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Design of eight channel 81MHz IF downconverter board in digital RF feedback system for TTF2

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1. Introduction

The main goal of the RF feedback system is to stabilize phase and amplitude in linear accelerator of the TTF2 and XFEL. The stabilization of phase, in the target project, has to be on the level of $(\sigma_\varphi)_{RMS} < 0.01°$, and amplitude $(\sigma_E /E)_{RMS} < 10^{-4}$. Fulfilling of these requirements will result in higher efficiency of the acceleration process; therefore one obtains the molecules of higher and more monochromatic energies.

The circuit diagram of RF feedback system with $IF_1 = 250\ [kHz]$ is shown in Fig.1. Among other components of the control loop, there are frequency downconverters. The downconverters convert the signal from individual cavities from 1,3 GHz frequency to lower intermediate frequency ($IF_1 = 250\ [kHz]$).

This IF_1 frequency lies in the bandwidth of noise that surrounds the accelerator, therefore a new type of downconverter was designed and built. Its intermediate frequency equals $IF_2 = 81\ [MHz]$. This frequency was also chosen because one of master oscillator's intermediate frequencies has the same value. In addition, the solution using this value of *IF* can get lower relative jitter (for $IF_1 = 250\ kHz \sim 0{,}4 \cdot 10^{-3} [\%]$, for $IF_2 = 81\ MHz \sim 1{,}23 \cdot 10^{-6}\ [\%]$).

The solution of RF feedback system with IF_2 downconverter is shown in Fig.2.

The use of higher intermediate frequency would cause additional analog to digital conversion problems in further parts of the RF control loop.

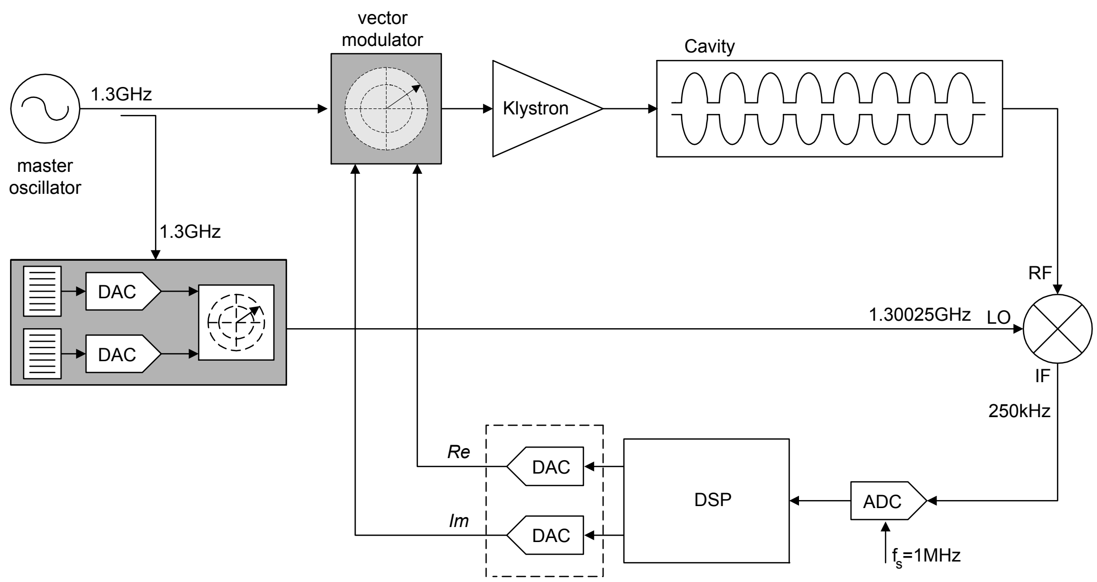

Figure 1. Structure of the digital RF feedback system.

For the sake of amplitude stability of the required order ~ 10^{-4}, it is necessary to use ADCs with $N < \log_2 10^4$ bit resolution ($N > 14$ effective conversion bits).
For required phase stability it is necessary to use master oscillator that has very low phase noise and very stable clock for ADC [1].

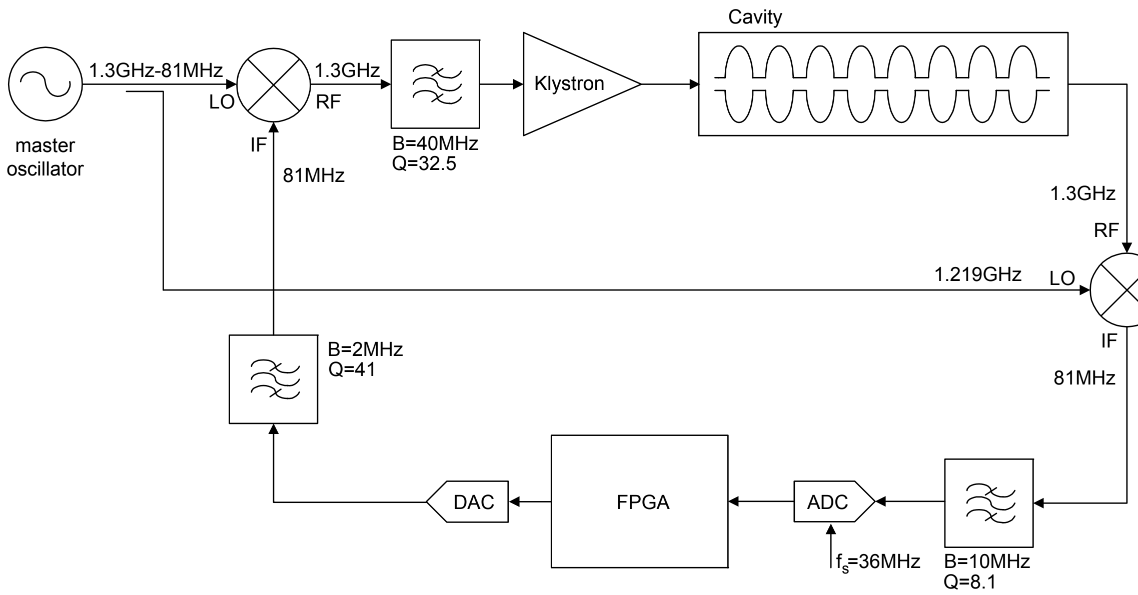

Figure 2. Structure of digital RF feedback system with 81MHz downconverter

2. Requirements

To meet the main objective, which is the RF feedback system precision of stabilization improvement, the initial version of downconverter board should have the following parameters:

1. Input frequency 1,3 $[GHz]$ +/- 10 $[MHz]$
2. Input impedance $50[\Omega]$
3. Input VSWR max. 1.5:1 desired, 1.8:1 acceptable
4. Nominal Input power range - 20 to + 3 $[dBm]$
5. Isolation RF and LO at IF > 70 $[dB]$
6. Intermediate frequency $f_{IF} = 81\ [MHz]$
7. Output bandwidth $20[MHz]$
8. Output impedance $50[\Omega]$

[1] This is the present consideration for RF feedback system.

9. Output level signal $v_{out} > 400[mV_{pp}]$ on $1[k\Omega]$, $@P_{RF} = -12[dBm], P_{LO} = -10[dBm]$
10. Level of 1st to 2nd output harmonic > 70 [dB]
11. IIP3 > 15[dBm], OIP3 > 20[dBm]
12. 1dB compression point: $1dB_{IN} > 7$ [dBm]
13. Inter-channel crosstalk > 70[dB]
14. Operating temperature range: -10 deg. C to +70 deg. C
15. Humidity: max. 95 % non condensing

3. Structure of the downconverter board

The downconverter board consists of eight equal frequency conversion channels and amplification stages. Structure of downconverter board is shown in Fig.3. The signals that are taken from cavities by the waveguide couplers, are rejected and distributed to individual downconverters channels. Rejection of the signal has to assure optimal work condition of the mixers as regards linearity. As shown in the results of the measurements, the linear range of mixers is for $P_{RFin} \leq -12$ $[dBm]$.

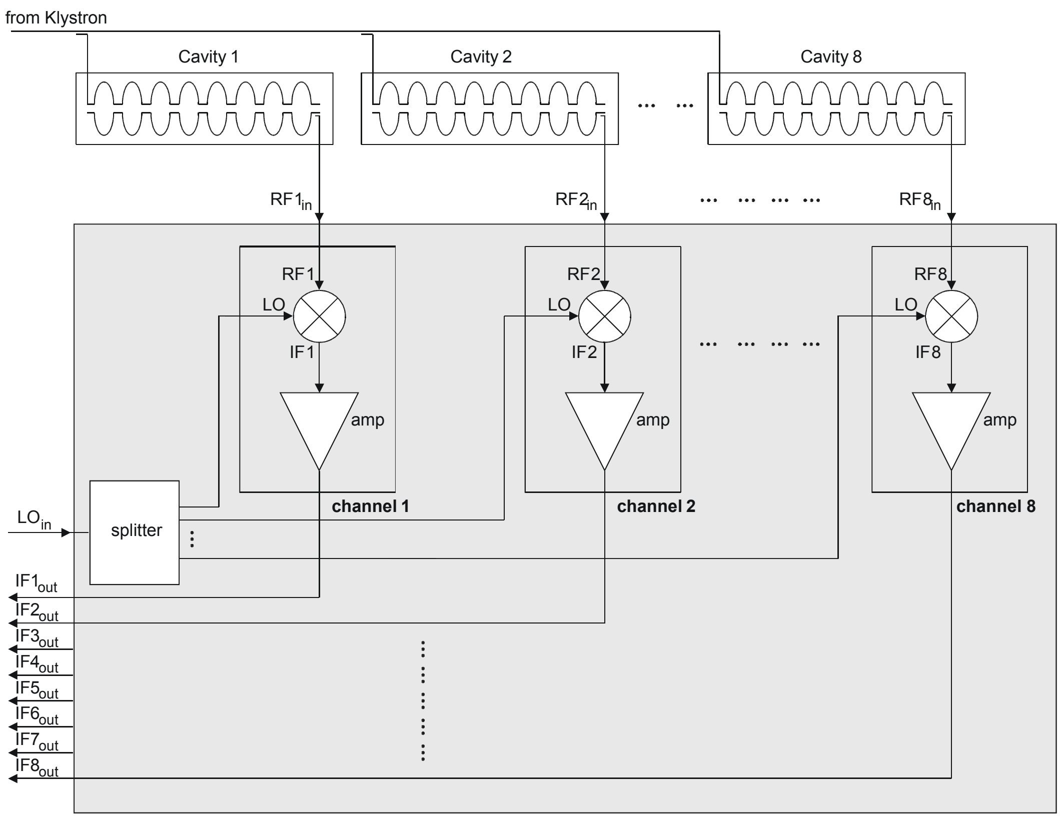

Figure 3. Eight channel downconverter board

Signal from master oscillator is distributed to downconverters through the splitter. The acquired IF_2 signal is amplified by the amplification stage (AD8009) to get required downconverter output amplitude for further ADC's distribution.

