System design of a re-configurable receiver for UMTS and GSM

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Overview

- Most important RF test specifications
- From BER to SNR
- System noisefigure
- Linearity considerations
- Blocking tests
- Self blocking in the UMTS FDD mode
- LO phase noise

Specifications

Technical Specifications

- **UMTS FDD: 3GPP TS 25.101 v 5.2.0**

  UE Radio Transmission and Reception

- **UMTS TDD: 3GPP TS 25.102 v 5.0.1**

  UE Radio Transmission and Reception

- **GSM, DCS: ETSI GSM 05.05 v 8.4.0**

  Radio transmission and reception

Specifications

- **Problem:**

  Test cases specified by Bit Error Rates that shall not be exceeded. BER < 0.001 contains no information about RF performance.

- **Solution:**

  Find relation between BER and SNR by baseband simulation or estimation from test cases described in the specifications.

From BER to SNR

UMTS FDD and TDD:

- For all test cases the BER shall not exceed 0.001
- All test cases use the same DL reference channel
- Test case maximum input level employs well defined signal- and interferer-level
- Signal and interferer definitely exceed all other noise sources
- Interferer can be regarded as noise

UMTS FDD: Test case maximum input power

$$\frac{DPCH\_Ec}{I_{or}} = -19dB$$

Energy per chip in DPCH over total power spectral density

$$\hat{I}_{or} = -25\frac{dBm}{3.84MHz}$$

Total received power spectral density

$$\frac{S}{I} = \frac{\frac{DPCH\_Ec}{I_{or}}}{1-\frac{DPCH\_Ec}{I_{or}}} = \frac{10^{-\frac{19}{10}}}{1-10^{-\frac{19}{10}}} = 0.0127 \quad \Leftrightarrow \quad \textbf{SNR = -18.9 dB}$$

From BER to SNR

GSM / DCS:

Test case cochannel interference

C/Ic = 9 dB $\Rightarrow$ SNR = 9 dB

Mode	UMTS FDD	UMTS TDD	GSM DCS
SNR	-18.9 dB	-6 dB	9 dB

Noisefigure

Test case reference sensitivity level:

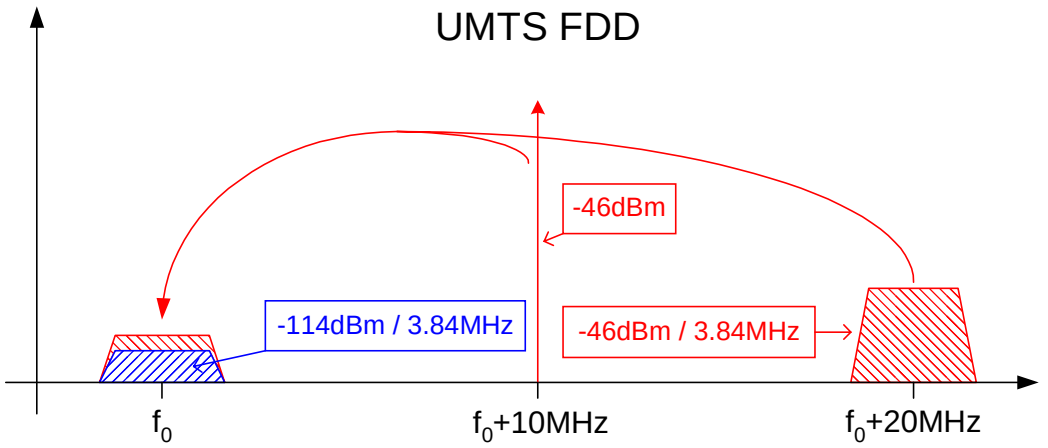
System noisefigure can be calculated from reference sensitivity level, thermal noise, bandwidth and SNR:

Mode	UMTS FDD	UMTS TDD	GSM DCS
NF	9.6 dB	9.2 dB	10 dB

Linearity considerations

Third order intermodulation

Two interfering signals produce an intermod-ulation product at the desired frequency.



BER $\leq$ 0.001

$\Longrightarrow$ SNR $\geq$ -18.9 dB.

DPCH_Ec = <REFSENS> + 3dB

I_{or} = <REFI$_{or}$> + 3dB

I_{ouw1} (CW) = -46 dBm @ 10 MHz offset

I_{ouw2} (mod) = -46 dBm @ 20 MHz offset

Linearity considerations

IIP3

BER $\leq$ 0.001 $\Rightarrow$ SNR $\geq$ -18.9 dB

DPCH_Ec = <REFSENS> + 3dB = -114 dBm/3.84 MHz

N_{tot} = DPCH_Ec – SNR = -95.1 dBm / 3.84 MHz

$IIM_3 = N_{tot} - N_{th}$ = -95.3 dBm / 3.84 MHz

IIP_3 = -21.3 dBm

Mode	UMTS FDD	UMTS TDD	GSM DCS
IIP3	-21.3 dBm	-20.9 dBm	-18 dBm

Linearity considerations

IIP2

- For UMTS FDD and TDD IIP2 can be calculated from blocking at 15 MHz offset
- For GSM / DCS IIP2 can be calculated from AM suppression characteristics

Mode	UMTS FDD	UMTS TDD	GSM DCS
IIP2	8 dBm	8 dBm	43 dBm

Blocking

- **Out of band blocking**

  Blockers outside the desired band can be attenuated by front end filters

- **In band blocking**

  Blockers inside the desired band can be attenuated by channel filter at baseband frequency

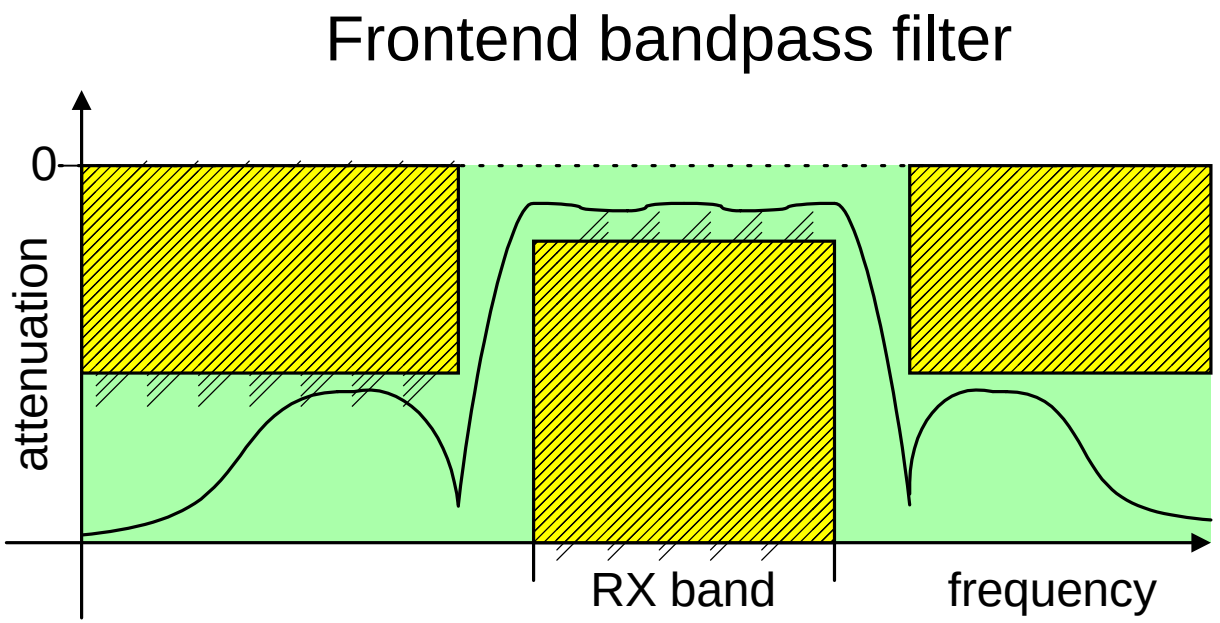
- **Adjacent channel selectivity (ACS)**

