SwissFEL C-band downconverter design

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Abstract

The SwissFEL C-band LLRF downconverter concept follows a modular approach and offers 24 synchronous measurement channels with superior isolation, high linearity and low noise. Using a discrete dual channel double balanced mixer design with octoquad high barrier junction Schottky diodes helps to optimize the mixer performance at its desired frequency, while keeping the costs per channel low compared to broadband high performance integrated mixers. The microstrip design and non-linear harmonic-balance simulation has been done using Keysight's Advanced Design System and agrees very well with lab measurements. This poster will present the downconverter design, simulations and its achieved performance.

Overview

The SwissFEL LLRF system is based on a separated digital backend and a „Pizza-Box" analogue frontend used for up- & downconversion of S-, C- or X-band signals. Each superhet downconverter box (Fig. 2) carries 24 highly synchronous channels with adjustable channel gain and additional high gain preamplifiers for weak beam induced signals (Fig. 1). A second box holds the baseband IQ-upconverter, ADC/DAC clock dividers and LO generation. Due to the high degree of system modularity it is easily possible to adapt those frontends for different frequency standards or channel requirements.

IF_{out} noise density	< -143 dBm/Hz
channel isolation	> 76 dB
IF_{out} OIP3	> 40 dBm
IF_{out} P1dB	> 21 dBm
SFDR (w/o harmonics)	> 95 dBc
Phase Noise @40MHz (10Hz-10MHz) RMS	< 10 mdeg