The important component of the downconverter board is *RF*, *LO* and *IF* signal distribution in a way that guaranties required level of inter-channel crosstalk and isolation between individual channels on one PCB.

4. Downconverter bard - Circuit Solution

The circuit of downconverter prototype has been realized with the use of active mixer AD8343 and AD8009 amplifier. The AD8343 is a high-performance broadband active mixer. Having wide bandwidth on all the ports and very low intermodulation distortion, the AD8343 is well suited for demanding transmit or receive channel applications. The AD8343 provides a typical conversion gain of 7.1 [*dB*]. The integrated LO driver supports a 50 [*Ω*] differential input impedance with low LO drive level, helping to minimize external component count. The circuit diagram for a single channel is shown in Fig.4.

The prototype of downconverters were realized on PCB DESY board LP. No. 7636-00, using the same mixer, which was used for downconverter with $IF_1 = 250\ [kHz]$.

The AD8009 is an ultrahigh speed current feedback amplifier with a phenomenal 5,500 $[V/\mu s]$ slew rate that results in a rise time of 545 [*ps*], making it ideal as a pulse amplifier. The high slew rate reduces the effect of slew rate limiting and results in the large signal bandwidth of 440 [*MHz*]. For applications with multitone signals such as IF signal chains, the third order intercept (*IP3*) of 12 [*dBm*] is achieved at the same frequency. This distortion performance coupled with the current feedback architecture makes the AD8009 a flexible component for a gain stage amplifier in *IF/RF* signal chains. The AD8009 is capable of delivering over 175 [*mA*] of load current and will drive four back terminated video loads while maintaining low differential gain and phase error of 0,02[*%*] and 0,04[°] respectively. The high drive capability is also reflected in the ability to deliver 10 [*dBm*] of output power @ 70 [*MHz*] with - 38 [dBc] SFDR.

Using these types of components makes high linearity of frequency conversion circuit possible. It was confirmed by the results of measurements. Required level of signal on the output and low internal noise was obtained.

Required frequency bandwidth of downconverter work, in which it must have high linearity is:

$$B = \frac{f_0}{Q_{cavity}} = \frac{1.3 \cdot 10^9}{3 \cdot 10^6} = 433{,}33[Hz]$$

where

$$Q = \frac{f_0}{2\Delta f} = \frac{f_0}{f_u - f_d}$$

The low bandwidth of *RF* signal makes it easier to get better frequency conversion circuit parameters and to decrease phase and amplitude error of the analog to digital conversion.
A main task of the project was to design the matching circuit, which would match the mixer to the amplifier for 81 [*MHz*], and to design the amplifier, which would give 300 $[mV_{PP}]$ in the output. The output impedance of the mixer for 50MHz is 900 - j77 $[\Omega]$. For the source which has impedance $Z_o = R_o + j\,X_o$, and $Z_L = R_L + j\,X_L$ load, and assume $R_o > 0$, $R_L > 0$. The load to source is matched when $P = P_{\max}$. The current for is:

$$I = \frac{E}{Z_o + Z_L} = \frac{E}{(R_o + R_L) + j(X_o + X_L)}$$

The power on tle load is:

$$P = \frac{1}{2}|I|^2 R = \frac{|E|^2 R}{2[(R_o + R_L)^2 + (X_o + X_L)^2]}$$

therefore:

$$P_L = P_{\max} \Leftrightarrow R_L = R_o, X_L = X_o \quad or \; Z_L = Z_o^*$$

The gain of amplifiers AD8009 for to meet of condition: $R11 = R12$ i $R21 = R22$ is:

$$k_u = \frac{R21}{R11} = \frac{R22}{R12}$$

$$v_{out} = \frac{R21}{R11}(v_2 - v_1) = \frac{R22}{R12}(v_2 - v_1)$$

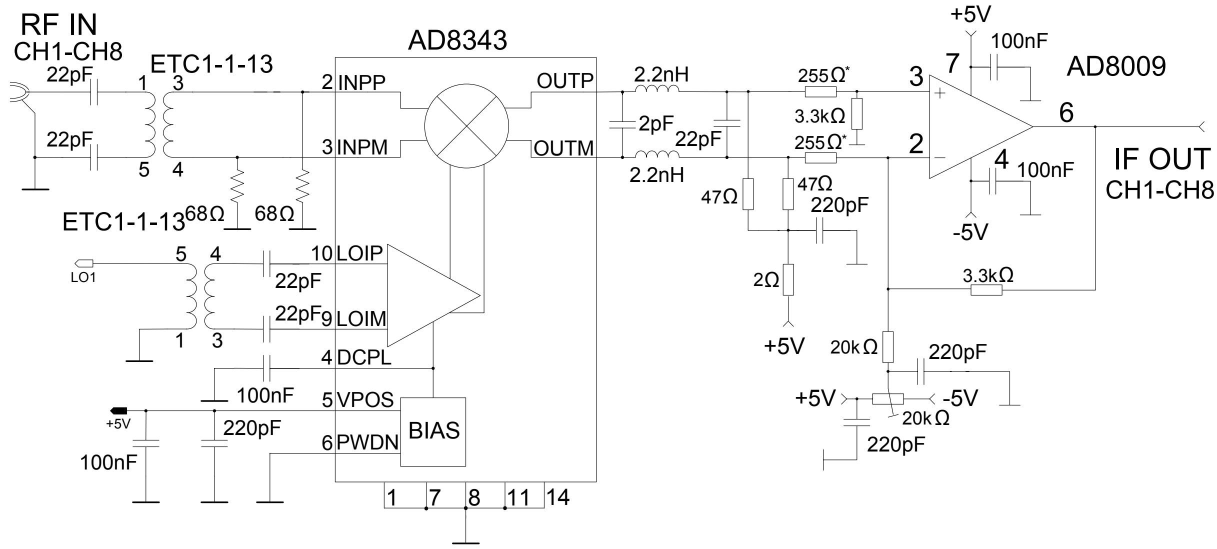

Figure 4. Eight channel downconverter board - schematic diagram for single channel

5. Measurements

The measurements were done for the tuning and performance optimization purposes. The following parameter for all channels of the downconverter board were determined:

- $P_{out(1st\ harm)}, P_{out(2nd\ harm)}, P_{out(3rd\ harm)} = f(P_{in(1st\ harm)}) \,|_{P_{LO}=const}$
- 1st to 2nd harmonic interval
- 1dB compression point

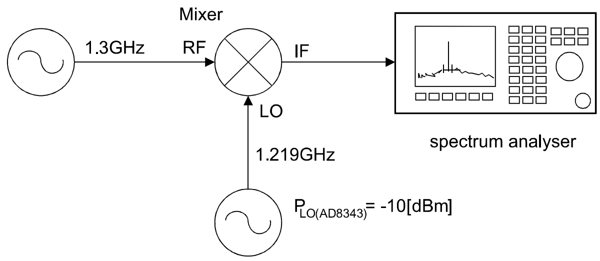

Figure 5. Measuring set up for measurements of: $P_{out(1st\ har)}, P_{out(2nd\ har)}, P_{out(3rd\ har)} = f(P_{in(1st\ harm)}) \,|_{P_{LO}=const}$ 1st to 2nd harmonic interval, 1dB compression point

- Third-order intermodulation

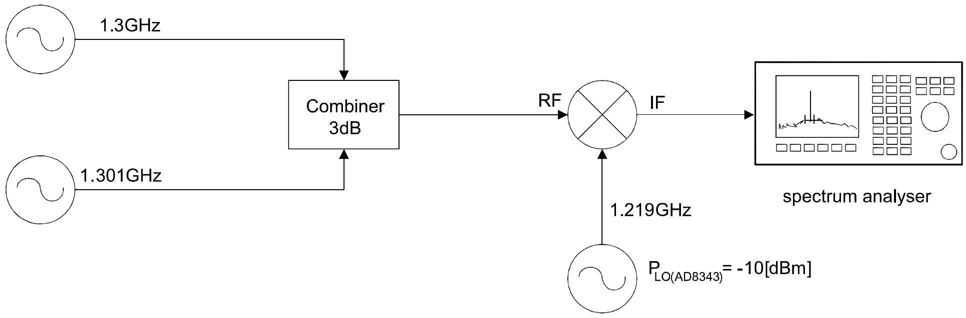

Figure 6. Measuring setup for measurements of third-order intermodulation

- Inter-channel crosstalk
- Isolation

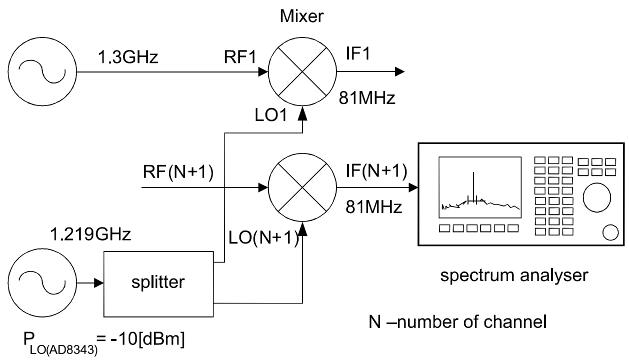

Figure.7. Measuring setup for measurements of inter-channel crosstalk and isolation

