Karlsruhe Institute of Technology

Modern Radio Systems Engineering – Tutorial 1 Part 2

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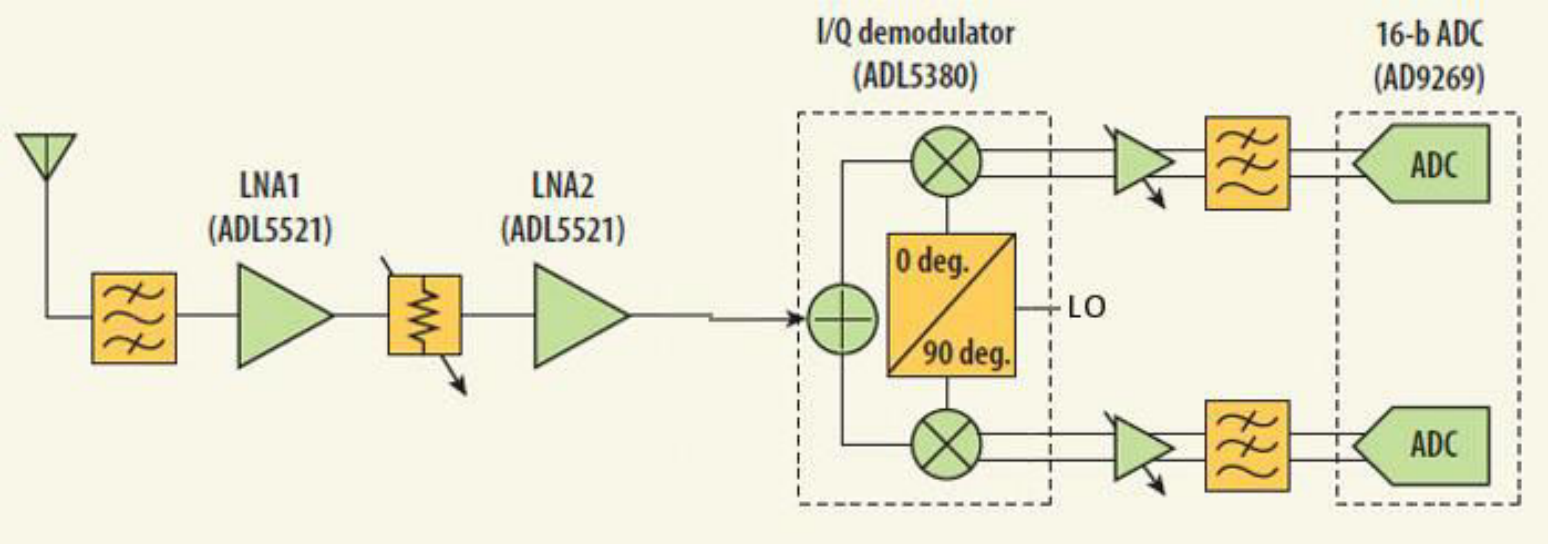
INSTITUT FÜR HOCHFREQUENZTECHNIK UND ELEKTRONIK