Table 1: performance summary

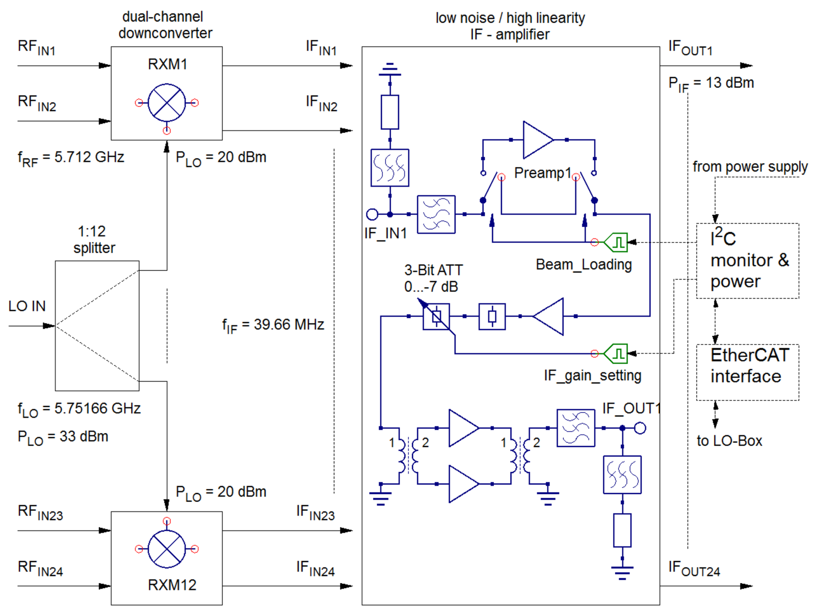

Figure 1: downconverter concept

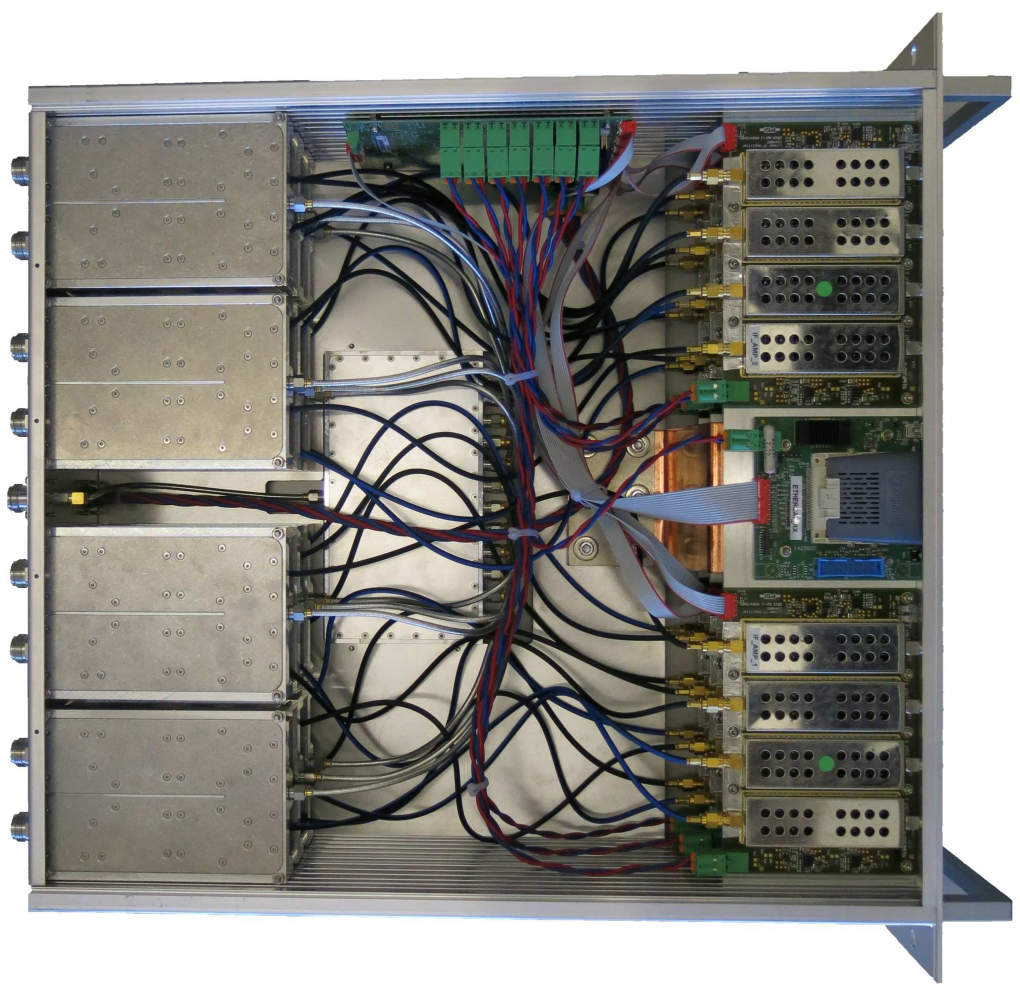

Figure 2: 3HE 19" downconverter „Pizza Box"

