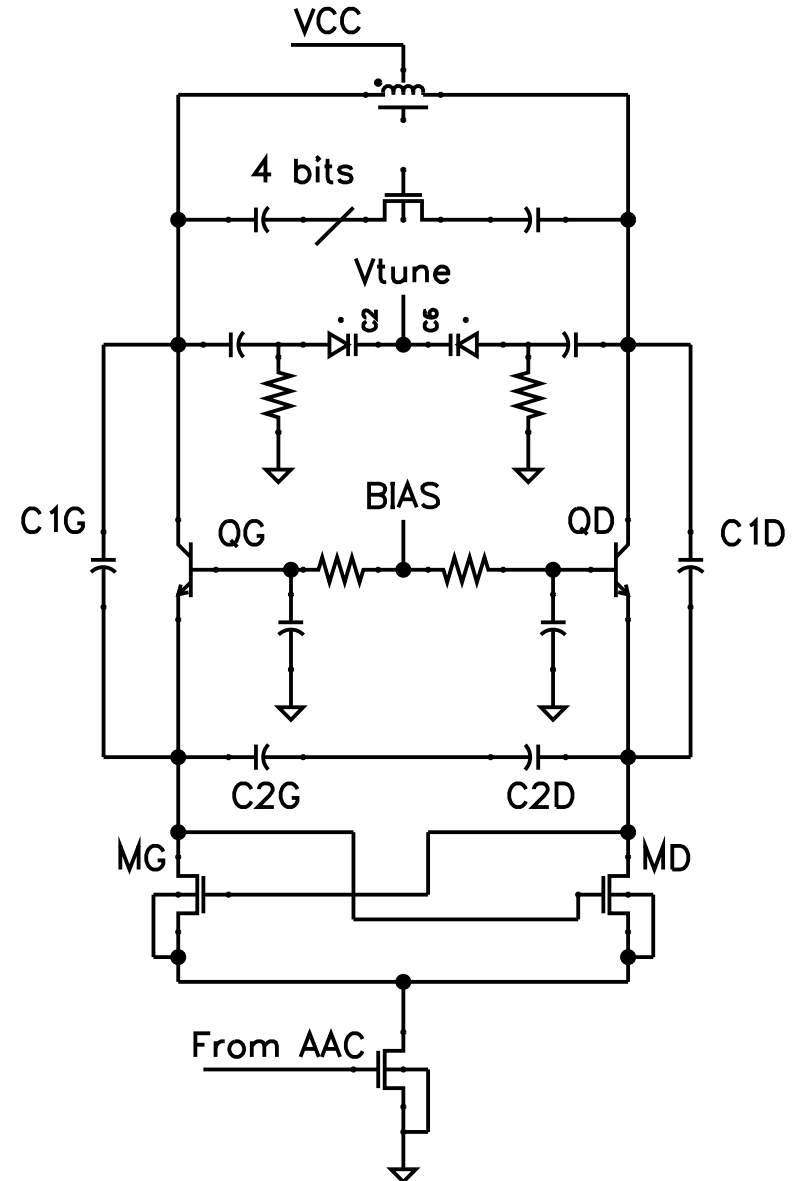




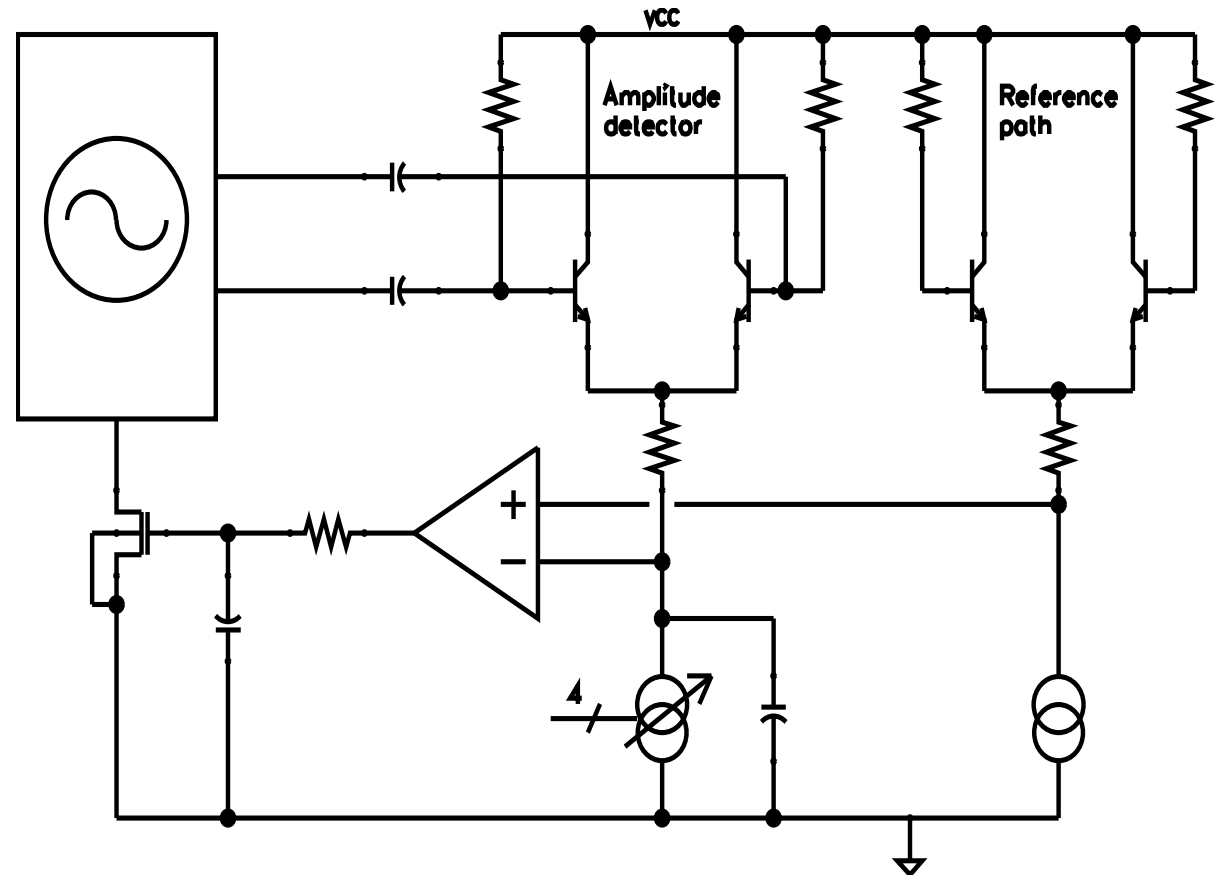
Core oscillator

- differential Colpitts architecture [1]:
 - bipolars connected in Colpitts configuration for best phase noise.
 - cross-coupled MOSFETs switch current from the source twice by period to reduce current.
- Differential structure rejects common mode noise coming from substrate.
- Tail source for isolation from supply.

[1] R. Aparicio, A. Hajimiri, "A CMOS differential noise-shifting Colpitts VCO", ISSCC 2002.