  Blockers in adjacent channels are too close for considerable attenuation by baseband filter

Blocking

Out of band blockers specify the frontend filters

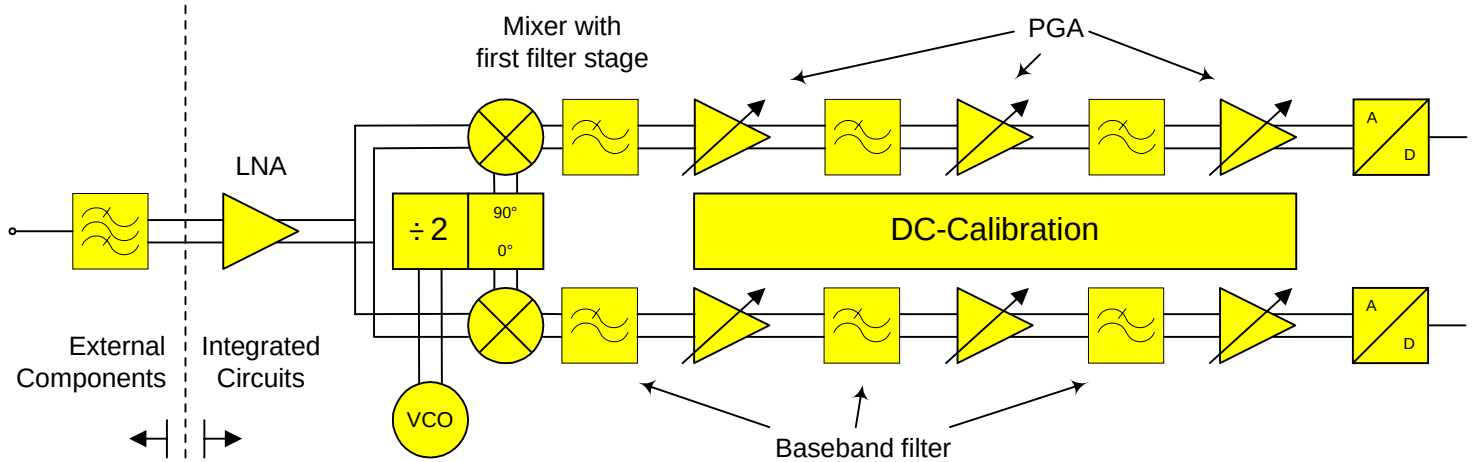
Blocker outside the desired band have to be attenuated to a level comparable to in band blockers



Blocking

In band blocker

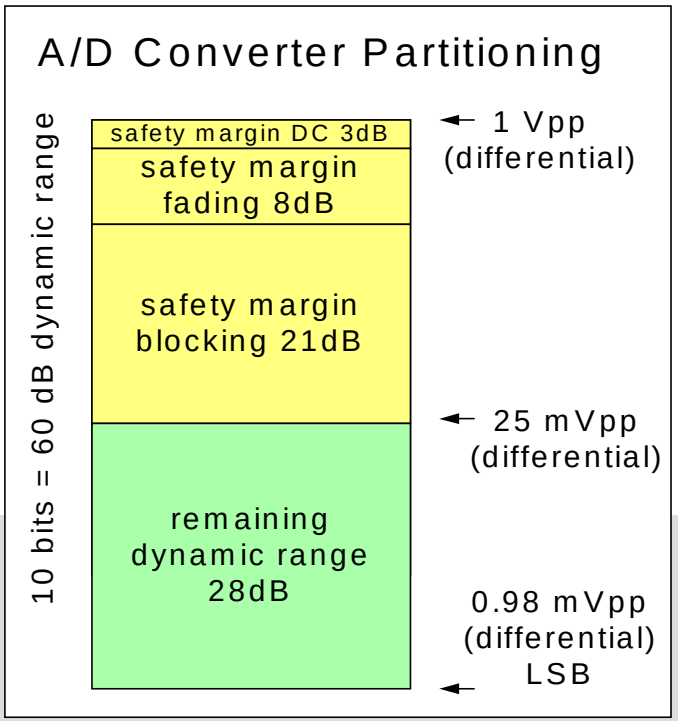
- Specify linearity of the front end stages (LNA…)
- Specify characteristic of the base band filter
- Gain partitioning for every input level has to be planned (no stage must be driven into saturation under any circumstances)



Adjacent channel performance GSM / DCS

Wanted signal: -82 dBm

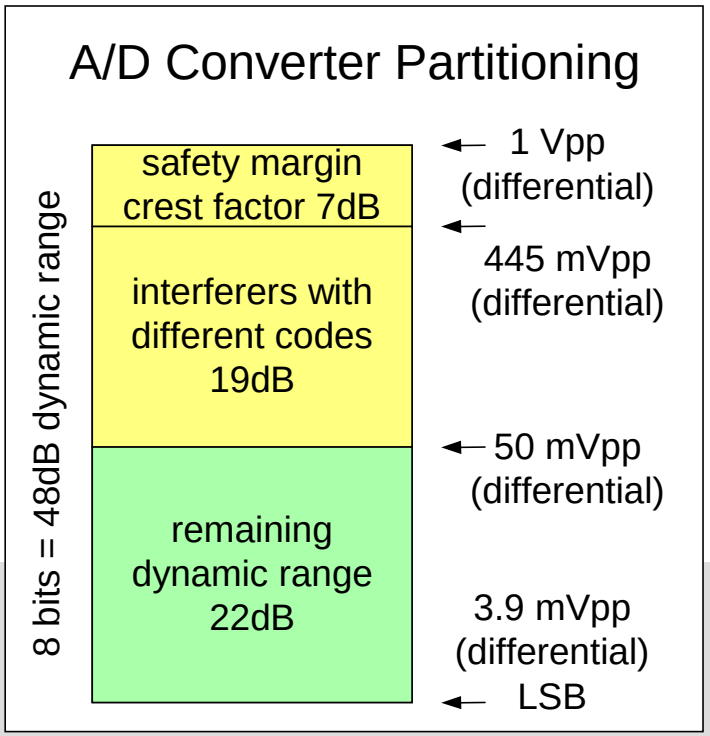
- Cochannel interference : C/Ic = 9 dB
- Adjacent channel (200 kHz) interference: C/Ia1 = -9 dB
- Adjacent channel (400 kHz) interference: C/Ia1 = -41 dB
- Adjacent channel (600 kHz) interference: C/Ia1 = -49 dB



Interferer at 400 kHz and 600 kHz offset can not be attenuated sufficiently to be neglected. At the end of the receiver chain residual interferer is considerably above the desired signal.