Dual channel double balanced mixer

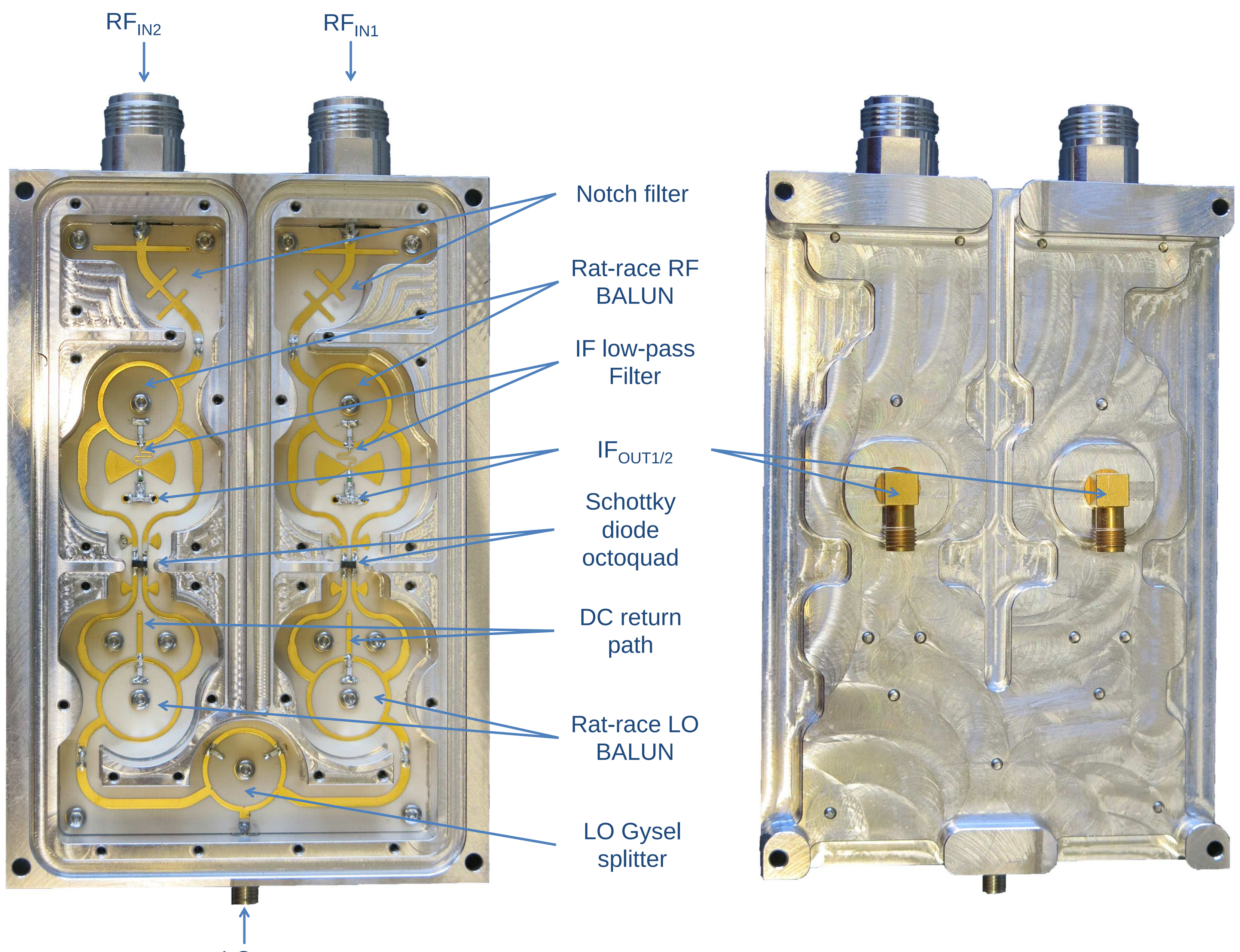

Figure 3: dual channel mixer design top/bottom

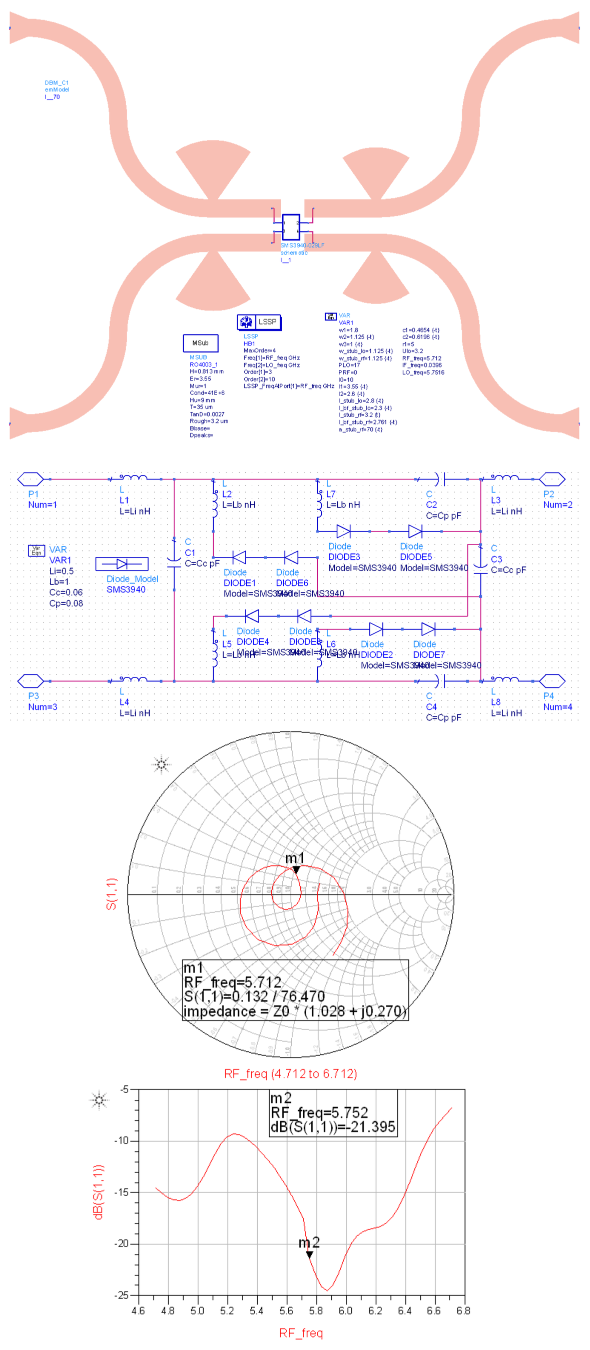

Figure 4: ADS mixed EM/schematic Large Signal S-Parameter simulation

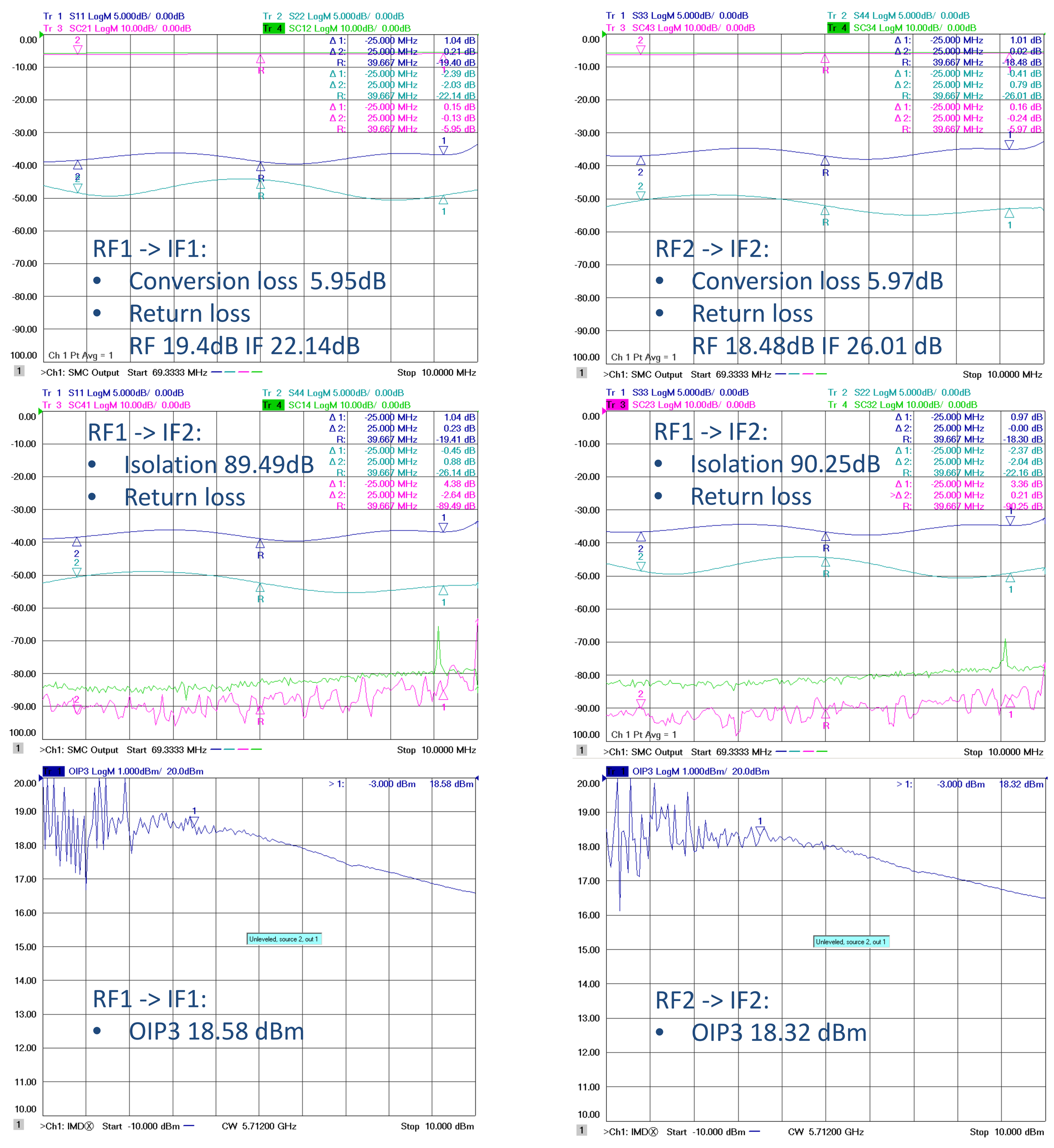

Figure 5: Scalar conversion measurements of dual channel mixer

Downconverter performance

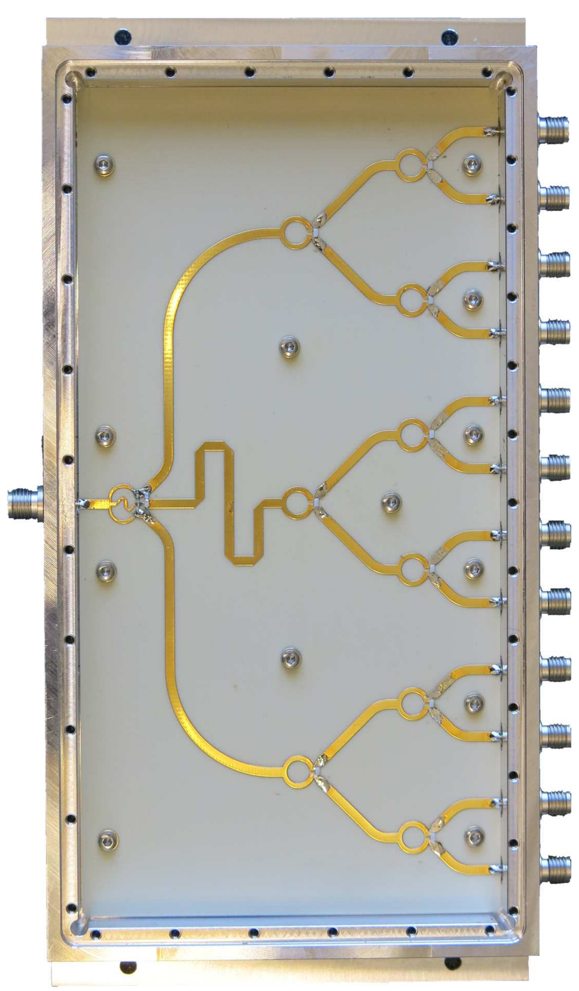

Figure 6: High isolation 12-way Wilkinson splitter

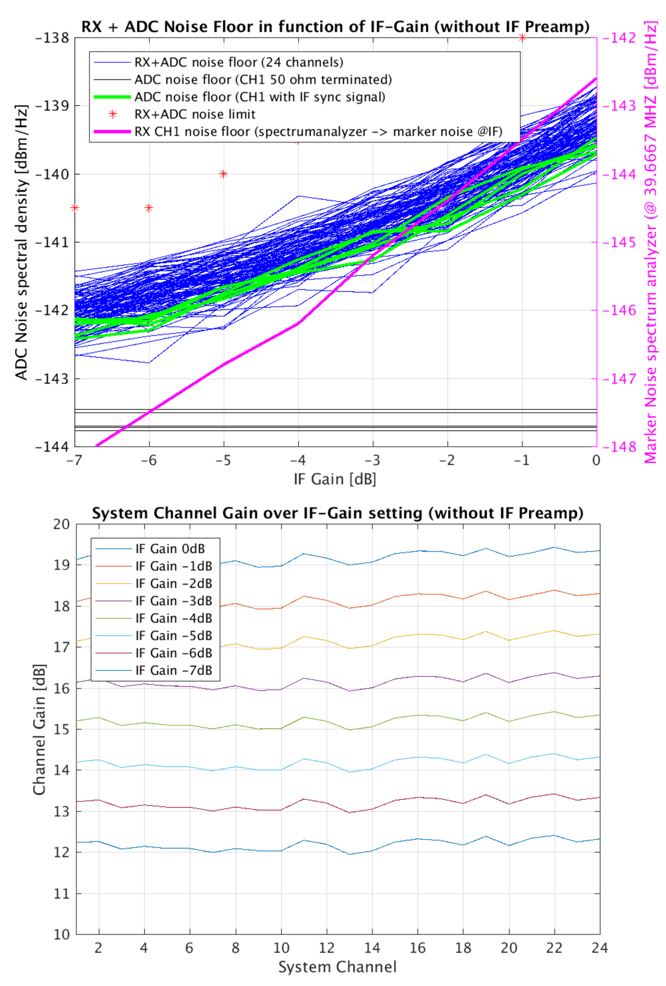

Figure 7: Noise vs. Channel Gain