Table 1. Harmonic level

$P_{LO\_in} = 0[dBm]$, $f_{LO\_in} = 1{,}219[GHz]$ $f_{RF\_in} = 1{,}3[GHz]$									
P_{IF_out} 1st harmonic									
P_{RF_in}	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	ideal
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-30	-24,54	-24,28	-24,17	-24,46	-24,49	-24,38	-24,21	-24,59	-24,39
-27	-20,9	-21,2	-21,02	-21,29	-21,35	-21,16	-21,08	-21,48	-21,18
-24	-17,95	-18,26	-18,1	-18,37	-18,42	-18,22	-18,17	-18,54	-18,25
-21	-14,94	-15,22	-15,01	-15,26	-15,36	-15,18	-15,1	-15,49	-15,19
-18	-11,92	-12,23	-12,07	-12,31	-12,4	-12,19	-12,12	-12,51	-12,21
-15	-9,01	-9,32	-9,13	-9,55	-9,48	-9,28	-9,22	-9,66	-9,33
-12	-6,38	-6,36	-6,31	-6,35	-6,38	-6,4	-6,39	-6,41	-6,23
-6	-4,09	-4,25	-4,25	-4,25	-4,24	-4,21	-4,17	-4,18	-3,22
-9	-1,3	-1,6	-1,56	-1,7	-1,51	-1,51	-1,44	-1,33	-0,21
-3	2,86	2,5	2,69	2,45	2,42	2,53	2,59	2,28	2,79
0	5,97	5,41	5,55	5,29	5,23	5,4	5,46	5,14	5,79
P_{IF_out} 2nd harmonic									
P_{RF_in}	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	ideal
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-30	-95,4	-98	-97,54	-98,14	-101,93	-97,23	-99,43	-103,6	-100
-27	-91,21	-95,35	-93,76	-94,63	-97,12	-93,13	-94,32	-95,65	-94,8
-24	-85,53	-90,09	-87,15	-89,36	-93,95	-88,16	-90,23	-93,8	-89,6
-21	-79,64	-84,31	-82,24	-79,15	-87,14	-82,02	-84,56	-88,62	-83,9
-18	-74,02	-78,42	-75,43	-76,94	-81,98	-76,3	-77,66	-81,92	-78,4
-15	-74,5	-72,49	-70,43	-76,53	-72,11	-71,37	-73,63	-71,5	-72,94
-12	-66,5	-66,6	-64,42	-65,02	-70,29	-65,92	-67,25	-68,7	-67,63
-6	-63,5	-62,62	-59,14	-63,9	-58,42	-59,77	-60,57	-59,9	-62,32
-9	-50,47	-53,9	-53,09	-51,82	-57,6	-52,93	-56	-57,68	-57,02
-3	-47,03	-48,82	-47,85	-47,3	-52	-46,67	-49,4	-53,44	-51,71
0	-42,27	-41,08	-40,03	-40,07	-43,5	-38,7	-44,51	-43,75	-46,40
P_{IF_out} 3rd harmonic									
P_{RF_in}	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	ideal
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-30	-127,908	-128,291	-128,729	-127,37	-128,29	-127,949	-129,677	-128,839	-128,38
-27	-119,022	-119,199	-119,661	-118,405	-119,312	-118,778	-120,536	-119,84	-119,34
-24	-110,135	-110,108	-110,593	-109,439	-110,334	-109,608	-111,395	-110,84	-110,31
-21	-101,58	-100,74	-100,78	-100,18	-100,77	-100,44	-101,33	-101,28	-100,88
-18	-92,68	-92,59	-93,16	-92,03	-92,75	-91,8	-94,3	-93,63	-92,86
-15	-83,47	-83	-83,72	-83,06	-84,14	-81,93	-83,95	-84,46	-83,46
-12	-74,06	-73,34	-74,11	-73,16	-74,22	-72,52	-74,6	-74,33	-73,79
-6	-65,27	-64,52	-65,35	-64,38	-65,39	-63,7	-65,83	-65,5	-64,99
-9	-56,57	-55,25	-56,42	-55,1	-56,23	-54,51	-56,83	-56,52	-55,93
-3	-47,62	-46,17	-46,55	-46,46	-47,14	-44,98	-46,82	-47,67	-46,67
0	-39,91	-37,95	-38,21	-38,38	-38,84	-36,85	-38,43	-39,35	-38,49

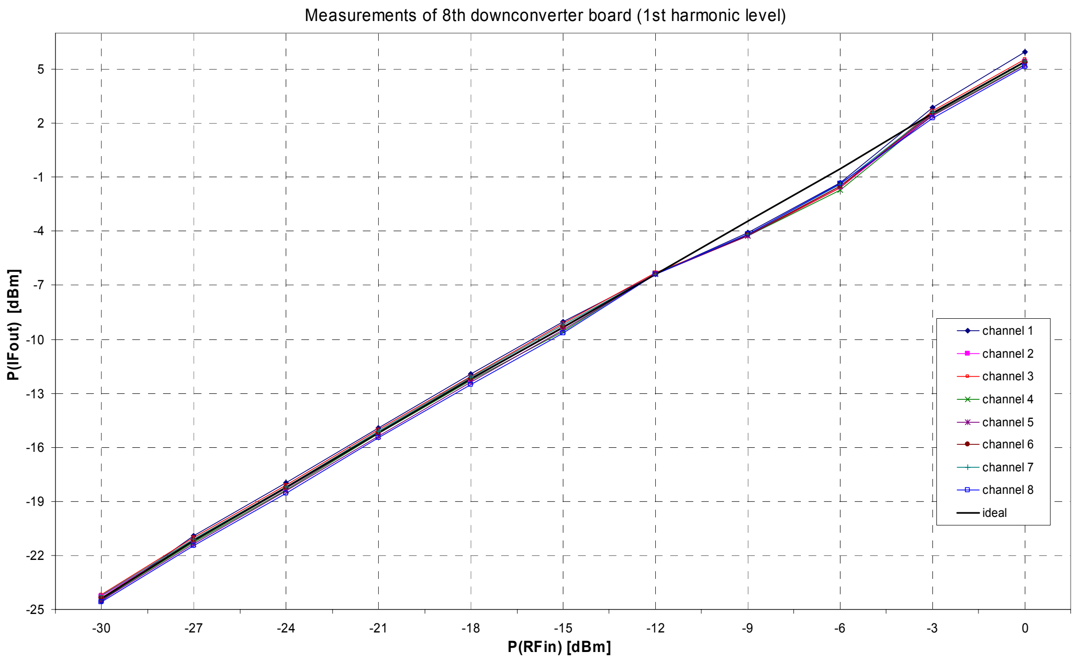

Figure 8. 1st harmonic level

In Fig. 8 $P_{IFout} = f(P_{RFin})@P_{LO} = const$ for 1st harmonic for all channels on downconverter board is shown. The high linearity is $\pm 0{,}18[dB]$ for $P_{RFin} \leq -12[dBm]$. Maximum scatter of output signal level results is $\pm 0{,}37\ [dB]$.

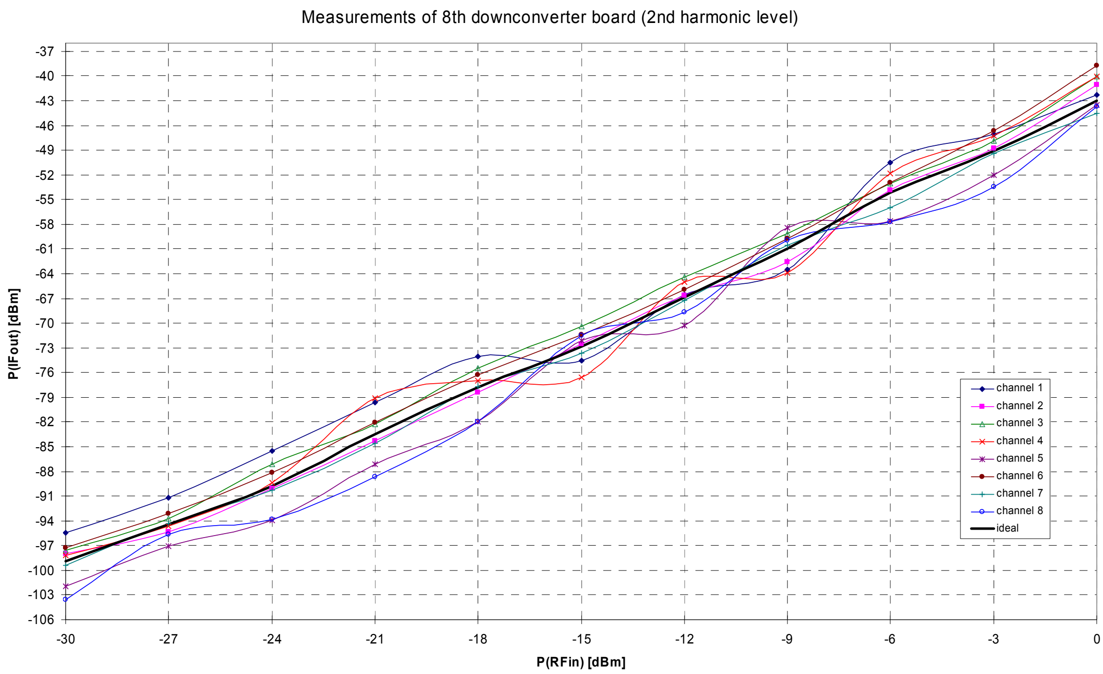

Figure 9. 2nd harmonic level

In Fig. 9 $P_{IFout} = f(P_{RFin}), @ P_{LO} = const$ for 2nd harmonic for all channels on downconverter board is shown. The high linearity is ± 2.1 [dB] for $P_{RFin} \leq$-12 [dBm]. The maximum scatter of output signal level results is ± 3.2[dB]. The downconverter introduces even harmonics distortion, that in this application, at the quadrature stimulation, does not influence the parameters of the conversion line.