- output is rectified and compared to reference.
- good low-pass filtering is needed to get good low-offset phase noise (i.e. @ 1 MHz and less).
- settling time for a full-range step is 2- 3 μ s.

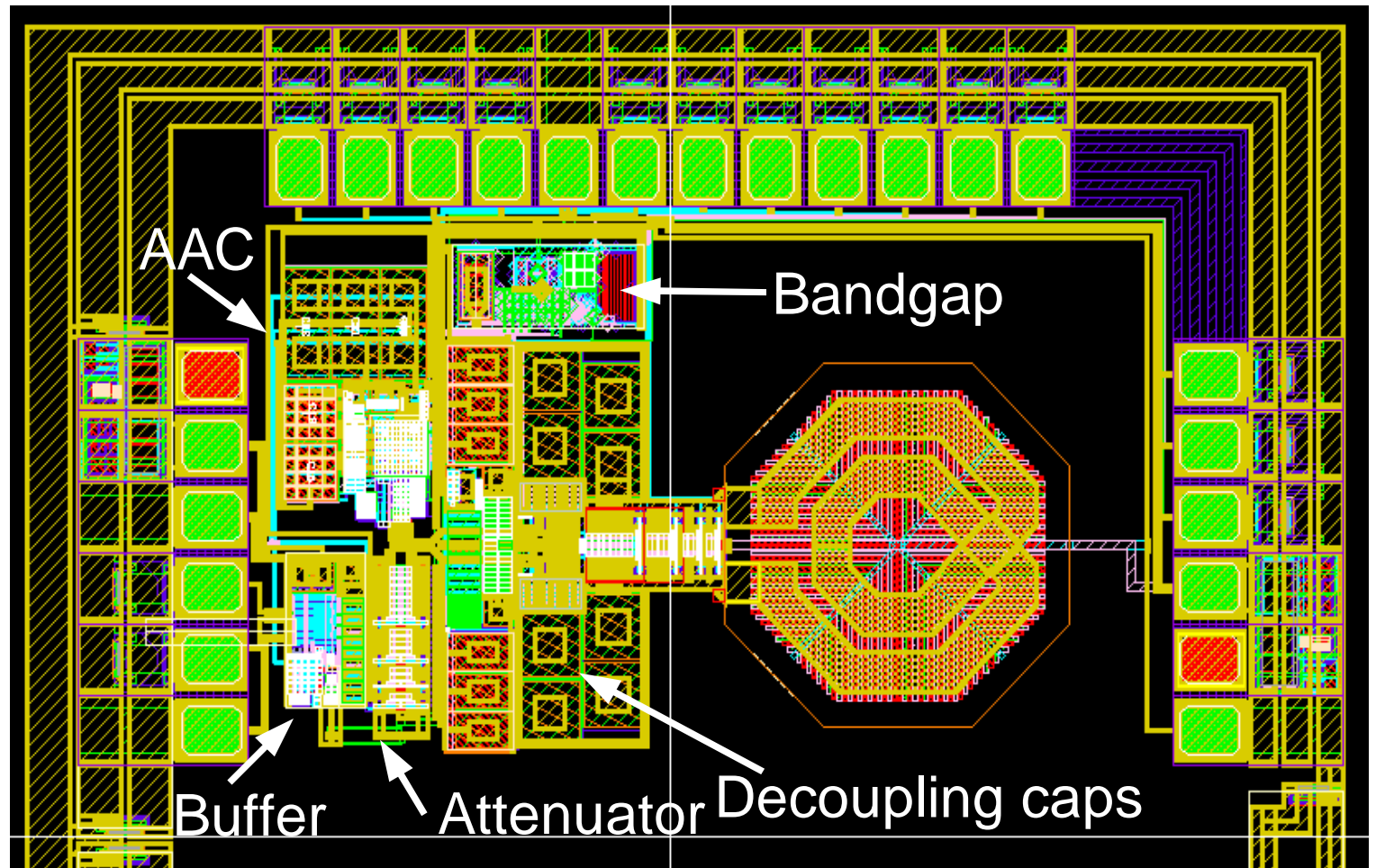




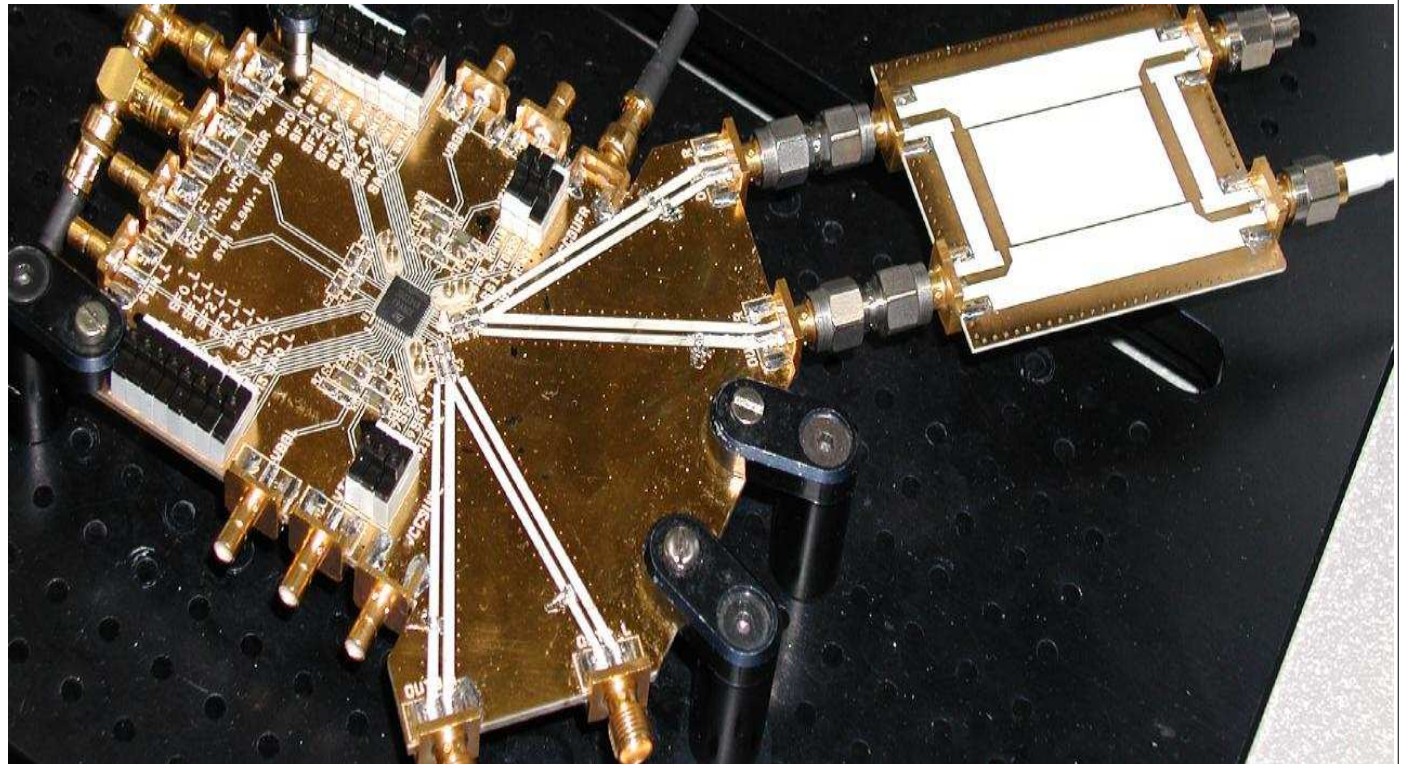
Layout

Size without bonding pads :
1000 x 600 μm .