UMTS FDD: Maximum input power test case

$$\frac{DPCH\_Ec}{I_{or}} = -19dB \qquad \hat{I}_{or} = -25\frac{dBm}{3.84MHz}$$



- -44 dBm useful data at f_{RX}

  $\Rightarrow$ 50 mVpp

- -25 dBm received signal at f_{RX}

  $\Rightarrow$ 445 mVpp

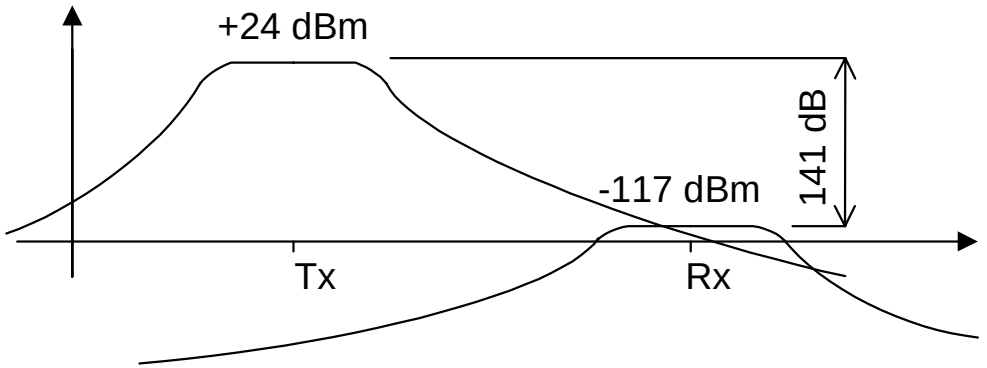
Problem:

Transmit signal:

+24 dBm at f_{TX}

Received signal:

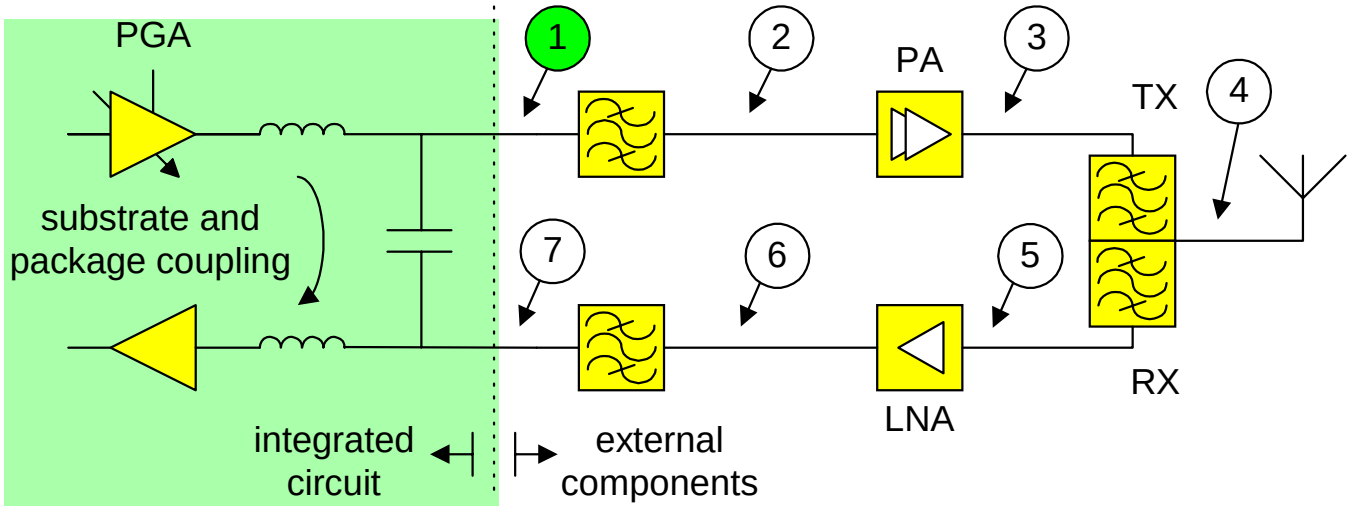
-117 dBm at f_{RX}



The TX-Signal itself is a blocking signal for the receiver

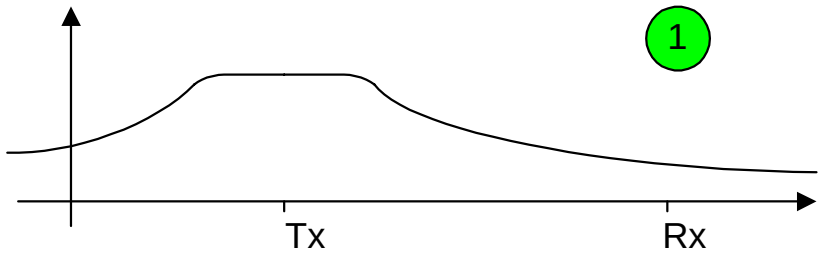
The noise sidebands of the signal shall be considerably below the thermal noise floor