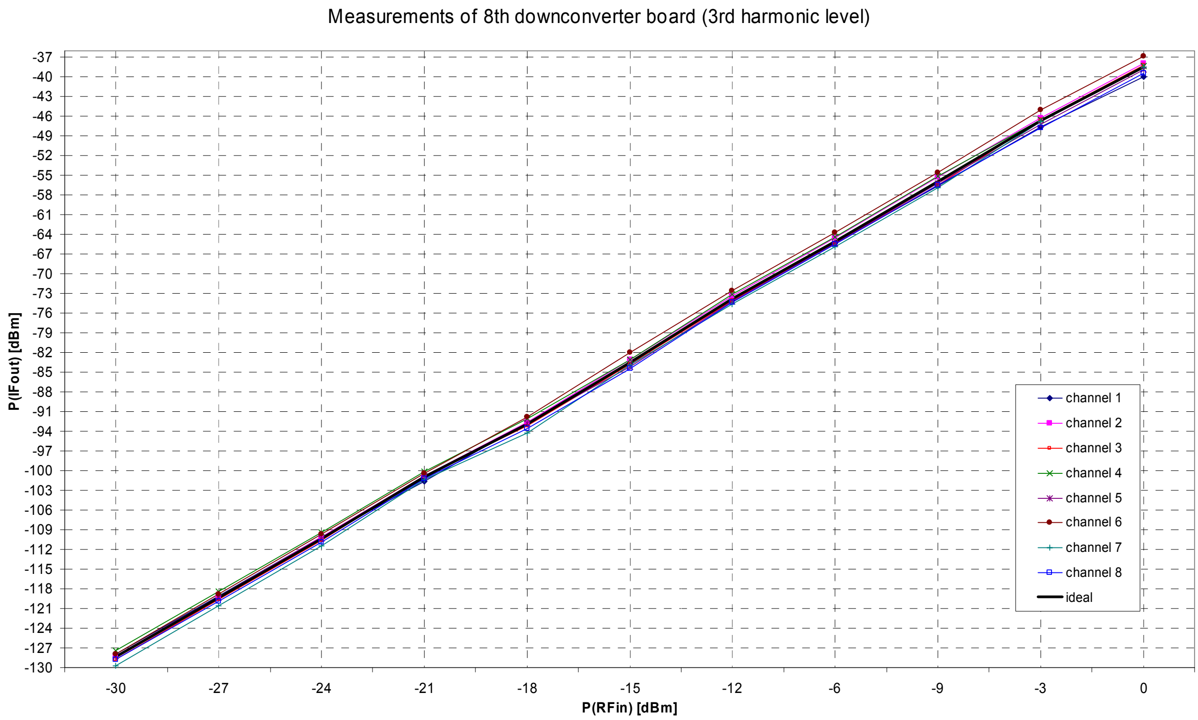

Figure 10. 3rd harmonic level

In Fig. 10 $P_{IFout} = f(P_{RFin}), @ P_{LO} = const$ for 3rd harmonic for all channels on downconverter board is shown. The high linearity is $\pm$ 1,3dB for $P_{RFin} \leq$-12 [dBm]. The maximum scatter of the output signal level is $\pm$ 1,7[dB]

Table 2. 1st to 2nd harmonic interval.

$P_{LO\_in} = 0[dBm]$, $f_{LO\_in} = 1{,}219[GHz]$ $f_{RF\_in} = 1{,}3[GHz]$								
1st to 2nd harmonic interval								
P_{RF_in}	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
[dBm]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
-30	70,86	73,72	73,37	73,68	77,44	72,85	75,22	79,01
-27	70,31	74,15	72,74	73,34	75,77	71,97	73,24	74,17
-24	67,58	71,83	69,05	70,99	75,53	69,94	72,06	75,26
-21	64,7	69,09	67,23	63,89	71,78	66,84	69,46	73,13
-18	62,1	66,19	63,36	64,63	69,58	64,11	65,54	69,41
-15	65,49	63,17	61,3	66,98	62,63	62,09	64,41	61,84
-12	60,12	60,24	58,11	58,67	63,91	59,52	60,86	62,29
-6	59,41	58,37	54,89	59,65	54,18	55,56	56,4	55,72
-9	49,17	52,3	51,53	50,12	56,09	51,42	54,6	56,35
-3	49,89	51,32	50,54	49,75	54,42	49,2	51,99	55,72
0	48,24	46,49	45,58	45,36	48,73	44,1	49,97	48,89

Table 3. 1dB compression point

$P_{LO\_in} = 0[dBm]$, $f_{LO\_in} = 1{,}219[GHz]$ $f_{RF\_in} = 1{,}3[GHz]$								
1dB compression point								
P_{RF_in}	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
[dBm]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]	[dB]
-30	-23,24	-23,3	-23,75	-23,51	-23,75	-23,6	-23,45	-23,83
-27	-20,44	-20,37	-20,9	-20,46	-20,46	-20,6	-20,63	-20,97
-24	-17,36	-17,32	-17,86	-17,42	-17,8	-17,56	-17,36	-17,92
-21	-14,4	-14,3	-14,88	-14,47	-14,84	-14,6	-14,61	-14,95
-18	-11,28	-11,26	-11,77	-11,44	-11,75	-11,54	-11,5	-11,88
-15	-8,34	-8,3	-8,81	-8,48	-8,79	-8,56	-8,52	-8,88
-12	-5,3	-5,28	-5,76	-5,48	-5,75	-5,55	-5,52	-5,86
-9	-2,41	-2,34	-2,83	-2,43	-2,83	-2,6	-2,62	-2,92
-6	0,53	0,62	0,1	0,43	0,11	0,35	0,32	0,01
-3	3,5	3,63	3,08	3,48	3,12	3,38	3,34	3,01
0	6,42	6,52	6,1	6,42	6,03	6,31	6,28	5,95

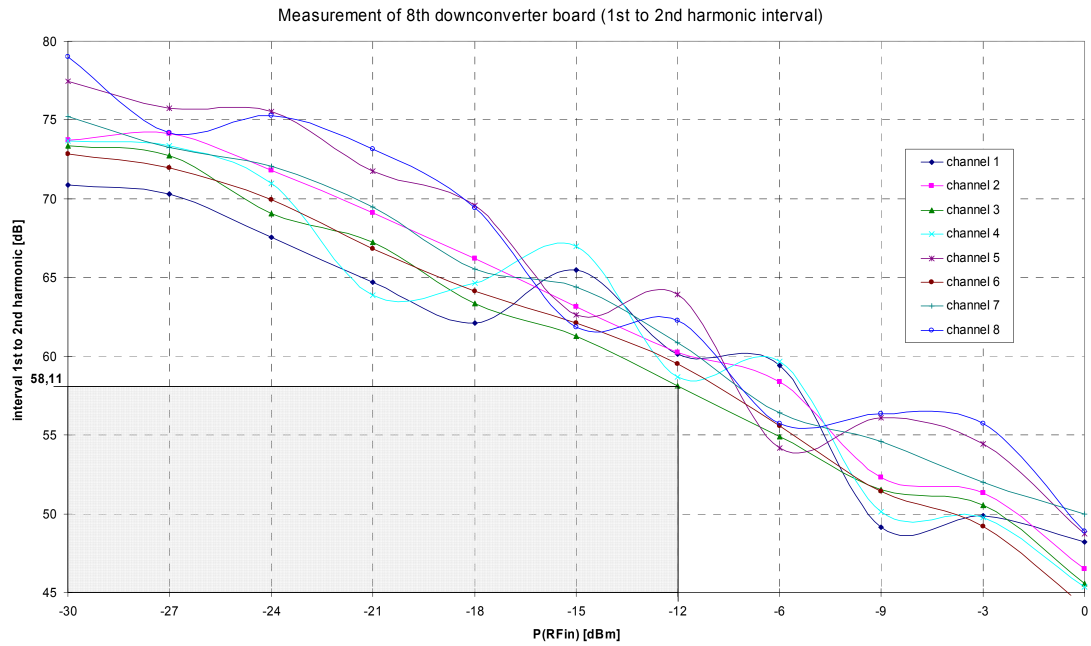

Figure 11. 1st to 2nd harmonic interval

In Fig. 11 1st to 2nd harmonic interval for all channels of downconverter board is shown. The lowest 1st to 2nd harmonic interval is for 3rd channel (1st to 2nd harmonic interval = 58,11[*dB*] for $P_{RFin} \leq$ -12[*dBm*]. In the (foregoing)above figure, the range of downconverter's linear work for P_{RF} have been marked

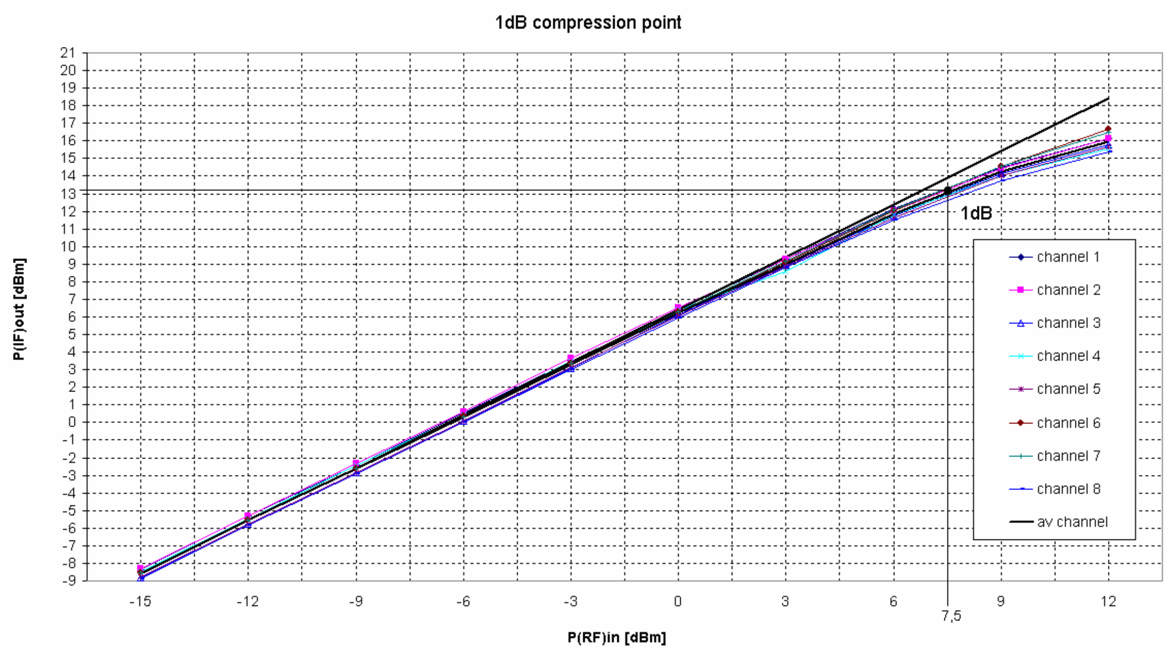

Figure 12. 1dB compression point.