Output buffer has its own supply.



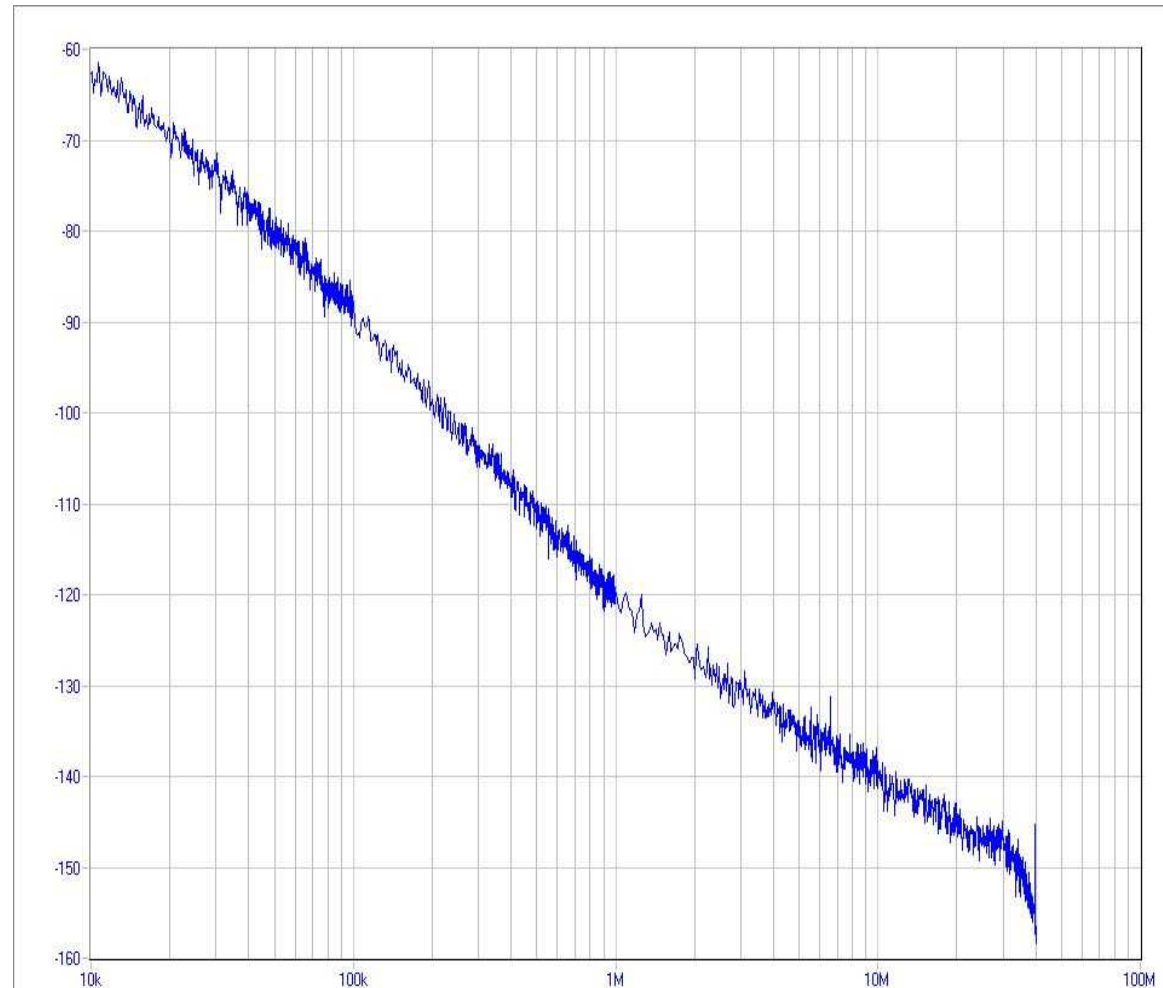
- Rogers 4350 board + hybrid coupler (diff - > single) on outputs.
- $2 \times 100 \Omega \rightarrow 2 \times 50 \Omega$ matching made on PCB \Rightarrow accurate output power.