UMTS FDD

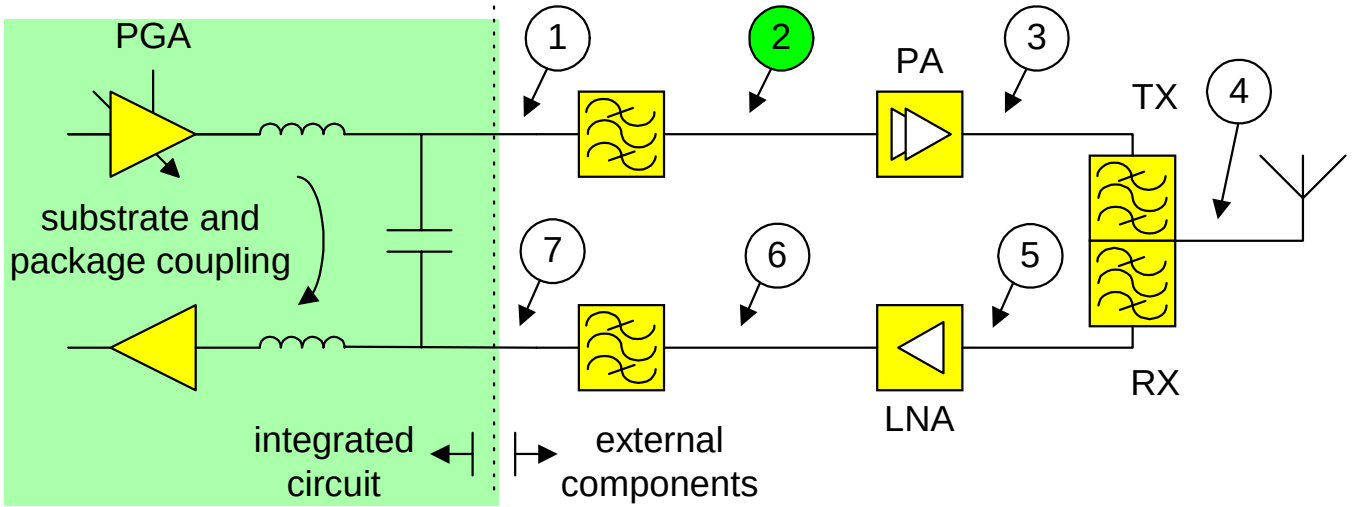


Signal TX: +1 dBm

N @ f_{RX}: -147 dBm/Hz

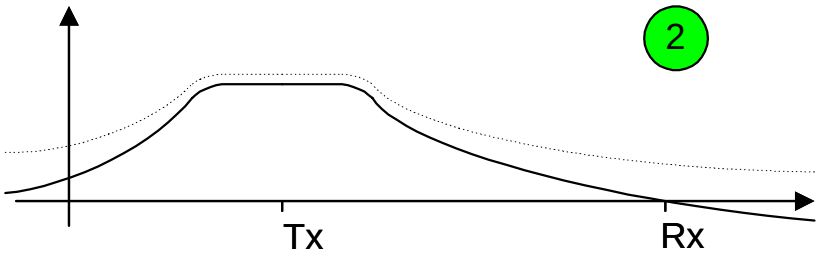


UMTS FDD

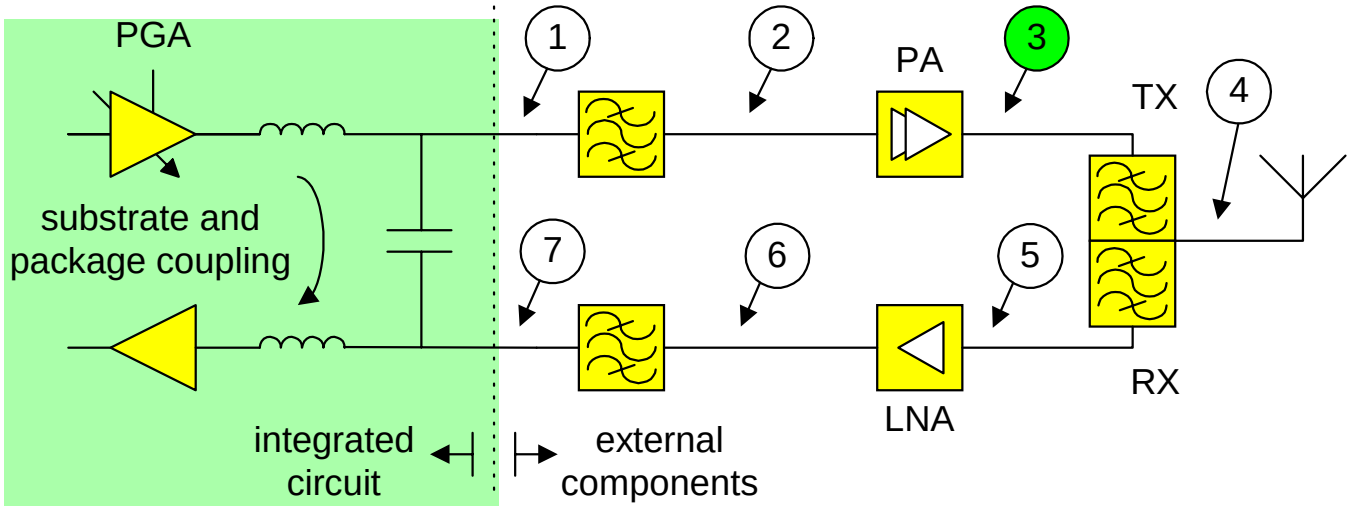


Signal TX: -2.5 dBm

N @ f_{RX}: -174 dBm/Hz

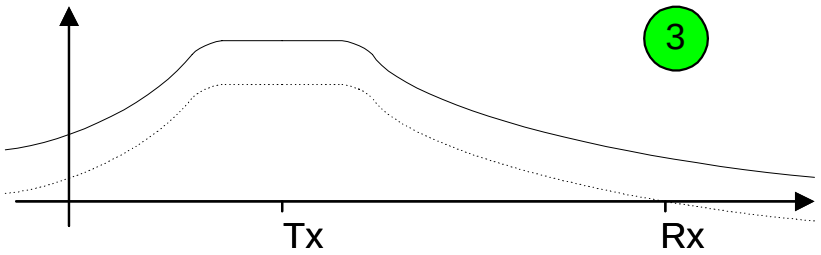


UMTS FDD

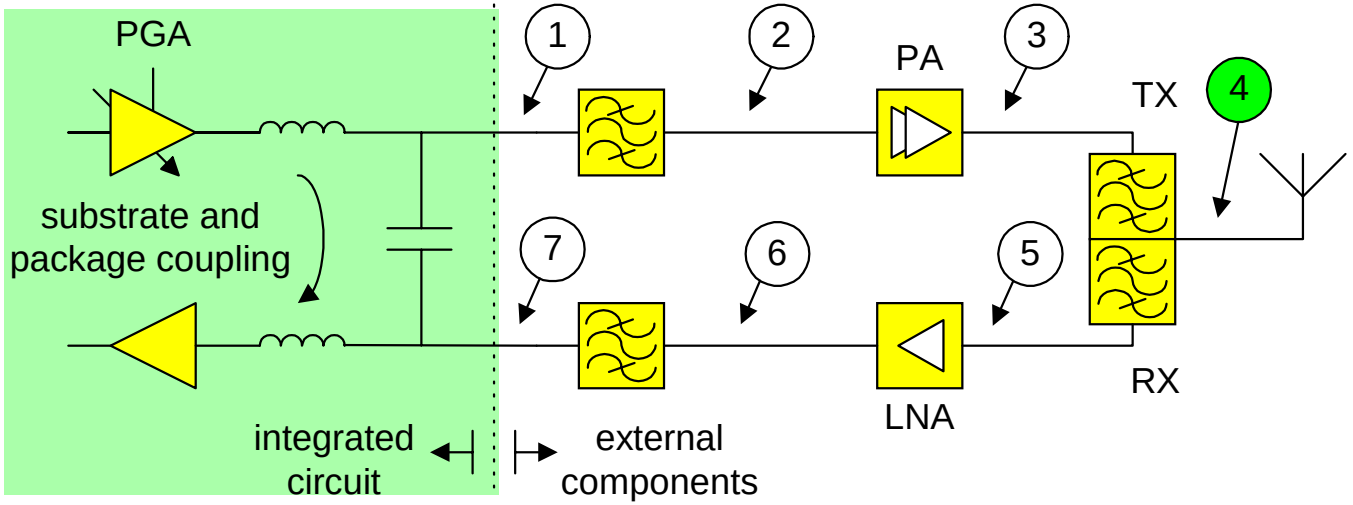


Signal TX: +25.5 dBm

N @ f_{RX}: -136 dBm/Hz



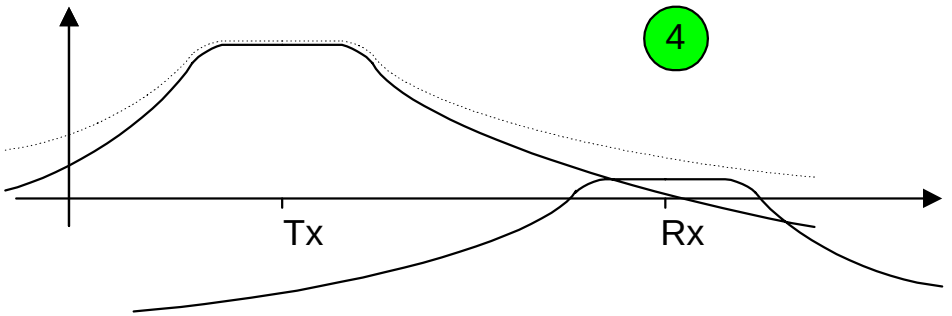