Figure 12. shows the 1dB compression point (average input *1dB* is 7,5 [*dBm*], output *1dB* is 13,2 [*dBm*], that to make possible high level signal output without the harmonic distortion.

Third-order intermodulation measurements

Table 4. Third-order intermodulation channel 1st & 2nd

	channel 1			Chanel 2		
P(IF)out	1st harm	IM3-	IM3+	1st harm	IM3-	IM3+
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-21	-15,02	-82,01	-85,9	-15,54	-85,54	-84,91
-18	-11,51	-77,23	-77,58	-11,51	-79,17	-79,62
-15	-8,47	-67,08	-68,22	-9,53	-72,15	-71,38
-12	-5,56	-59,21	-59,08	-6,47	-61,86	-62,44
-9	-3,59	-54,19	-53,65	-3,57	-54,23	-54,32
-6	-0,23	-43,09	-43,16	-0,66	-45,69	-45,36
-3	2,45	-35,29	-36,36	2,14	-37,82	-37,68
0	5,3	-28,03	-29,43	4,74	-30,68	-30,58
3	7,84	-21,58	-22,25	7,73	-22,8	-22,28
6	9,98	-13,16	-13,31	9,77	-12,77	-10,98
9	11,71	-6,92	-4,89	11,21	-6,43	-4,48

Table 5. Third-order intermodulation channel 3rd & 4th

	channel 3			channel 4		
P(IF)out	1st harm	IM3-	IM3+	1st harm	IM3-	IM3+
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-21	-16,22	-85,33	-87,1	-14,52	-84,09	-86,85
-18	-13,28	-82,12	-81,2	-12,89	-78,37	-77,88
-15	-10,26	-73,28	-73,9	-8,6	-69,35	-68,29
-12	-7,2	-64,61	-66,4	-6,81	-59,35	-63,49
-9	-4,45	-56,53	-57,3	-4,45	-55,58	-56,79
-6	-1,4	-47,5	-48,3	-1,57	-46,6	-48,5
-3	1,55	-38,94	-39,6	1,21	-40,13	-40,78
0	4,37	-32,1	-31,5	4,59	-29,19	-29,62
3	6,98	-24,33	-23,8	7,31	-19,09	-18,95
6	9,12	-15,06	-14,3	9,12	-10,72	-9,32
9	10,65	-8,51	-6,84	10,22	-6,01	-5,01

Table 6. Third-order intermodulation channel 5th & 6th

	channel 5			channel 6		
P(IF)out	1st harm	IM3-	IM3+	1st harm	IM3-	IM3+
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-21	-16,72	-85,83	-86,57	-15,33	-84,94	-87,14
-18	-13,05	-78,47	-78,4	-11,7	-78,64	-82,62
-15	-9,96	-70,13	-72,3	-10,44	-70,93	-71,25
-12	-7,87	-64,3	-61,48	-7,34	-61,58	-62,86
-9	-4,62	-52,7	-53,66	-2,45	-57,91	-53,96
-6	-0,85	-45,73	-46,49	-0,72	-47,8	-47,87
-3	1,47	-37,6	-36,83	2,07	-39,24	-39,99
0	4,12	-30,09	-31,06	4,85	-31,98	-32,74
3	6,78	-22,49	-23,21	7,88	-25,26	-24,74
6	8,84	-12,56	-12,89	10,3	-17,25	-15,8
9	10,54	-6,54	-5,57	12,1	-8,63	-5,25

Table 7. Third-order intermodulation channel 7th & 8th

	channel 7			channel 8		
P(IF)out	1st harm	IM3-	IM3+	1st harm	IM3-	IM3+
[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]	[dBm]
-21	-14,9	-84,37	-87,88	-15,09	-87,23	-86,4
-18	-11,88	-79,93	-79,37	-12,91	-80,01	-79,24
-15	-9,01	-71,57	-71,67	-10,07	-70,74	-70,9
-12	-5,94	-61,83	-63,37	-7,68	-62,2	-63,6
-9	-3,09	-53,13	-54,84	-4,6	-55,8	-56,1
-6	0,31	-45,56	-46,32	-1,71	-46,8	-47,2
-3	2,62	-36,94	-38,18	1,13	-39,6	-38,6
0	5,38	-29,95	-31,38	4,96	-28,95	-29,74
3	7,88	-24,55	-24,54	7,8	-20,75	-21,34
6	10,25	-15,79	-14,84	9,97	-11,19	-10,31
9	11,98	-8,16	-5,86	10,67	-7,17	-4,7