Phase noise measurement

Frequency : 3.95 GHz
Core VCO current : 7.5 mA





Phase noise figures

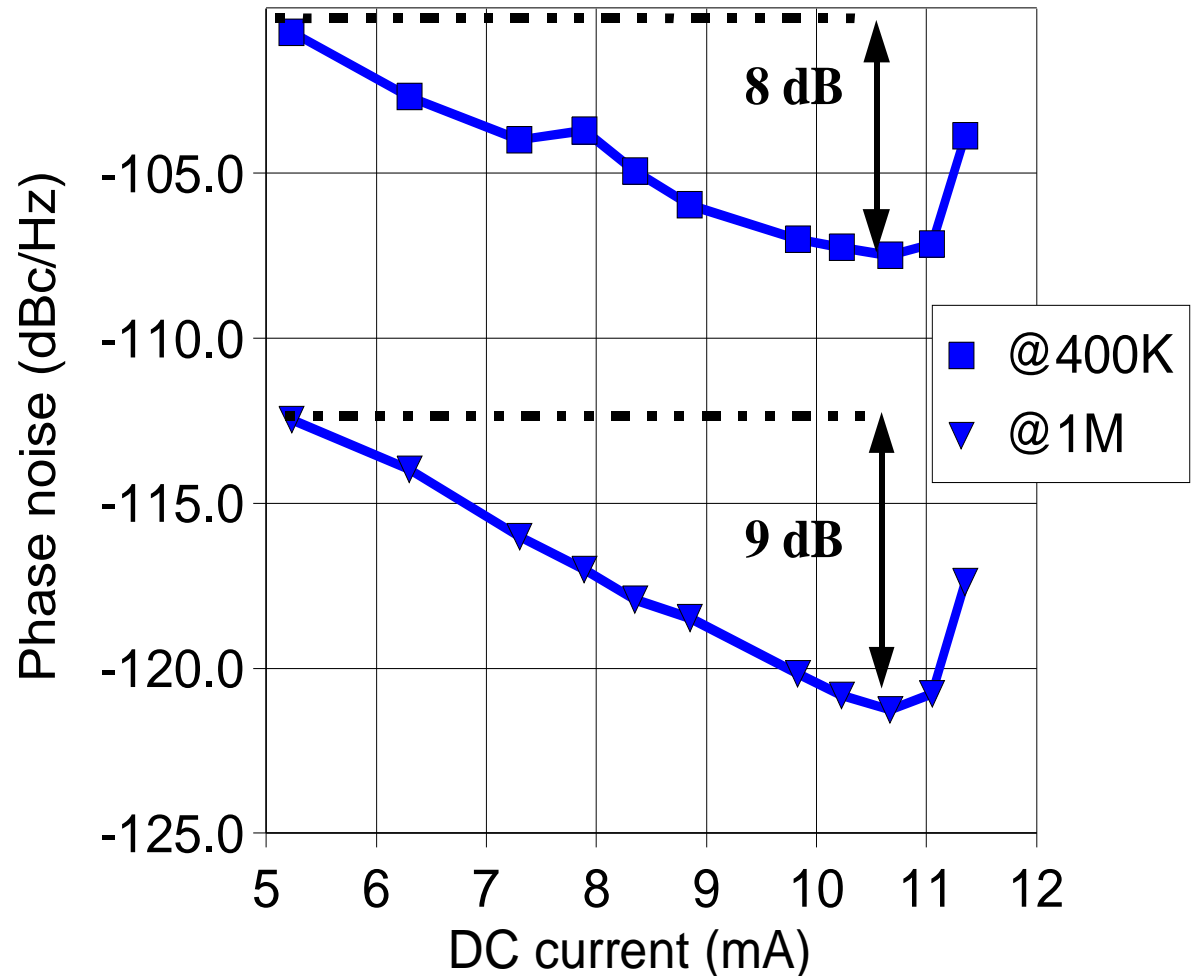
Freq. offset	VCO		UMTS W-CDMA	
	Meas.	Simul.	RX	TX
@ 10KHz	-62.4	-61.3		
@ 100KHz	-88.9	-90.9		
@ 400KHz	-107.5	-113.9		
@ 600KHz	-113.4	-119.3		
@ 1MHz	-121.3	-124.8		
@ 3 MHz	-130.8	-134.6		-120.0
@ 5 MHz	-135.2	-139.0	-97.0	
@ 10MHz	-139.9	-145.4	-107.0	
@ 12.5MHz	-141.8	-147.3		-123.0
@ 15MHz	-143.4	-148.9	-119.0	
@ 20MHz	-144.8	-151.7		-145.0
@ 85MHz	n/a	-158.8		-148
@ 100MHz	n/a	-159.8		





Switching between low- power and low- noise configurations (1/4)

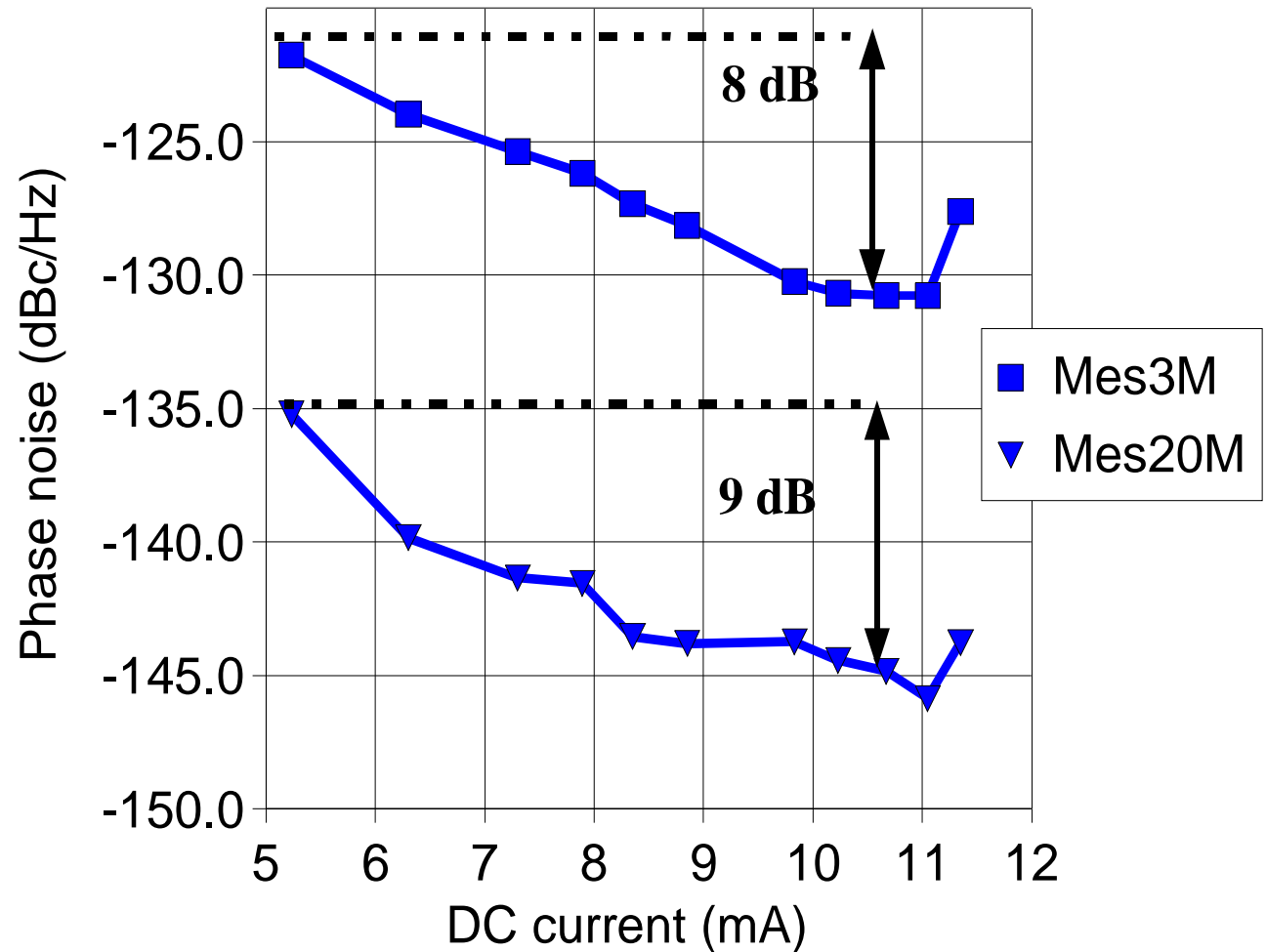
- When current is halved low- offset phase noise is degraded by 8 to 9 dB.