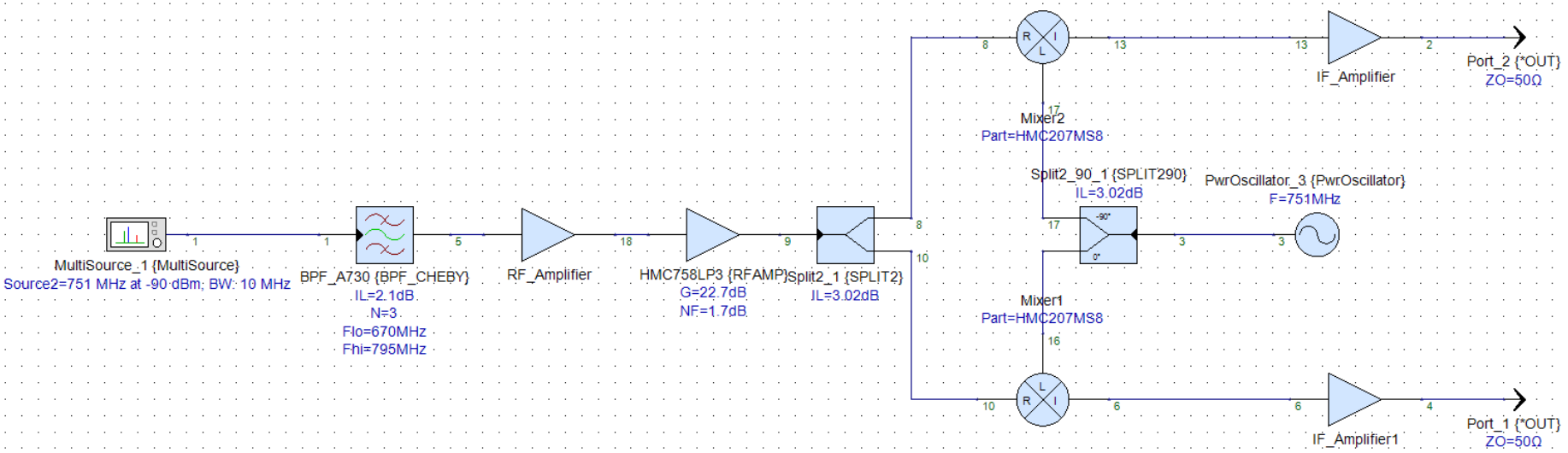
Direct-Conversion Design

- The simplified LTE receiver of the last tutorial shall be extended.
- A more sophisticated design needs IQ demodulation to be able to detect LTE (OFDM) carriers.
- The key advantage of a direct conversion approach is the lower ADC sampling rate requirement compared to an IF sampling receiver.



Basic Design

- The basic SystemVue implementation of the direct down conversion receiver is shown in the picture below.



RF Amplifier

Hittite MICROWAVE CORPORATION v00.1108

RoHS✓ EARTH FRIENDLY

HMC758LP3 / 758LP3E

GaAs SMT pHEMT LOW NOISE AMPLIFIER, 700 - 2200 MHz

Typical Applications

The HMC758LP3(E) is ideal for:

- Cellular Infrastructure, WiMAX & LTE/4G
- Software Defined Radios
- Repeaters and Femtocells
- Access Points
- Test & Measurement Equipment

Features

Noise Figure: 1.7 dB

Gain: 22 dB

Output IP3: +37 dBm

Single Supply: +3V to +5V

50 Ohm Matched Input/Output

16 Lead 3x3 mm SMT Package: 9 mm^2

Parameter	Vdd = +3V						Vdd = +5V						Units
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Frequency Range	700 - 1700			1700 - 2200			700 - 1700			1700 - 2200			MHz
Gain	19	21.8		16	19.4		20	22.7		18	21.3		dB
Gain Variation Over Temperature		0.005			0.01			0.004			0.01		dB/ °C
Noise Figure		1.6	2.5		1.4	1.8		1.7	2.6		1.6	2.0	dB
Input Return Loss		15			13			14			14		dB
Output Return Loss		11			15			10			12		dB
Output Power for 1 dB Compression (P1dB)	16	18		18	20		20.5	22.5		22	24		dBm
Saturated Output Power (Psat)		20			21.5			23.5			25		dBm
Output Third Order Intercept (IP3)		31			31.5			36			35		dBm
Supply Current (Idd)	80	102	130	80	102	130	190	227	260	190	227	260	mA

RF Amplifier

Hittite MICROWAVE CORPORATION v01.0610

HMC376LP3 / 376LP3E

GaAs PHEMT MMIC LOW NOISE AMPLIFIER, 700 - 1000 MHz

Typical Applications

The HMC376LP3 / HMC376LP3E is ideal for:

- Cellular/3G Infrastructure
- Base Stations & Repeaters
- CDMA, W-CDMA, & TD-SCDMA
- Private Land Mobile Radio
- GSM/GPRS & EDGE
- UHF Reallocation Applications

Features

Noise Figure: 0.7 dB

Output IP3: +36 dBm

Gain: 15 dB

Externally Adjustable Supply Current

Single Positive Supply: +5V

50 Ohm Matched Input/Output

Parameter	Min.	Typ.	Max.	Min.	Typ.	Max.	Units
Frequency Range		810 - 960			700 - 1000		MHz
Gain	12.5	14.5		11.5	14.5		dB
Gain Variation Over Temperature		0.005	0.01		0.005	0.01	dB / °C
Noise Figure		0.7	1.0		0.7	1.0	dB
Input Return Loss		13			14		dB
Output Return Loss		12			12		dB
Reverse Isolation		20			22		dB
Output Power for 1dB Compression (P1dB)		21.5			21		dBm
Saturated Output Power (Psat)		22			22		dBm
Output Third Order Intercept (IP3) (-20 dBm Input Power per tone, 1 MHz tone spacing)		36			36		dBm
Supply Current (Idd)		73			73		mA