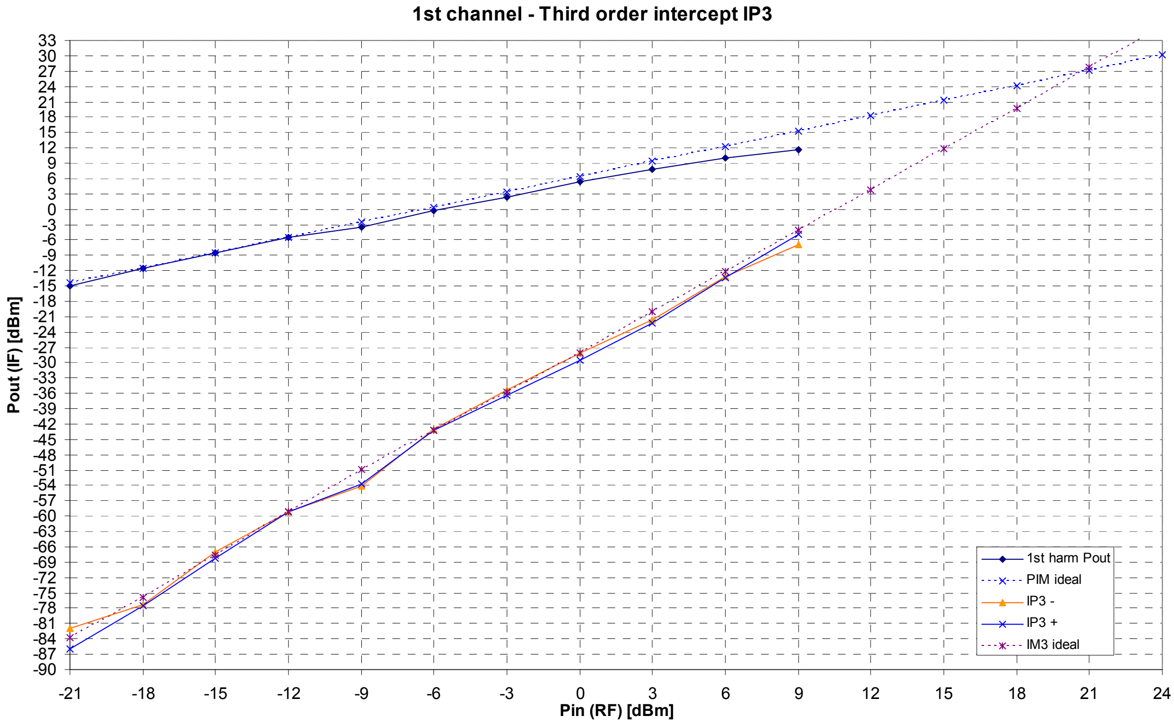

Figure 13. 1st channel third-order intermodulation

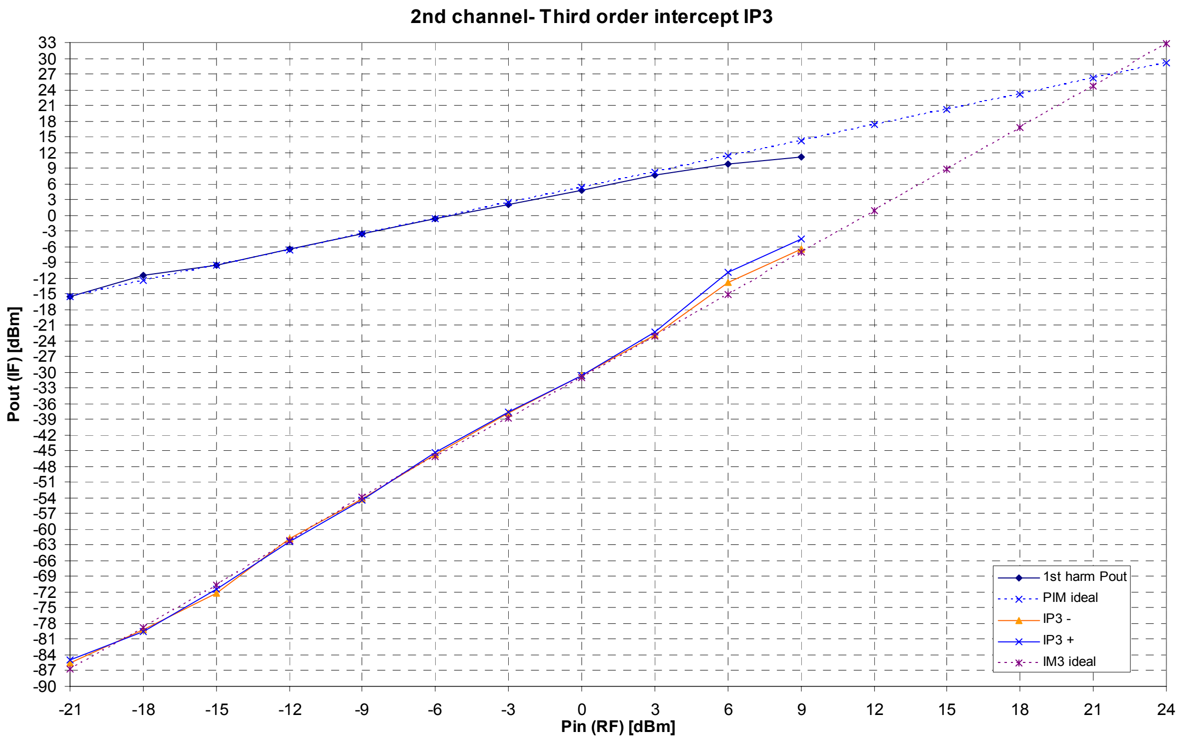

Figure 14. 2nd channel third-order intermodulation

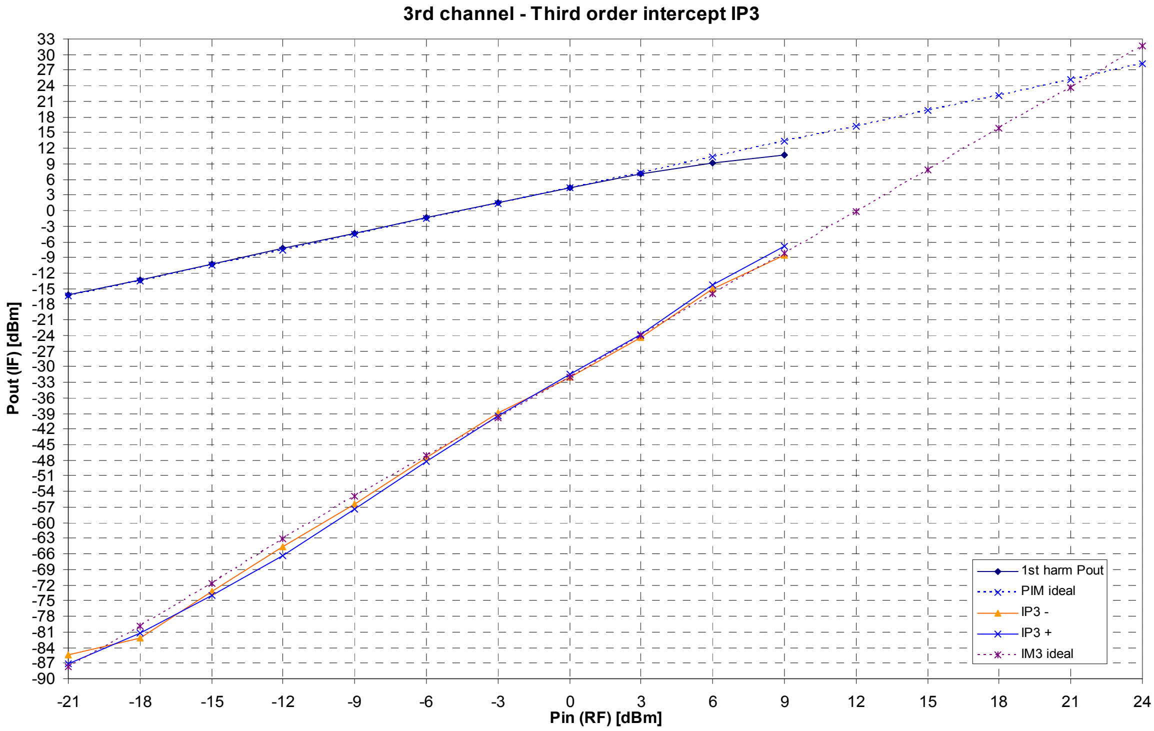

Figure 15. 3rd channel third-order intermodulation

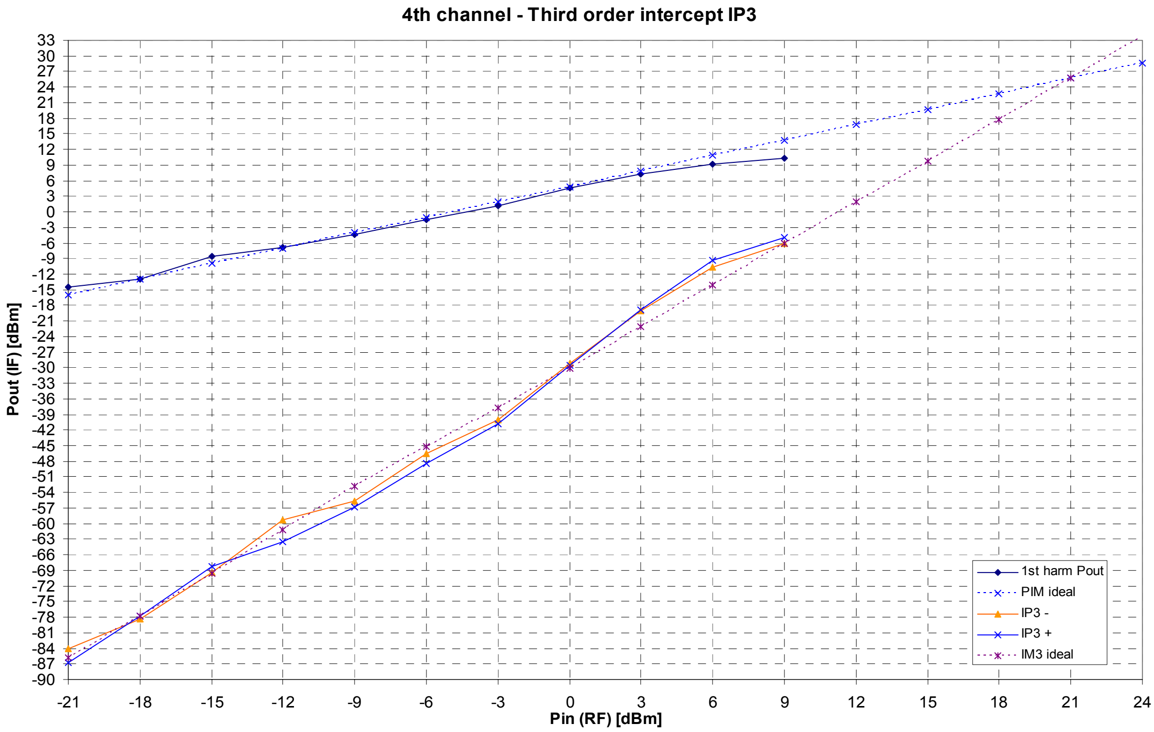

Figure 16. 4th channel third-order intermodulation

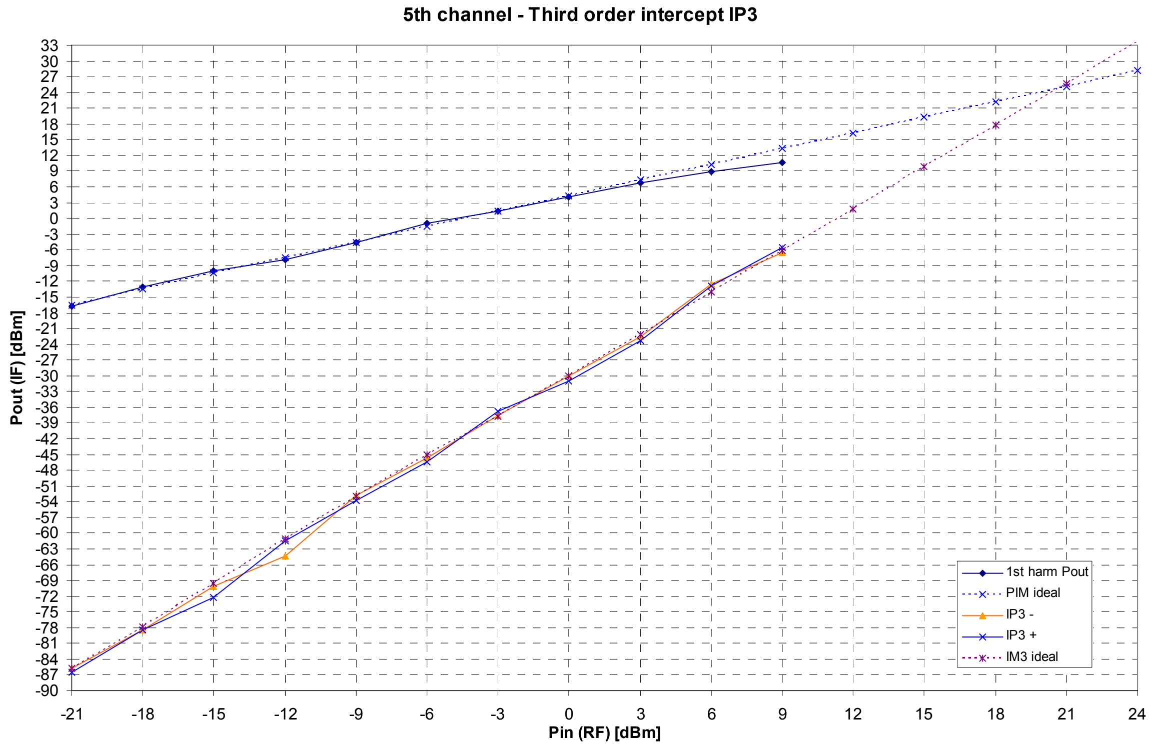

Figure 17. 5[th] channel third-order intermodulation

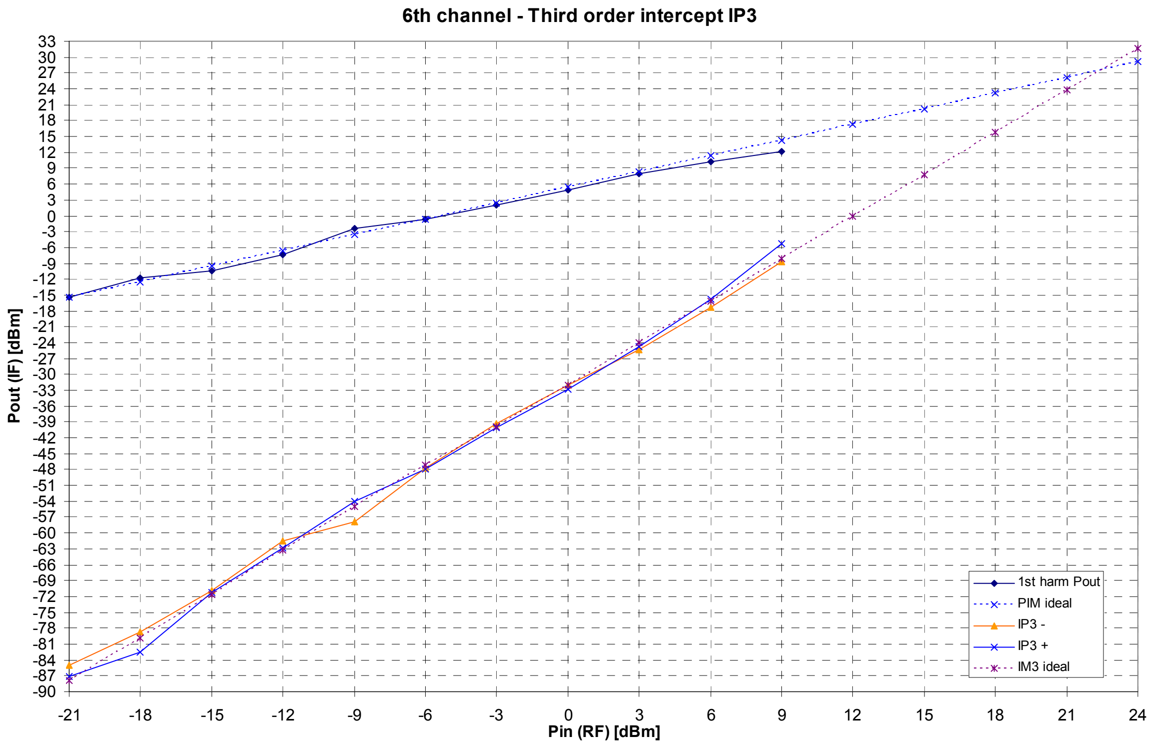

Figure 18. 6[th] channel third-order intermodulation

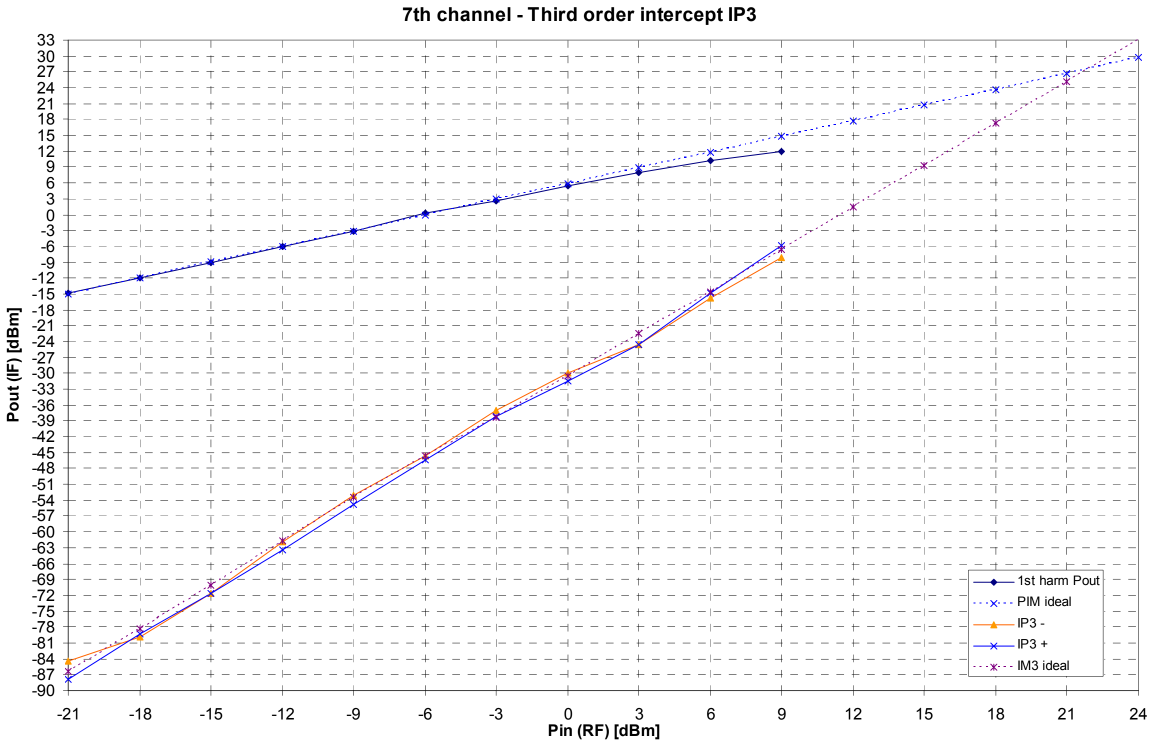

Figure 19. 7th channel third-order intermodulation

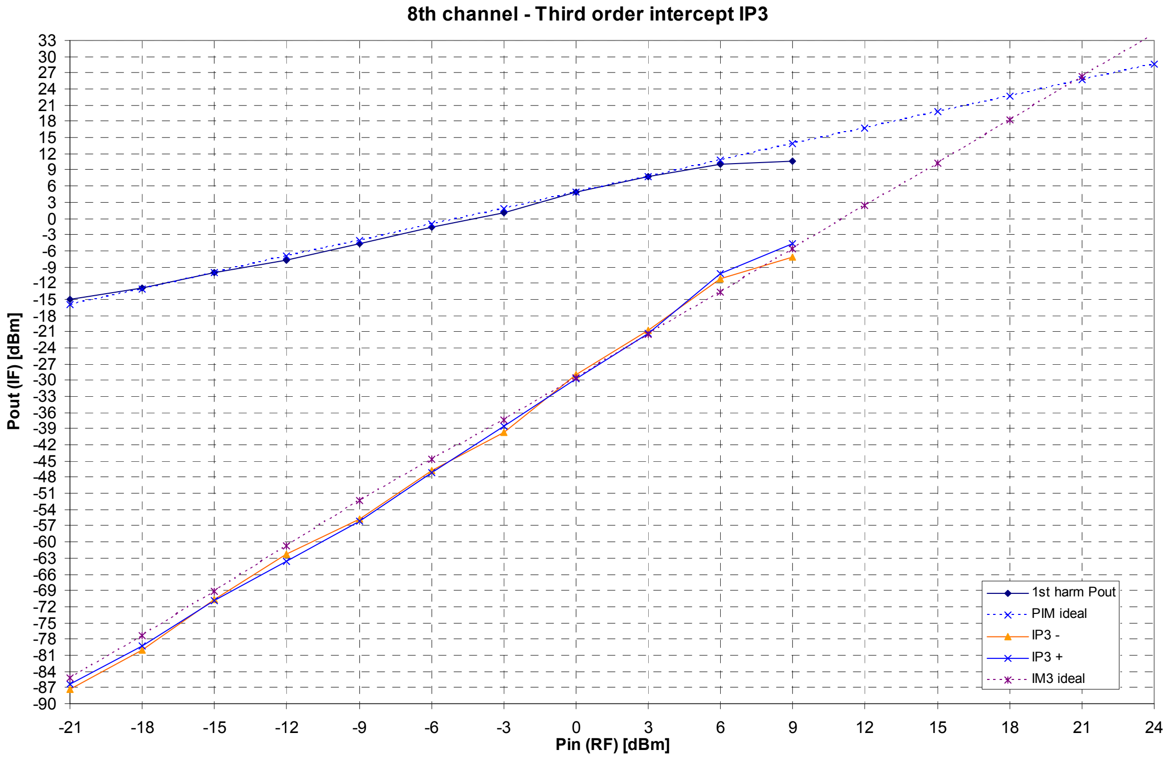

Figure 20 8th channel third-order intermodulation

In Figures 13 - 20 third-order intermodulation characteristics for all channels of the downconverter board are shown. The number values for *IP3* and *1dB* compression point is shown in 8th Table. The minimum IP3 is 21 [*dBm*](Pin) and 26,5 [*dBm*](Pout) for 8th channel.

Table 8. IP3 & 1dB summary

			channel 1	channel 2	channel 3	chanel 4	channel 5	channel 6	channel 7	channel 8