Switching between low- power and low- noise configurations (2/4)

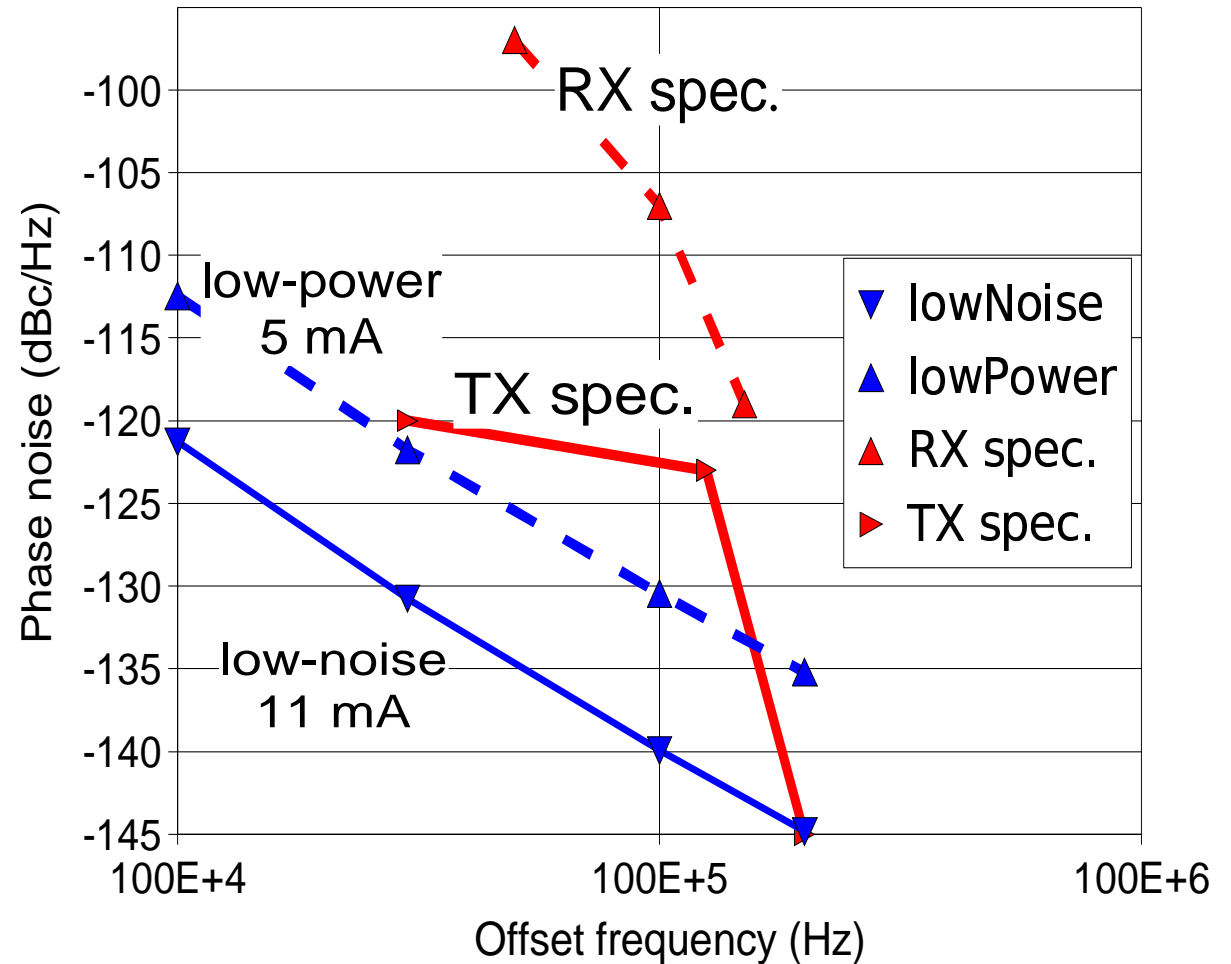
- When current is halved high- offset phase noise is degraded by 8 to 9 dB.





Low- noise and low- power configurations (3/4)

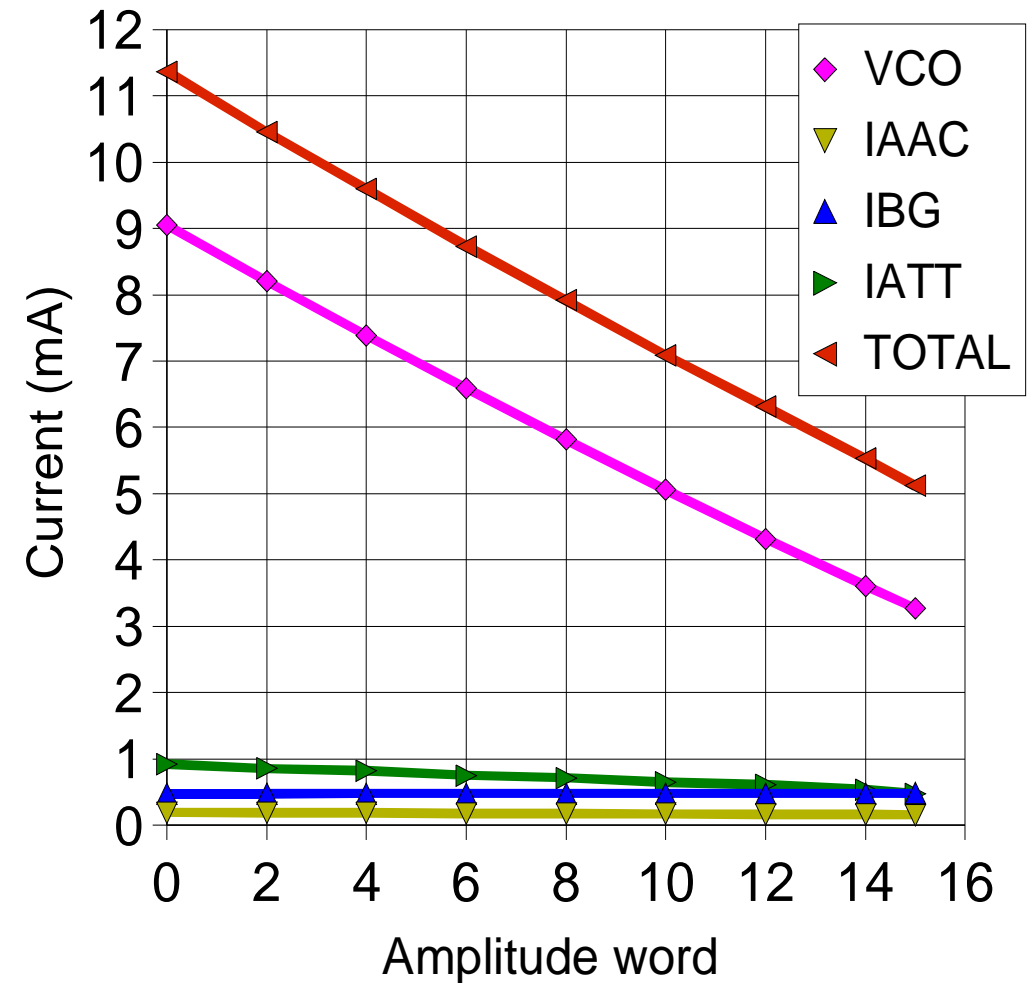
- Current consumption can be halved from TX to RX.