UMTS FDD



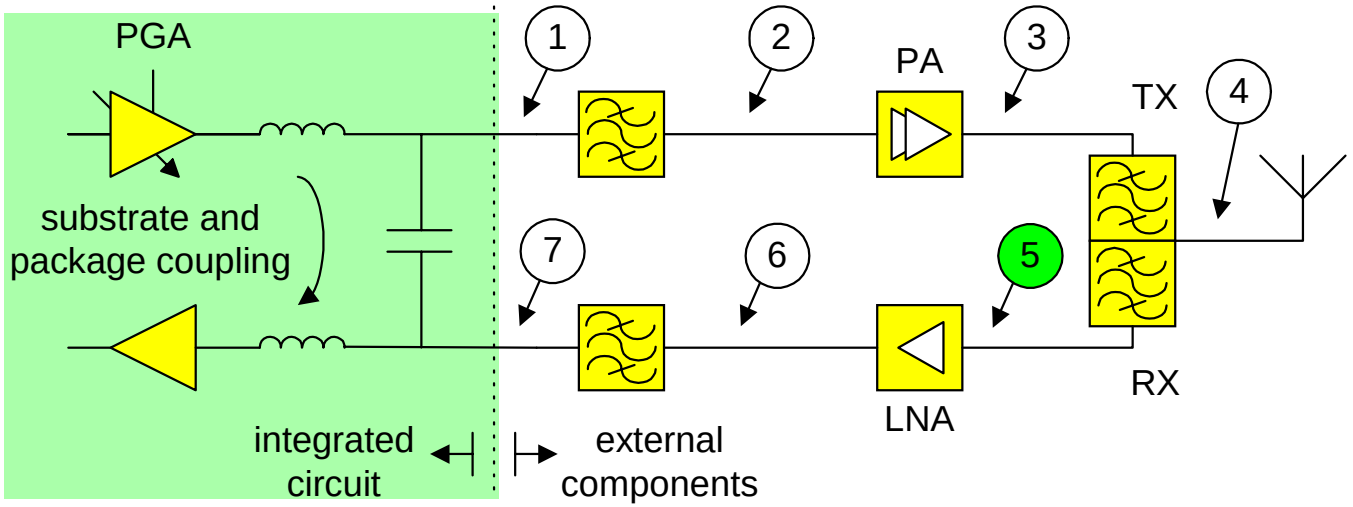
Signal RX: -117 dBm

Signal TX: +24 dBm

N @ f_{RX}: -174 dBm/Hz



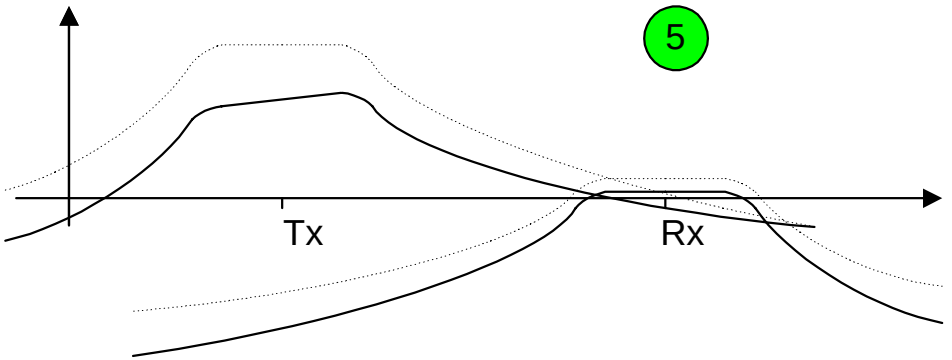
UMTS FDD



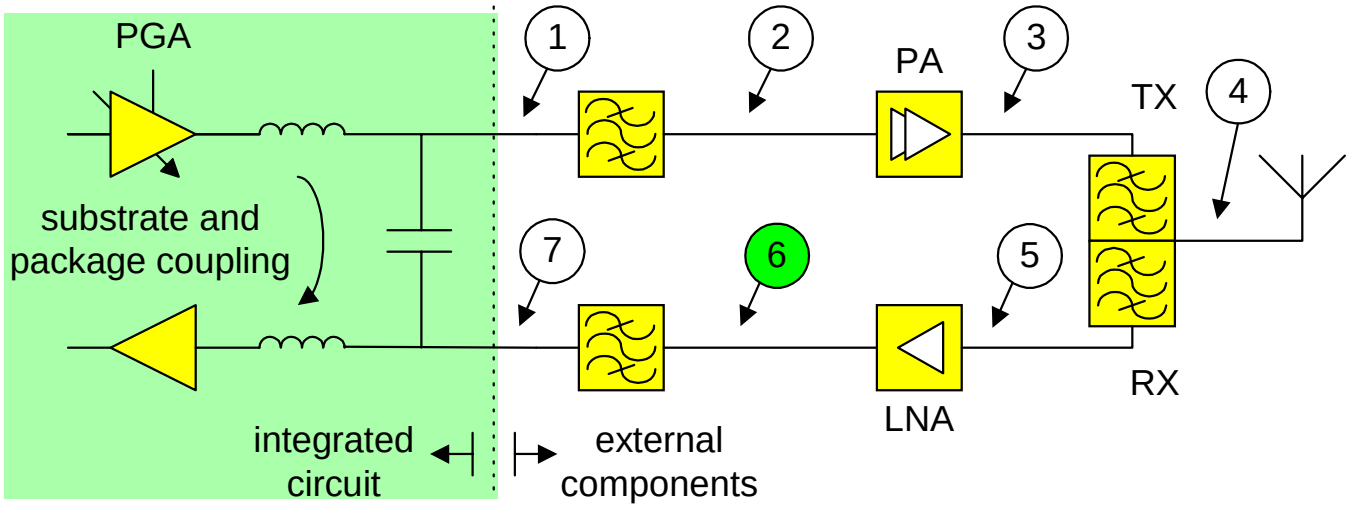
Signal RX: -120 dBm

Signal TX: -23 dBm

N @ f_{RX}: -174 dBm/Hz



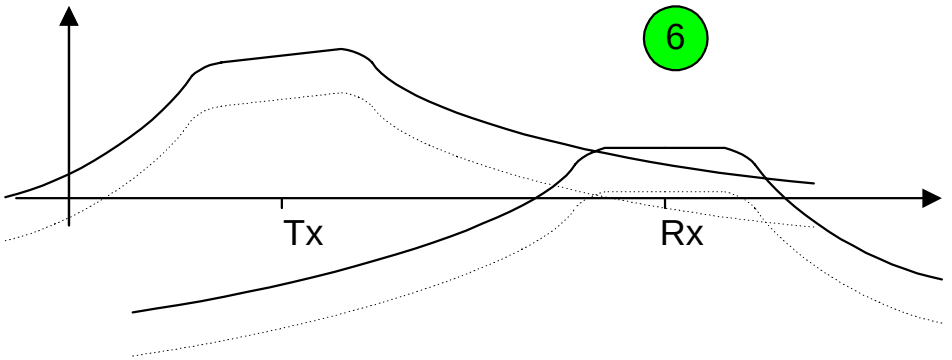
UMTS FDD



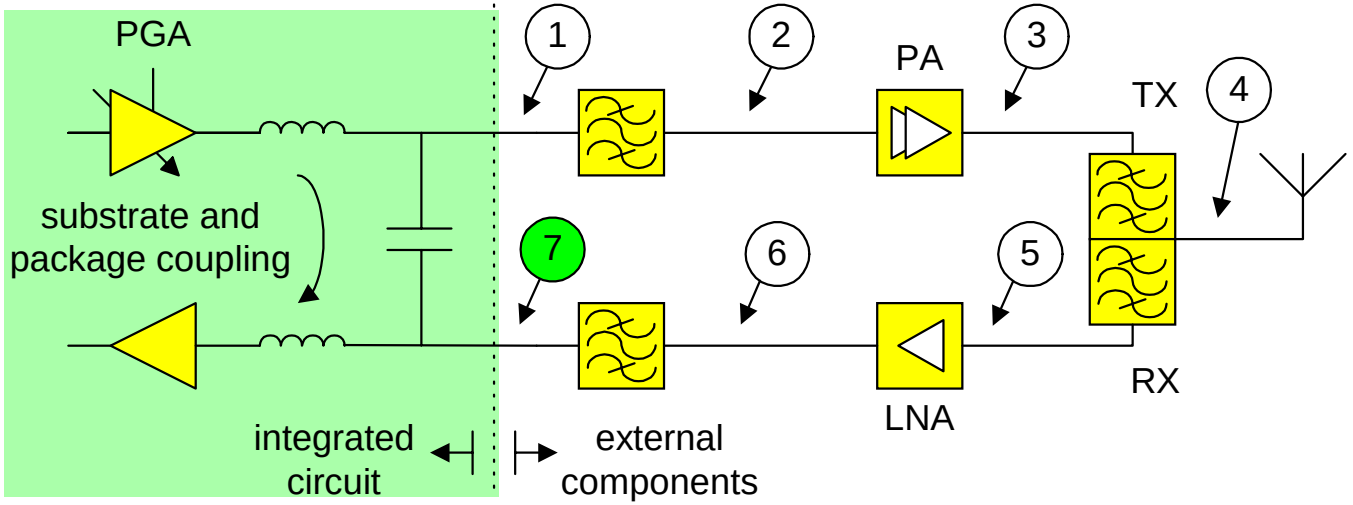
Signal RX: -105 dBm