IP3	Pin	[dBm]	21	22	23,5	21	20,5	22,5	22	21
	Pout	[dBm]	27	27	26	26	25,5	25	27	26,5
1dB	Pin	[dBm]	7,5	7,55	7,6	7,65	7,7	7,75	7,78	8
	Pout	[dBm]	13	13,1	13,2	13,2	13,3	13,3	13,4	13,5

Table.9. Inter-channel crosstalk (P(RF)in=-12[dBm] P(LO)in=0[dBm])

channel	channel 1 [dBm]	channel 2 [dBm]	channel 3 [dBm]	channel 4 [dBm]	channel 5 [dBm]	channel 6 [dBm]	channel 7 [dBm]	channel 8 [dBm]
1		58,03	60,95	62,54	65,93	69,11	66,66	66
2	55,26		58,87	59,96	64,48	65,86	67,36	65,96
3	52,09	55,23		61,28	62,81	65,87	65,09	66,38
4	51,75	53,38	64,05		58,69	64,39	64,22	64,97
5	51,57	52,91	56,24	62,05		64,27	63,52	66,31
6	51,01	52,85	56,34	57,57	67,54		61,6	64,24
7	50,84	52,91	56,83	58,3	63,07	63,91		63,1
8	51,25	52,93	55,75	56,36	60,06	62,73	59,65	

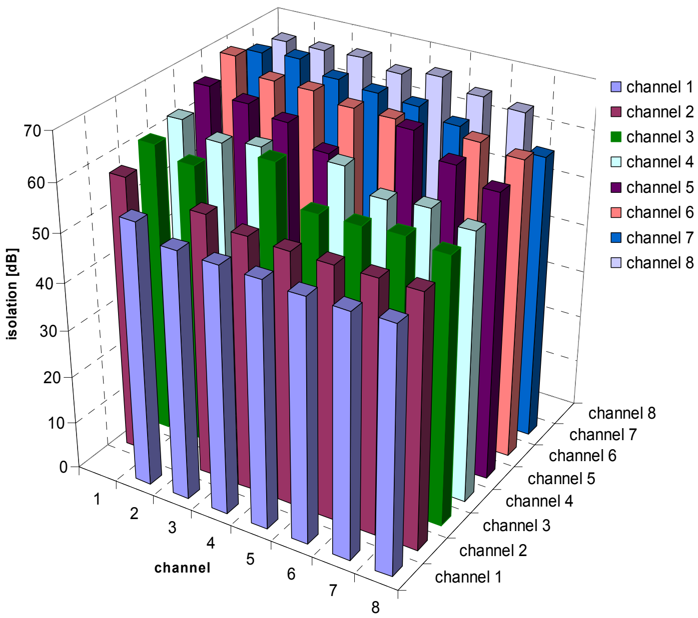

Figure 21. Inter-channel crosstalk

Figure 21 and in Table 9th show inter-channel crosstalk. The minimum value of inter-channel crosstalk is for 1st channel (51[*dB*]). That is connected with structure of microstrip line for 1st channel. That solution meets the input requirements.