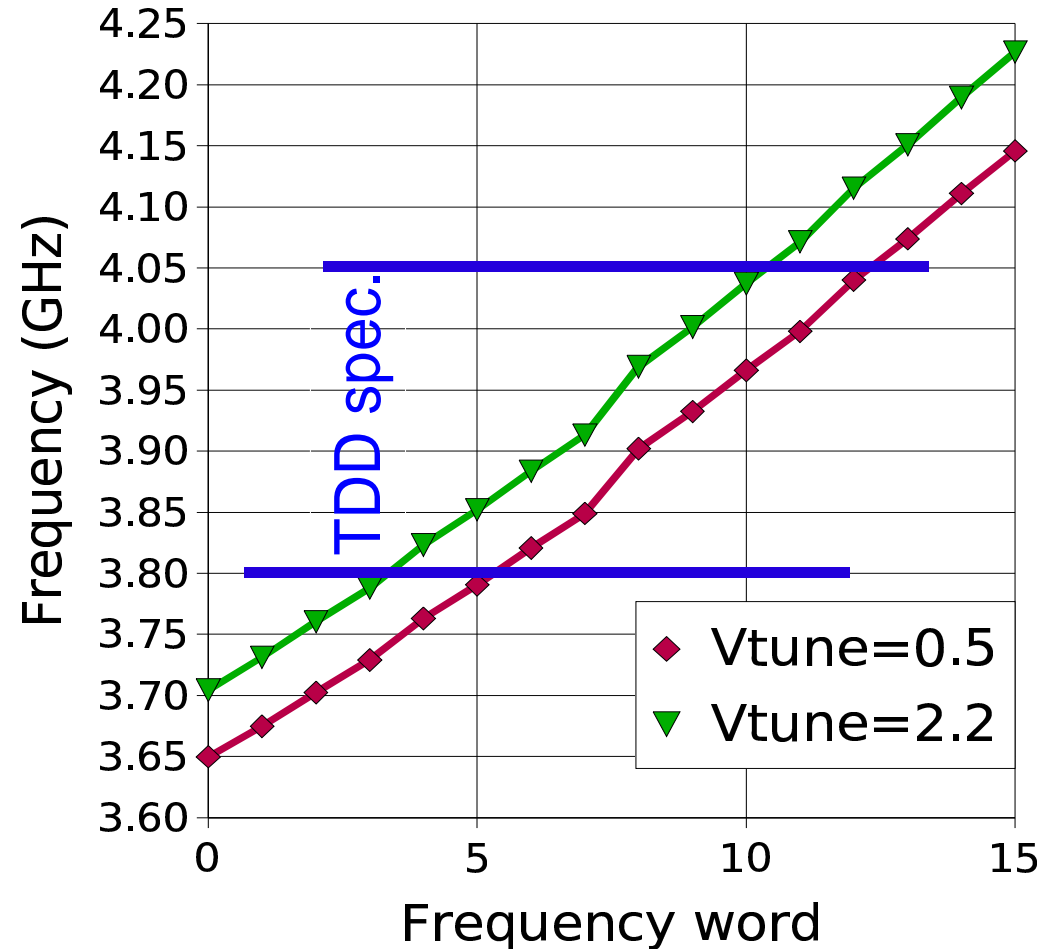


Low- noise and low- power configurations (4/4)

- Current sharing shows that auxiliary blocks have a low consumption .

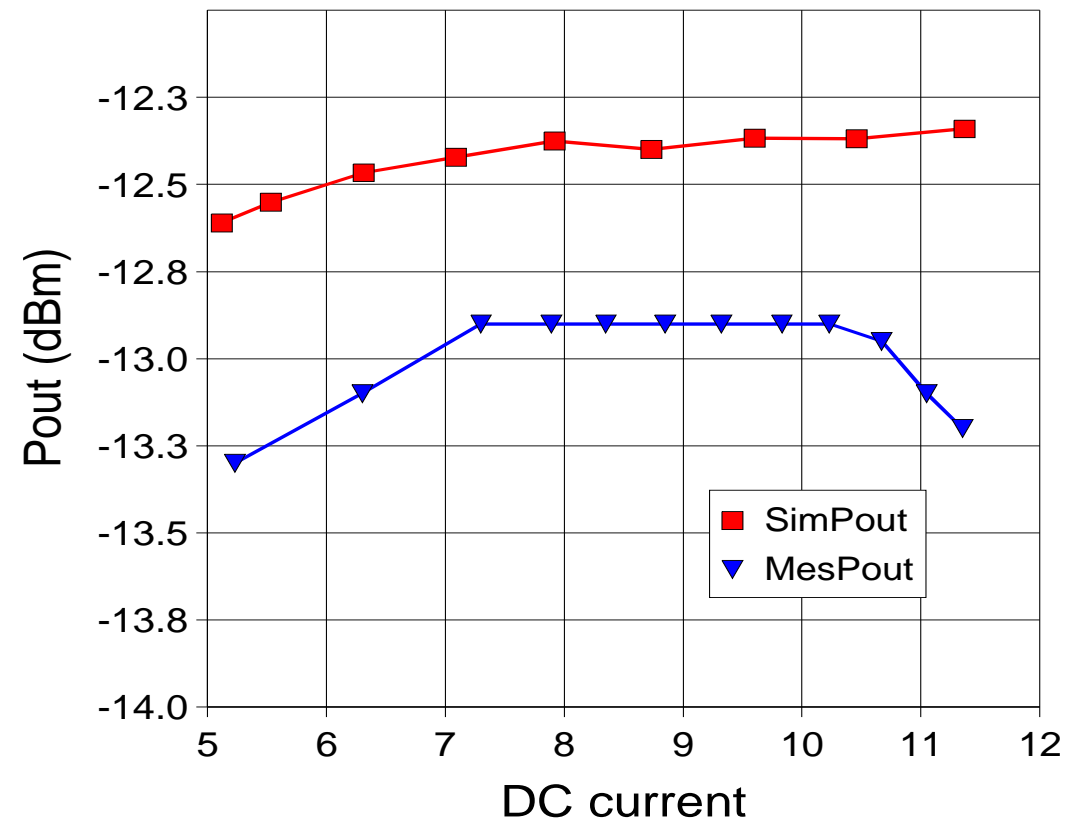


- the TDD version covers specifications with headroom for PVT variations.
- two other versions cover FDD TX and RX modes.