Signal TX: -8 dBm

N @ f_{RX}: -157 dBm/Hz



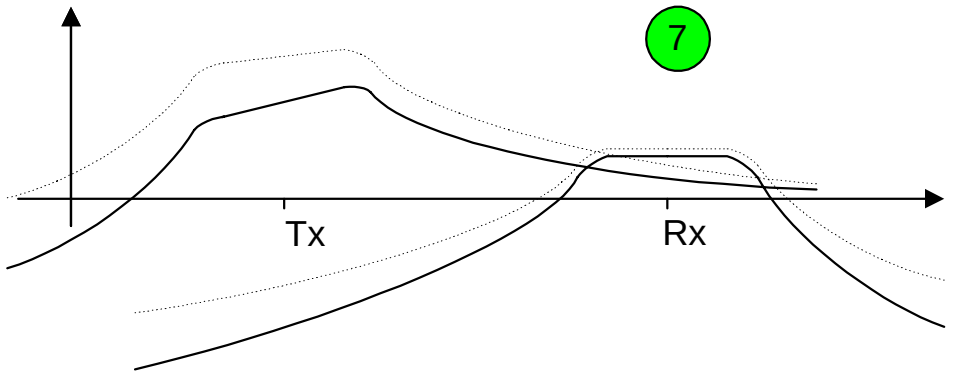
UMTS FDD



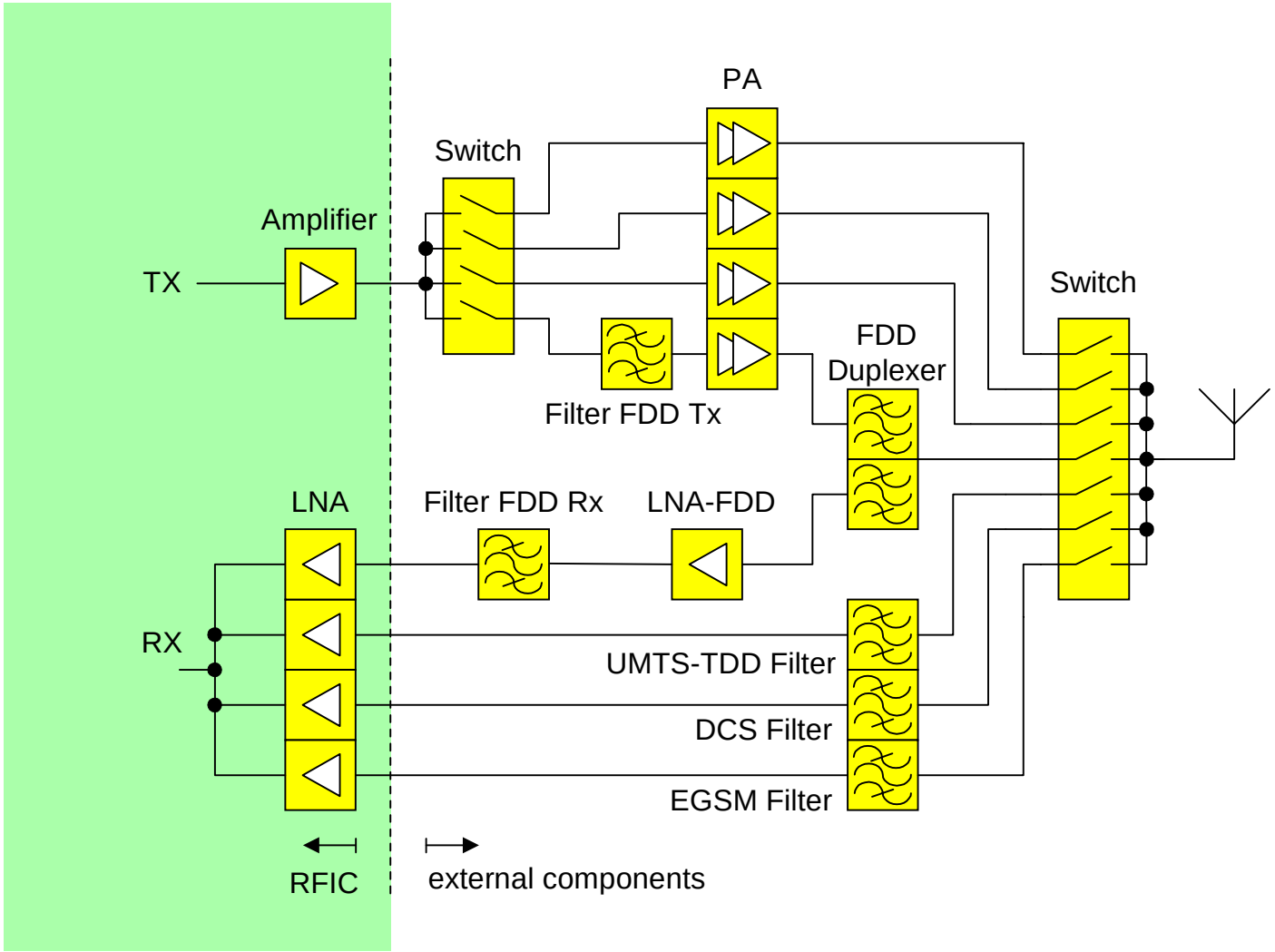
Signal RX: -109 dBm

Signal TX: -38 dBm

N @ f_{RX}: -161 dBm/Hz



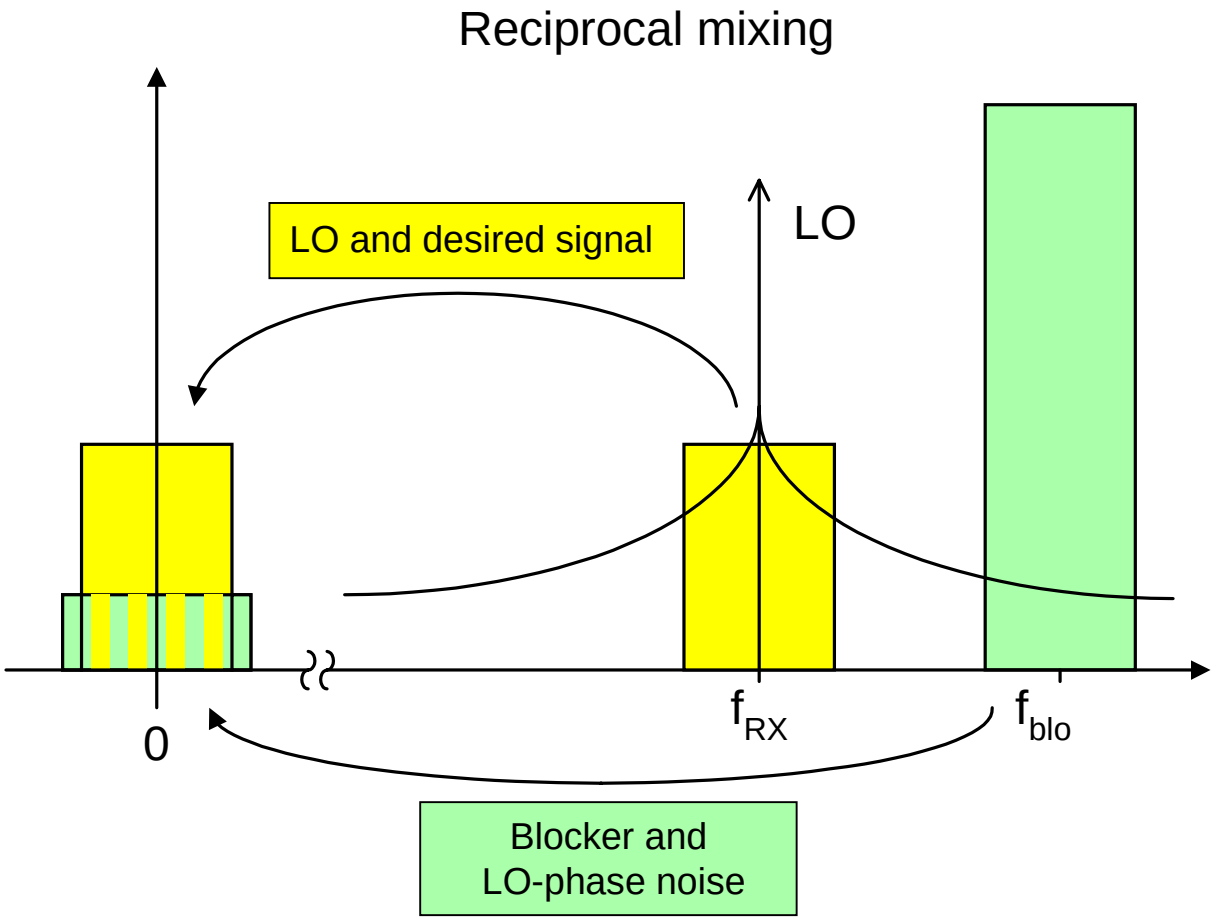
Re-configurable Front End



LO phase noise

LO and desired signal at f_{RX} produce a signal at baseband frequency

Blocker and LO-phase noise produce noise at baseband frequency