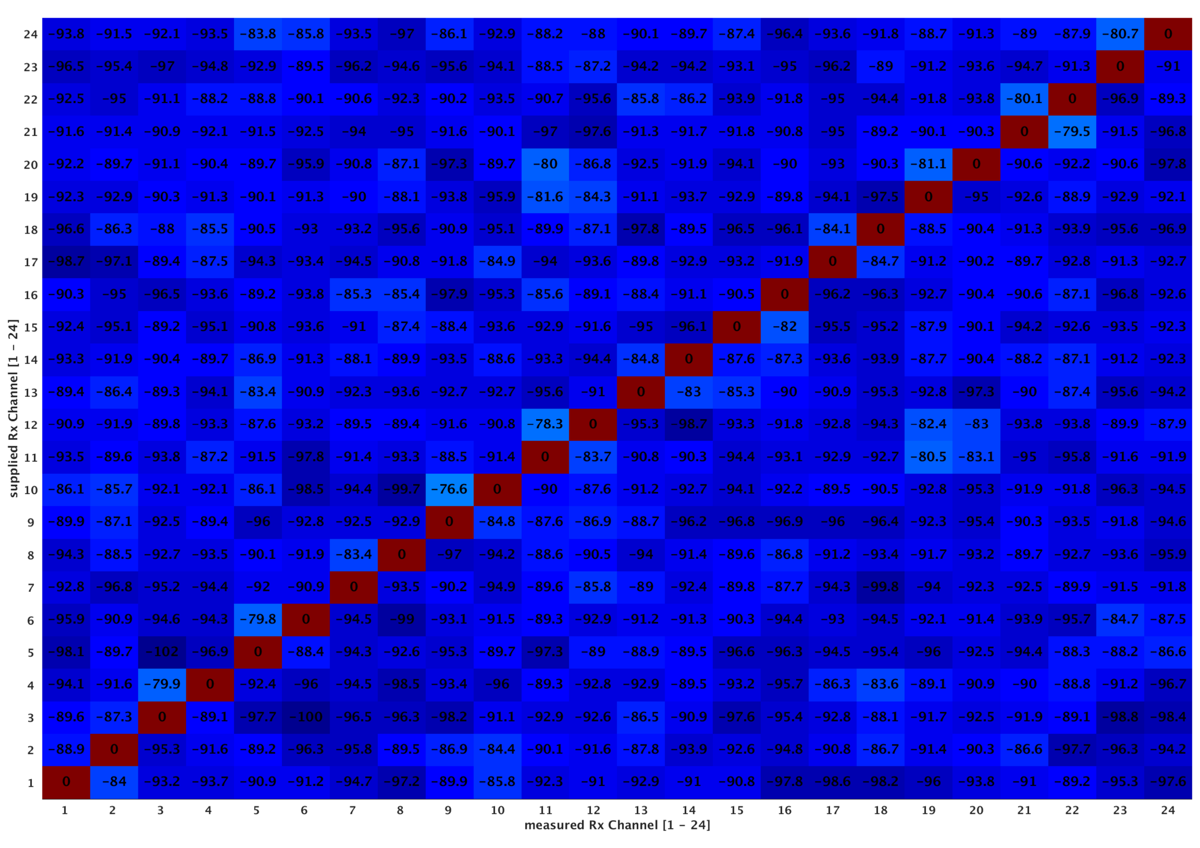

Figure 8: RX Crosstalk matrix

Figure 9: Absolute Phase Noise of downconverted 5.712 GHz reference signal @ 40 MHz

Drift Compensation / Reference Tracking

Phase drift compensation is a well-known practice in LLRF applications against slow temperature and humidity changes to guaranty RF phase stability. Therefore the presented downconverter offers two major advantages required for applying a poor man's technique called reference tracking, where some or at least one channel is fed with the stabilized reference signal, while all other channels are corrected in phase respectively.

An important constraint is to expect every channel to have the same LO phase which is guaranteed by using one central LO amplifier and equal phased feeding lines. The other constraint is to expect all channels to have the same group delay which requires a symmetrically downconverter architecture.

Conclusion

Based on the concept of S-band LLRF frontends used for SwissFEL's injector the system modularity has been proven to be a major benefit concerning the reuse and mass production of frequency independent components and long term maintainability. The presented C-band downconverter shows excellent performance and tight parameter deviation over the production lot of 30 systems (720 converter channels) which have been produced for SwissFEL's LINAC sections. By using the shown discrete dual channel mixer design with low-cost Schottky diodes the costs per channel could be drastically reduced compared to high performance integrated mixers.

Abbreviations:
RX (Receiver) / LO (Local Oscillator)

Revision 1, DL84, 27.09.2017, LLRF17