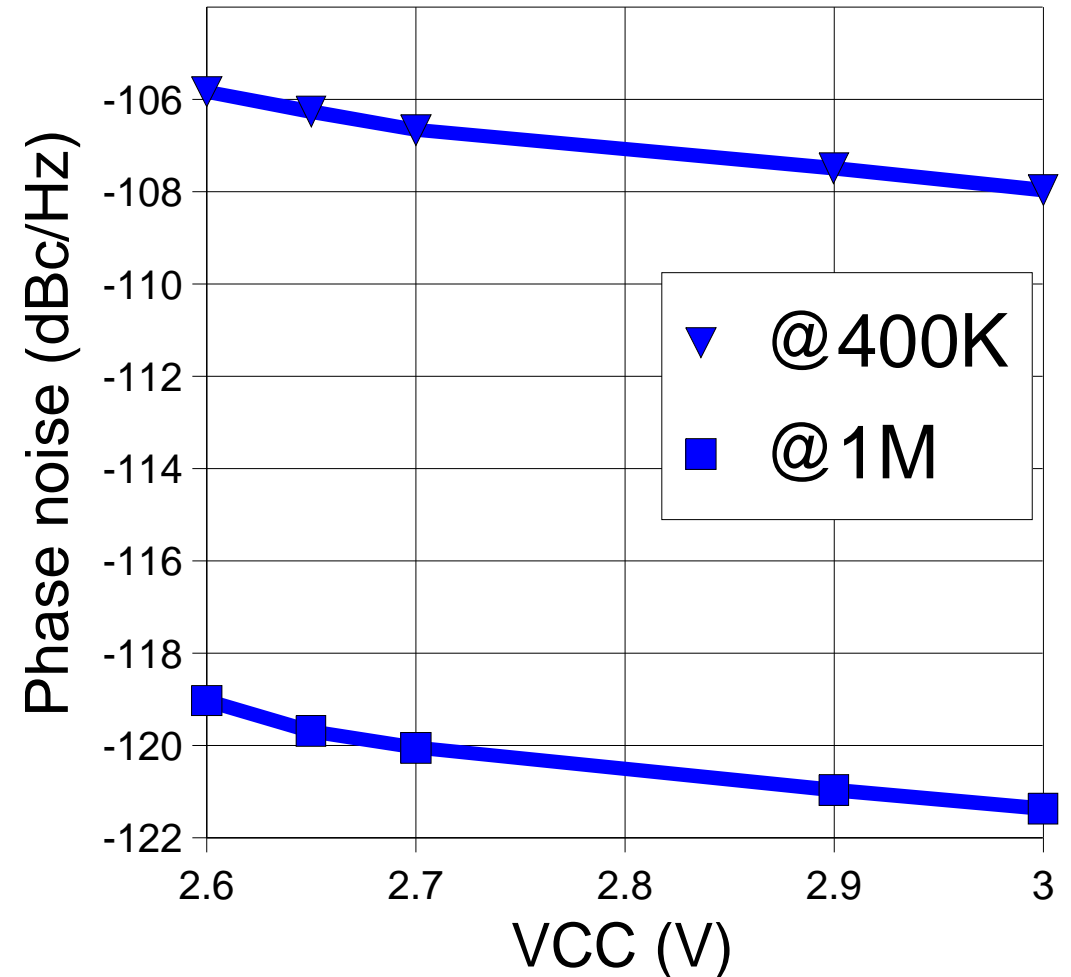
- Output level remains within 0.5 dB when switching between low-power and low-noise configurations.
- The combination of the amplitude control and the variable attenuator performs well.

Pout vs current



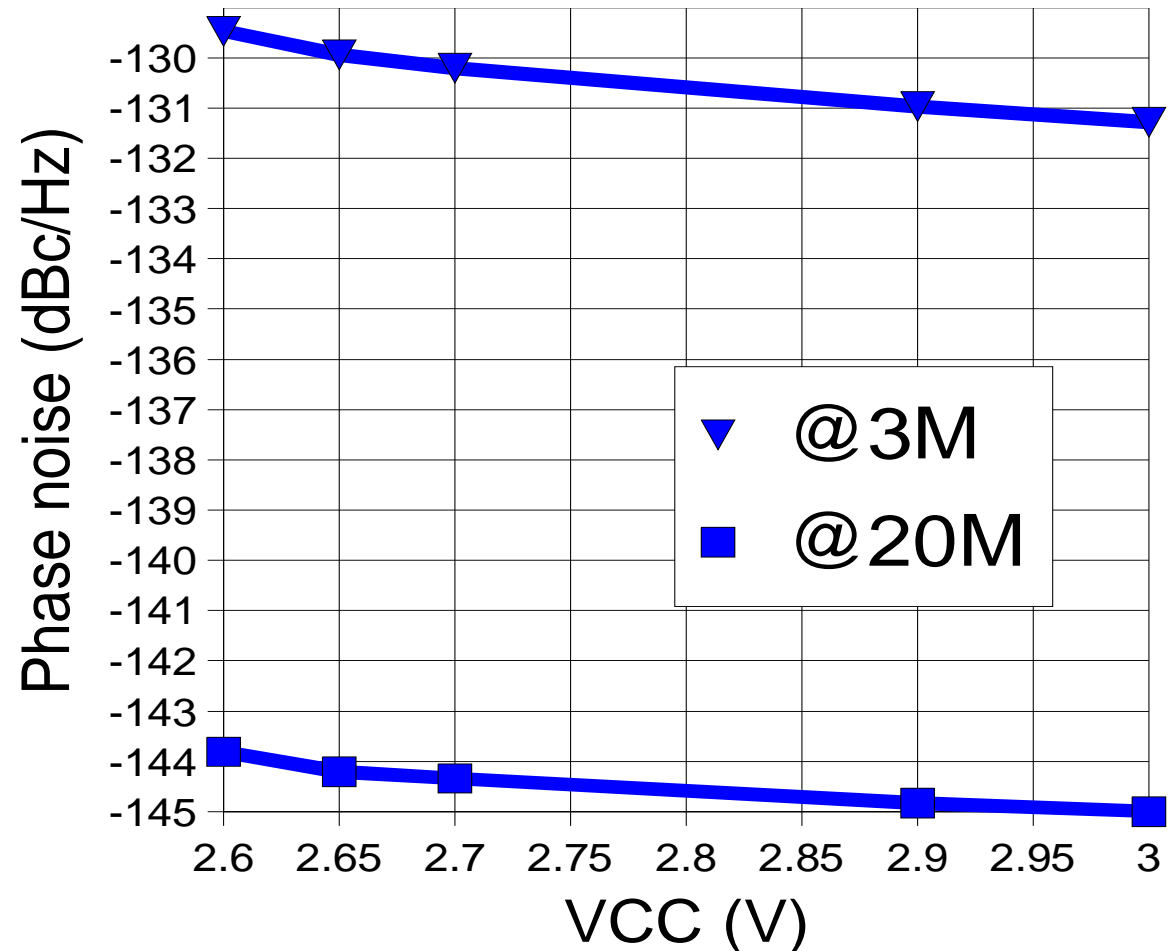
Varying supply voltage (1/4)

- Low- offset phase noise loosely depends on V_{CC} .