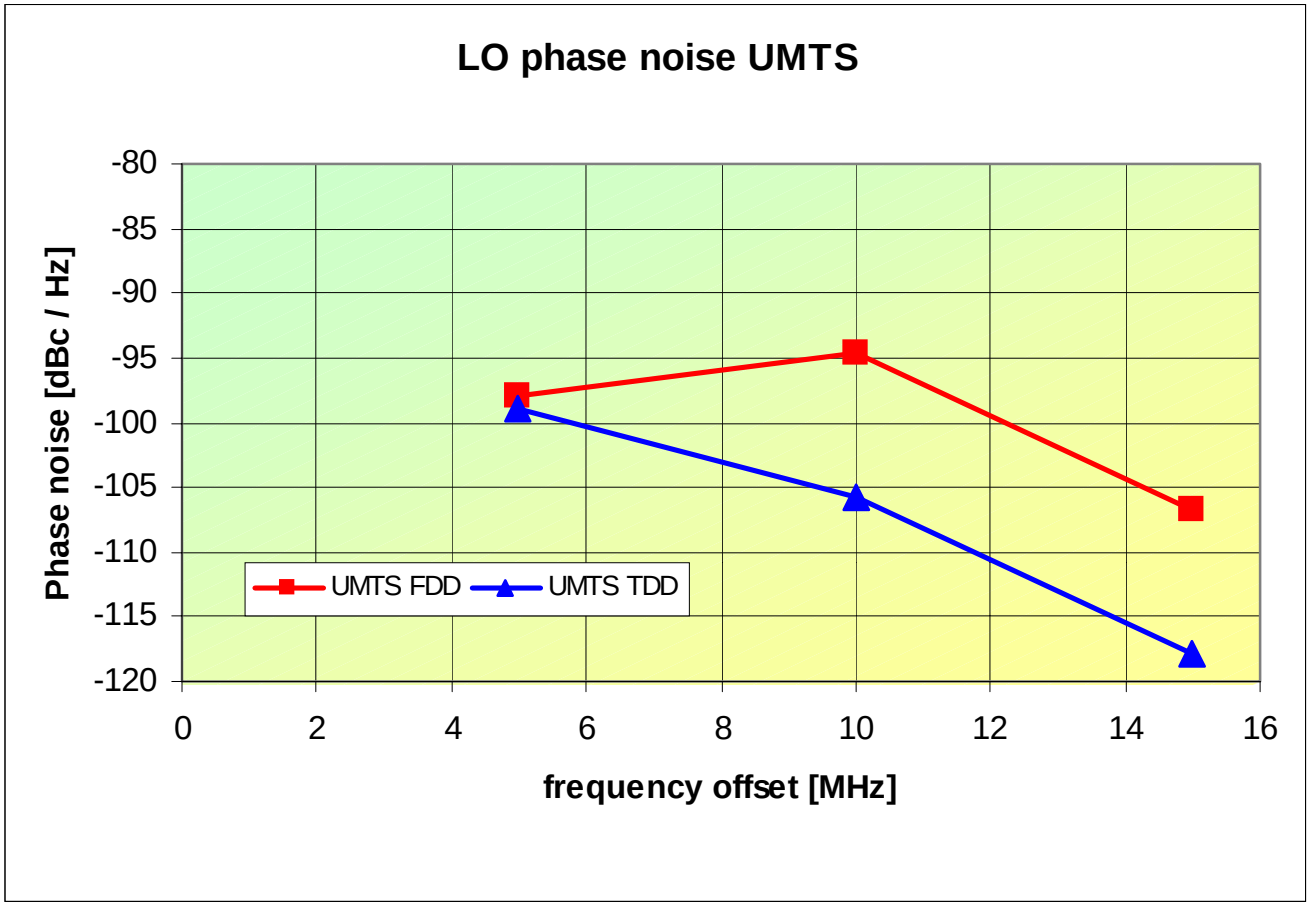
LO phase noise

UMTS FDD:

Offset:	Phase noise:
5 MHz	-97.8 dBc/Hz
10 MHz	-94.6 dBc/Hz
15 MHz	-106.6 dBc/Hz

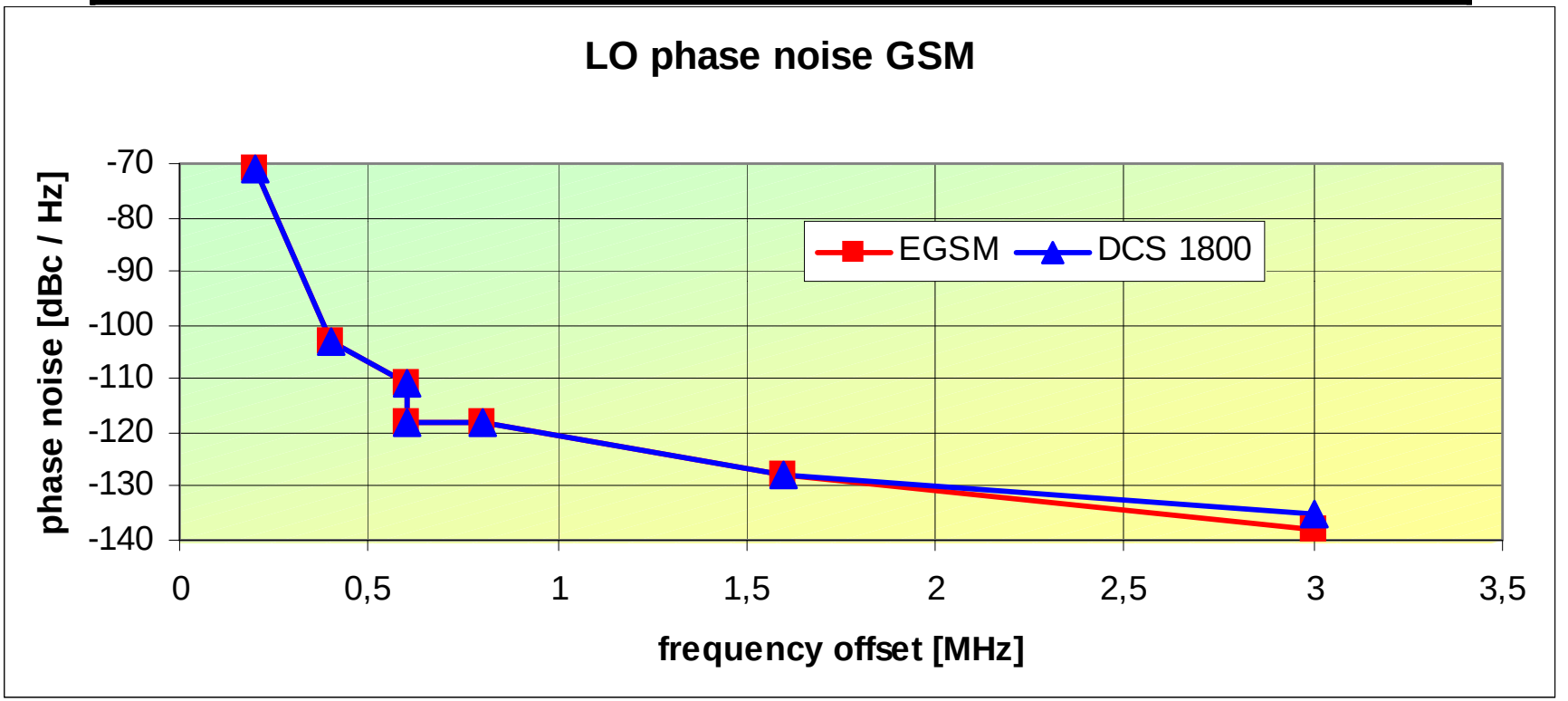
UMTS TDD:

Offset:	Phase noise:
5 MHz	-98.8 dBc/Hz
10 MHz	-105.9 dBc/Hz
15 MHz	-117.8 dBc/Hz



LO phase noise

Offset / MHz	0.2	0.4	0.6	0.6	0.8	1.6	3
PN EGSM / dBc/Hz	-71	-103	-111	-118	-118	-128	-138
PN DCS / dBc/Hz	-71	-103	-111	-118	-118	-128	-135



Conclusion

- RF specifications can be derived from test cases described in standards
- Negative effects do not occur independently from each other
- The derived RF specifications for the building blocks are starting values for an iterative process
- Achievable performance of building blocks have to be considered for the next iteration