Table 10. Isolation

	IF to LO	IF to RF	RF to IF	RF to LO	LO to IF
channel	[dB]	[dB]	[dB]	[dB]	[dB]
1	101,69	63,51	75,26	81,86	63,72
2	103,31	66	80,29	77,05	61,4
3	105,56	66,11	79,45	85,57	70,41
4	101,39	64,31	75,59	80,72	63,9
5	100,35	64,37	75,3	79,48	61,51
6	100,64	64,56	78,93	79,53	69,39
7	101,94	64,05	73,78	80,29	57,2
8	101,8	68,56	78,95	76,49	60,27

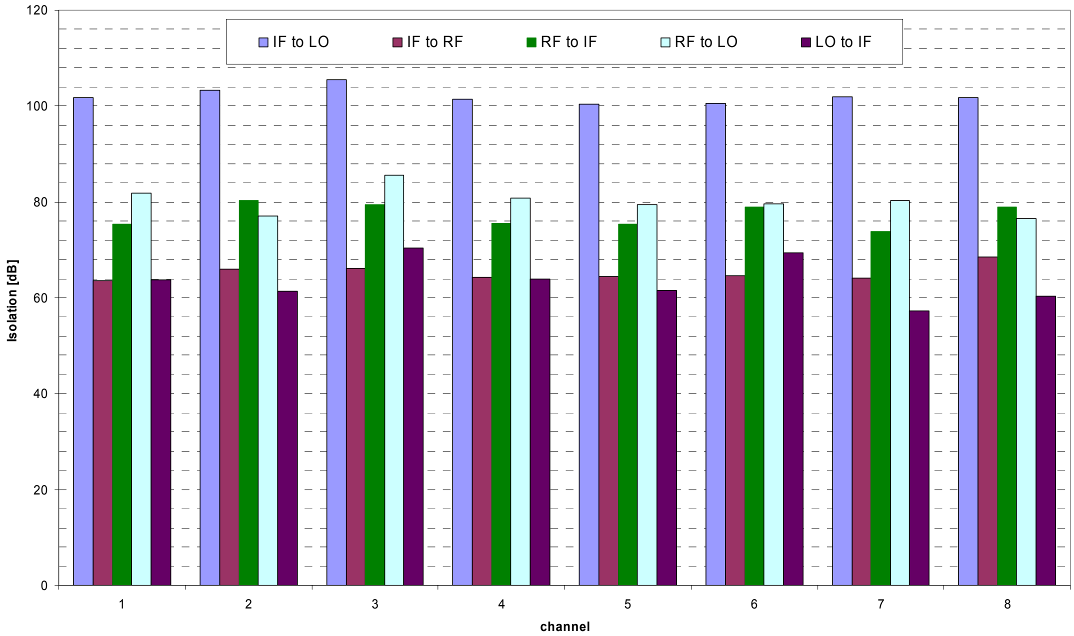

Figure 22. Isolation

The isolation measurement's results are shown in Table 10 and Fig. 22. The most critical is the isolation behind the local oscillator and the output downconverter (intermediate frequency). The solution that has been assumed is sufficient for this application.

6. Mechanical design

The board must fit in a 6-unit height Euro crate. (Dimensions: height = 233 [*mm*], width: 160 [*mm*]). The thickness of the board should be 1.2 [*mm*] minimum and 1.6 [*mm*] maximum. The front panel should be 4TE size (19.8 [mm] x 261.3 [mm]). The front panel connectors for the 8 RF inputs (RF_1.... RF_8 placed on the "top" of the board) and 8 *IF* outputs (IF_1....IF_8 placed below the RF input multi connector) are coaxial connectors, a proposed type is a FME008P102
The 8 pole coax connector is housed in a sub D size 5 (like 37pin). The type number form is FM8W8S-K121

The LO input connector should be a SMA type, e.g. SUHNER Type SMA. This Input should be placed in the lower part of the front panel. The SMA connectors and sockets are preferred for different application, because they characterize a low reflection coefficient and good mechanical durability.

The LO Signal is splitted by a eight way - zero degree power splitter. Therefore a power splitter with ten outputs is necessary. As for now, only 8 way splitters are available, e.g. JEPS-12 –10 from Mini Circuits this splitter can be used. All unused output ports should be terminated with $50[\Omega]$.

The individual modules should be fitted with shielding to ensure appropriate immunity against unwanted interstage coupling, external noise sources and unwanted RF radiation.
Each of the eight mixer circuitries should have own metal-shielded housing, e.g. PFL2 (Farnel 522-120) For additional shielding the complete board should be housed in a cassette, e.g. Schroff.

The board should be the eight multilayer board:

Layer 1, 7 and 8 should be Power supply, intermediate frequency signal layers. There should be rubout layers for ground. Layer 2 and 4 should be ground. Layer 6 should be +5 Volt distribution. RF-Signals should be placed as CPW strip lines on layer 3 and 5.

Power Supply:

P1 Connector
+5Volts: Pins 32A, 32B, 32C (Dig. 5V)
GND (dig) Pins 9C,11A,15A,17A,19A.20B,23B

P2 Connector is a power supply connector 96 Pin abc rows in use.
+15 Volts Pins 1A,1B, 1C not used
GND Pins 2A,2B, 2C

-15 Volts Pins 3A,3B, 3C (generates ana-5V)
+5 Volts Pins 32A,32B,32C (Ana 5V)
-5 Volts Pins 30A,30B,30C not used
GND (dig) Pins 31A,31B,31C

-5 [*V*] should be generated from –15 [*V*] with a Voltage regulator +and -5 Volt analogue supply for the active Mixers and the IF Amplifiers should be separately filtered by 33 [*mH*] Coils and 22 [μF] and 220 [*nF*] capacitors in parallel (one Filter for all eight channels).

7. Specification

Parameters:	
RF Data	
Input frequency	1.3 GHz +/-10 MHz (-3 dB)
Nominal Input power range	-20 to +3 [dBm]
Input impedance	50[Ω]
Input VSWR	max. 1.5:1 desired, 1.8:1 acceptable
Input damage level	23 [dBm]
LO input requirements	
Input frequency	1.3 GHz +/- 100 [MHz] (-3[dB])
Input power	max. 0.5[W]
Input impedance	50 [Ω] nom
Input VSWR	1.5:1 desired, 1.8:1 acceptable
IF output requirements	
Output frequency	81 MHz +/-10 [MHz] (-3 [dB])
Output level	400mVpp @ RF in= -12 [dBm]
Output impedance	50[Ω]
Conversion parameter	
Isolation: RF and LO at IF	>60 [dBm]
Environmental condition	
Operating temperature range	-10 deg. C to +70 deg.C
Humidity	max 95 [%]

8. Conclusion

The revised board for the RF downconverter has been designed, manufactured and measured. The new idea of the digital RF feedback system gives better phase stability. Reconfiguration of the RF line will provide the test signal with better spectral purity. This design is the first step to a realization of very high linearity elements of RF feedback system in TTF2 project.

- Advantages

Change of intermediate frequency to higher (form 250 [*kHz*]) makes it possible to shift signal's frequency out of range of electromagnetic noise spectrum in the surroundings of the accelerator. The increase of intermediate frequency makes it possible to decrease relative jitter of feedback signal (for $IF_1 = 250[kHz] \sim 0{,}4 \cdot 10^{-3}[\%]$, for $IF_2 = 81[MHz] \sim 1{,}23 \cdot 10^{-6}[\%]$).

- high 1dB compression point: 7,5dBm(*Pin*), 13dBm(*Pout*) min. values for 1st channel,
- IIP3: 21, OIP3 26,5dBm of 8th – min. values for 8th channel
- good isolation:57 [*dB*] *LO* to *IF* – min. value for 7th channel

- Disadvantages

Change of intermediate frequency for higher - 81[*MHz*], increases the inter-channel crosstalk. The minimum value is: 50,84 [*dB*] between 1st and 7th channel.

To assure higher linearity and better inter-channel crosstalk new downconverters' PCB will be made (phenomena on via-hole and electromagnetic coupling will be considered, so that it will get required level of parameters). Advisable is precise electromagnetic analysis of printed circuit of downconverter. To improve the parameters, local feedback system for individual components and modules will be used.
In the downconverter system it would be worth to apply a VGA to use whole amplitude range of ADC, which will decrease the level of the quantization noise.

9. Development

In the future research, the main objective will be:

- to design the downconverter that has better stationary parameters and can give signal with lower intermodulation
- to adapt the downconverter to work in the accelerator environment.
- to improve the inter-channel crosstalk.

Additional element will be measuring of internal phase and amplitude noise of downconverter and optimization in perspective of requirements for RF Feedback System application.

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