Mixer

Hittite MICROWAVE CORPORATION v03.0709

RoHS✓ EARTH FRIENDLY

HMC207S8 / 207S8E

GaAs MMIC SMT DOUBLE-BALANCED MIXER, 0.7 - 2.0 GHz

Typical Applications

The HMC207S8 / HMC207S8E is ideal for:

- Base Stations
- Cable Modems
- Portable Wireless

Features

Conversion Loss: 9 dB

LO / IF Isolation: 45 dB

LO / RF Isolation: 40 dB

Input IP3: +17 dBm

Parameter	LO = +13 dBm IF = 70 MHz			LO = +10 dBm IF = 70 MHz			Units
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Frequency Range, RF & LO		0.7 - 2.0			0.8 - 1.2		GHz
Frequency Range, IF		DC - 0.3			DC - 0.3		GHz
Conversion Loss		9	10.5		7.5	10	dB
Noise Figure (SSB)		9	10.5		7.5	10	dB
LO to RF Isolation	32	40		40	45		dB
LO to IF Isolation	38	45		40	45		dB
RF to IF Isolation	17	23		18	22		dB
IP3 (Input)	14	17		12	15		dBm
1 dB Gain Compression (Input)	8	11		7	10		dBm

IF Amplifier

Hittite MICROWAVE CORPORATION v05.0710

HMC478ST89 / 478ST89E

SiGe HBT GAIN BLOCK
MMIC AMPLIFIER, DC - 4 GHz

Typical Applications

The HMC478ST89 / HMC478ST89E is an ideal RF/IF gain block & LO or PA driver:

- Cellular / PCS / 3G
- Fixed Wireless & WLAN
- CATV, Cable Modem & DBS
- Microwave Radio & Test Equipment

Features

P1dB Output Power: +18 dBm

Gain: 22 dB

Output IP3: +30 dBm

Cascadable 50 Ohm I/Os

Single Supply: +5V to +8V

Industry Standard SOT89 Package

Electrical Specifications, Vs= 5V, Rbias= 18 Ohm, T_A = +25° C

Parameter		Min.	Typ.	Max.	Units
Gain	DC - 1.0 GHz	19	22		dB
	1.0 - 2.0 GHz	16	19		dB
	2.0 - 3.0 GHz	13	16		dB
	3.0 - 4.0 GHz	11	14		dB
Gain Variation Over Temperature	DC - 4 GHz		0.015	0.02	dB/ °C
Input Return Loss	DC - 1.0 GHz		15		dB
	1.0 - 3.0 GHz		10		dB
	3.0 - 4.0 GHz		13		dB
Output Return Loss	DC - 3.0 GHz		13		dB
	3.0 - 4.0 GHz		15		dB
Reverse Isolation	DC - 4 GHz		20		dB
Output Power for 1 dB Compression (P1dB)	0.5 - 1.0 GHz	15	18		dBm
	1.0 - 2.0 GHz	13	16		dBm
	2.0 - 3.0 GHz	10	13		dBm
	3.0 - 4.0 GHz	8	11		dBm
Output Third Order Intercept (IP3) (Pout= 0 dBm per tone, 1 MHz spacing)	0.5 - 2.0 GHz		30		dBm
	2.0 - 3.0 GHz		28		dBm
	3.0 - 4.0 GHz		25		dBm
Noise Figure	DC - 2.0 GHz		3		dB
	2.0 - 4.0 GHz		4		dB
Supply Current (Icq)			62	82	mA

Bandpass filter

BPF-A730+

CASE STYLE: HQ1157
PRICE: $29.95 ea. QTY (1-9)

+ RoHS compliant in accordance with EU Directive (2002/95/EC)

The +Suffix has been added in order to identify RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications.