Varying supply voltage (2/4)

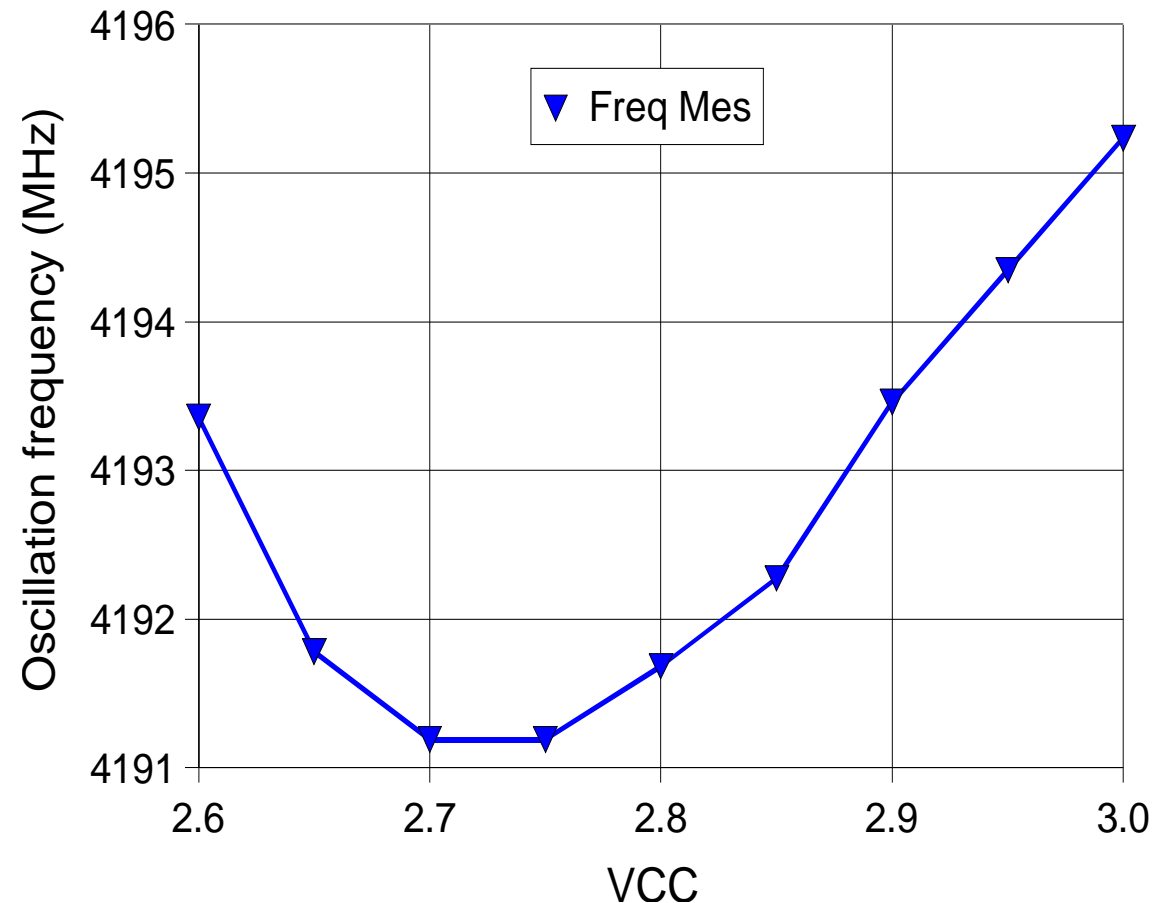
- High- offset phase noise loosely depends on V_{CC} .



Varying supply voltage (3/4)

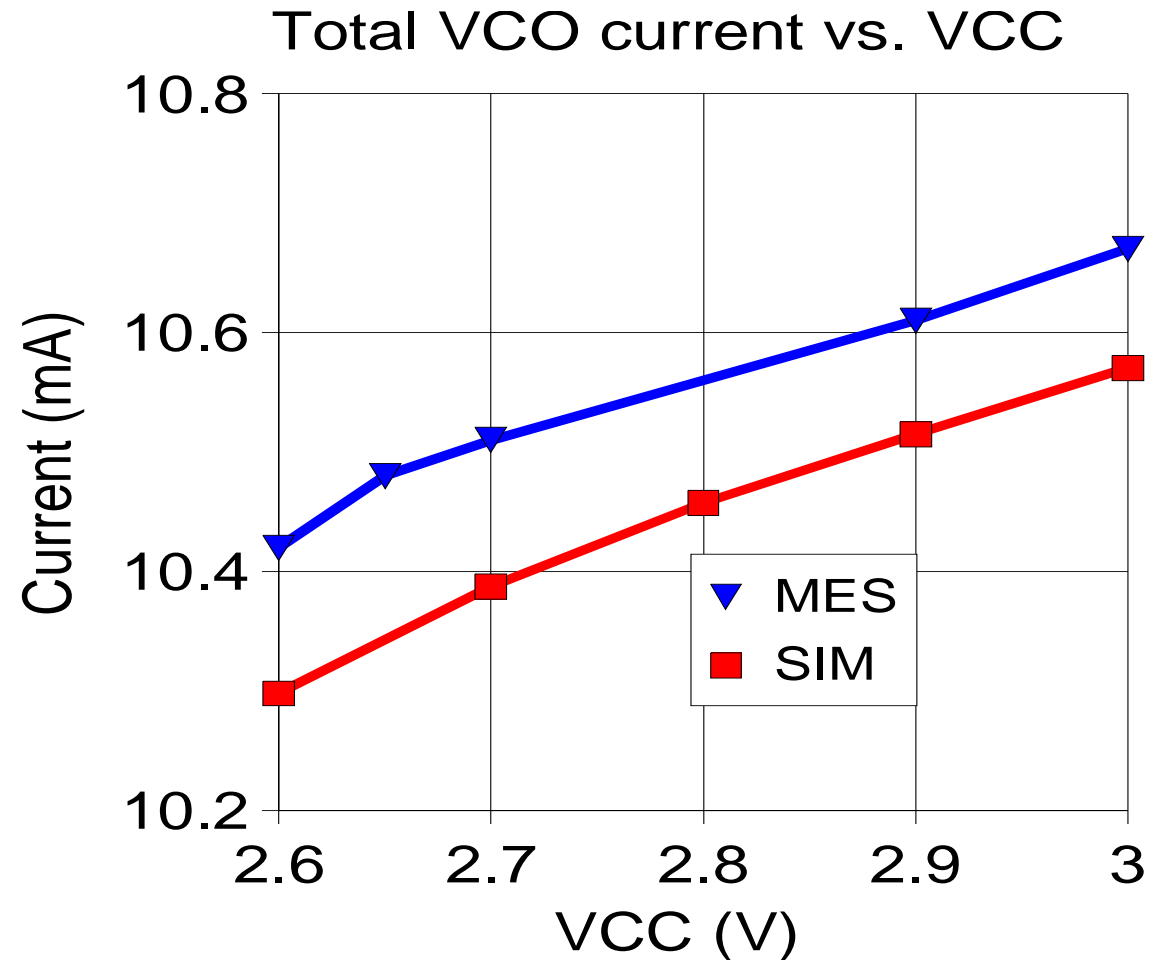
- low frequency pushing.
- fulfills the specifications near the nominal V_{CC} .

Frequency pushing



Varying supply voltage (4/4)

- the current consumption loosely depends on V_{CC} .





- UMTS W- CDMA TX & RX specifications from MuMoR fulfilled.
- benefits of reconfiguration demonstrated :
 - low-power or low- noise modes possible with the same VCO.
- differential Colpitts architecture demonstrates good performance :
 - FOM = - 180 dBc/Hz (measured).
 - this figure includes all the blocks not the standalone VCO.