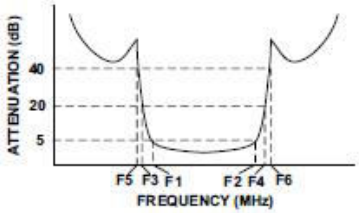
Features

- High rejection
- Shielded case
- Aqueous washable

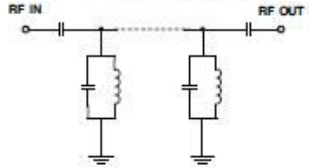
Applications

- Mobile TV (DVB)
- Harmonic rejection
- Transmitters/receivers

Typical Frequency Response



Functional Schematic



Bandpass Filter Electrical Specifications (T_{AMB} = 25°C)

CENTER FREQ. (MHz)	PASSBAND (MHz) (Loss < 5dB)	STOPBANDS (MHz) Loss > 20dB		Loss > 40dB		VSWR (:1) Passband		Stopband
Fc	F1 - F2	F3	F4	F5	F6	Typ.	Max.	Typ.
730	670 - 795	610	910	575	1100 - 1800	1.5	2.3	20

Typical Performance Data at 25°C

Frequency (MHz)	Insertion Loss (dB)	VSWR (:1)
0.5	92.82	6220.49
100.0	82.20	1395.51
300.0	81.87	214.15
575.0	55.60	25.50
610.0	34.24	14.57
640.0	16.18	7.93
655.0	7.72	3.94
670.0	3.30	1.60
700.0	2.51	1.72
730.0	1.97	1.32
770.0	2.23	1.62
795.0	2.45	1.12
810.0	4.72	1.35
820.0	6.77	3.83
840.0	13.45	10.65
910.0	30.74	30.16
1100.0	50.00	42.90
1800.0	49.55	63.65

Lowpass filter

SCLF-10+

CASE STYLE: YY161
PRICE: $8.95 ea. QTY (1-9)

+ RoHS compliant in accordance with EU Directive (2002/95/EC)

The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications.

Features

- wide selection of cut-off frequencies
- excellent rejection
- custom models available

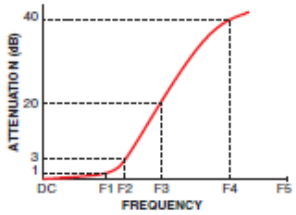
Applications

- defense communications
- receivers/transmitters
- harmonic rejection of VCOs

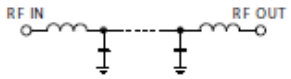
Electrical Specifications

Parameter		F#	Frequency (MHz)	Min.	Typ.	Max.	Unit
Pass Band	Insertion Loss	DC-F1	DC-10	—	—	1.0	dB
	Freq. Cut-Off	F2	12.2	—	3.0	—	dB
	VSWR	DC-F1	DC-10	—	1.2	—	:1
Stop Band	Rejection Loss	F3-F4	14-16	20	—	—	dB
		F4-F5	16-230	40	—	—	dB
	VSWR	F3-F5	14-230	—	18	—	:1

Typical Frequency Response



Electrical Schematic



Typical Performance Data

Frequency (MHz)	Insertion Loss (dB) $\bar{x}$	Insertion Loss (dB) σ	Return Loss (dB)
0.50	0.06	0.00	37.92
1.00	0.07	0.00	32.86
5.00	0.17	0.00	28.19
8.50	0.35	0.01	21.64
10.00	0.56	0.01	23.57
11.00	2.70	0.10	5.02
12.40	14.39	0.33	0.59
12.60	16.31	0.35	0.48
13.80	27.59	0.45	0.25
15.00	39.05	0.65	0.18
20.00	62.85	0.71	0.09
50.00	72.81	1.31	0.09
100.00	63.39	0.90	0.13
150.00	59.75	0.82	0.16
200.00	72.82	4.08	0.19
250.00	38.33	0.93	0.29
300.00	47.06	0.58	0.26
350.00	59.23	1.29	0.40
370.00	42.02	0.85	0.61
400.00	14.91	0.74	3.95

SystemVue Design

- Implement the direct conversion IQ receiver in SystemVue.

Hints:

- You may also use components from the RF vendor kit.
- Instead of the antenna use a „MultiSource“ with 751 MHz and a bandwidth of 10 MHz at -90 dBm. This is the minimum receive power of the LTE specification.
- How has the LO frequency to be chosen to convert the LTE signal to the baseband? Take account of the power splitter when choosing an appropriate LO power.
- For the amplifier, the mixer and the filter use the data provided on the previous slides.
- The receiver should be terminated with two 50 Ohm output ports.
- Set in the system simulation parameters the measurement bandwidth to 10 MHz.
- Run the simulation.

Tasks

Look at the power plot after each stage:

- Try to identify the different spectral components. From which effects do they result? (Click on the different spectral lines to get additional information)

The desired signal in the baseband must have the highest power to decode the information:

- The ratio between the desired signal and the unwanted signal components can be seen in the „Carrier to Noise and Distortion“ (CNDR) plot. How are the values calculated? What causes CNDR to drop?