DEVELOPMENT OF THE RF FRONT END ELECTRONICS FOR THE SIRIUS BPM SYSTEM

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Introduction

INTRODUCTION

To fulfil the beamline user's requirements for stability of the small and high brilliance photon beams, a very stable and linear electronics is required to perform the signal conditioning of the electron BPM system. Less than 0.14 µm drift for one-hour and less than 5 µm (RMS values) for one week are required. These values comprise all drifts and noise from electronics, BPM mechanics and BPMs support stands. The BPM system requirements are listed in [1].

The BPM electronics is central to beam stability performance. Since an orbit feedback system is going to lock the electron beam onto a well centred golden orbit measured by the BPM system, the stability of the beam is that of the BPMs.
The BPM electronics must achieve the desired resolution and stability in all modes of operation of the light source. To achieve the specifications the SIRIUS RF Front-End (RFFE) is based on a design that ensures linear operation over a broad range of input power and counts on an active temperature stabilization control and a crossbar-switching scheme designed to provide a stable operation.
The entire electronics, not only the RFFE, was designed according to the Open Hardware approach which makes it available to the whole accelerator community [2].

RF Front-End overview

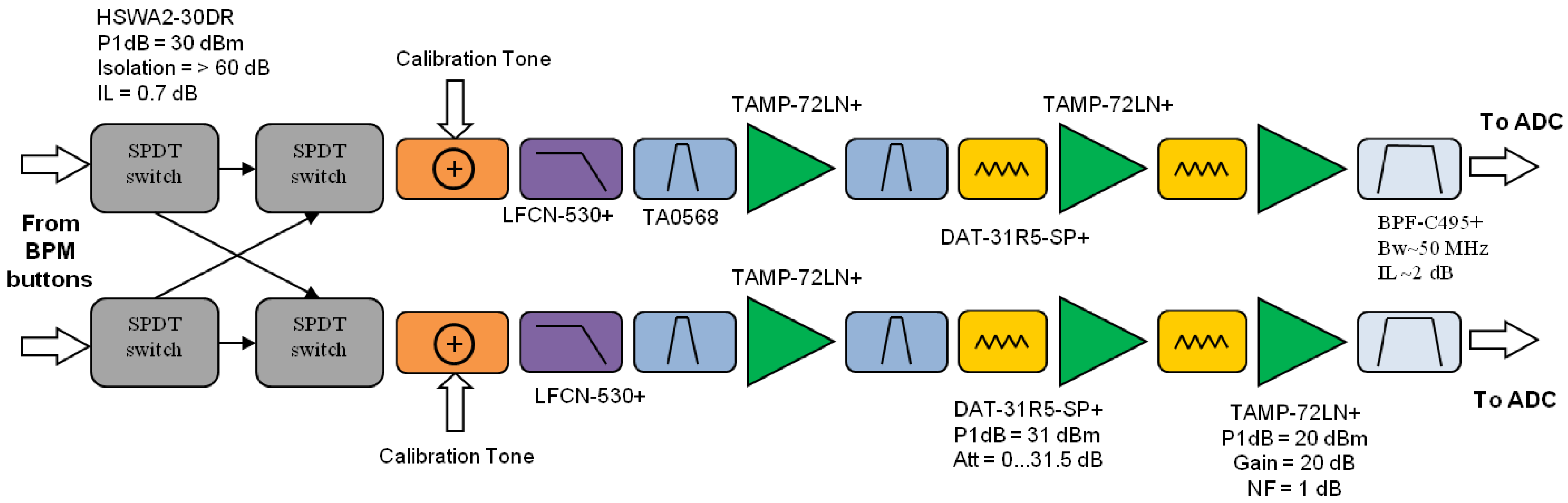
RF Design

The SIRIUS RF Front-End is made up of four channels, grouped by two. They provide up to 50 dB of adjustable gain for machine commissioning.

Sirius RF Front-End specifications

Parameter	Value
Dynamic Range	40 dB
Noise Figure	10 dB
Crosstalk	< -50 dB
Bandwidth (3 dB)	80 MHz
1 dB Compression Point	> 20 dBm
Long Term Stability (1 week)	$< 5\ 10^{-4}$
RFFE MTBF in user beam delivery	10 years

RFFE board. Ten layers of the Rogers RO4350 RF substrate.



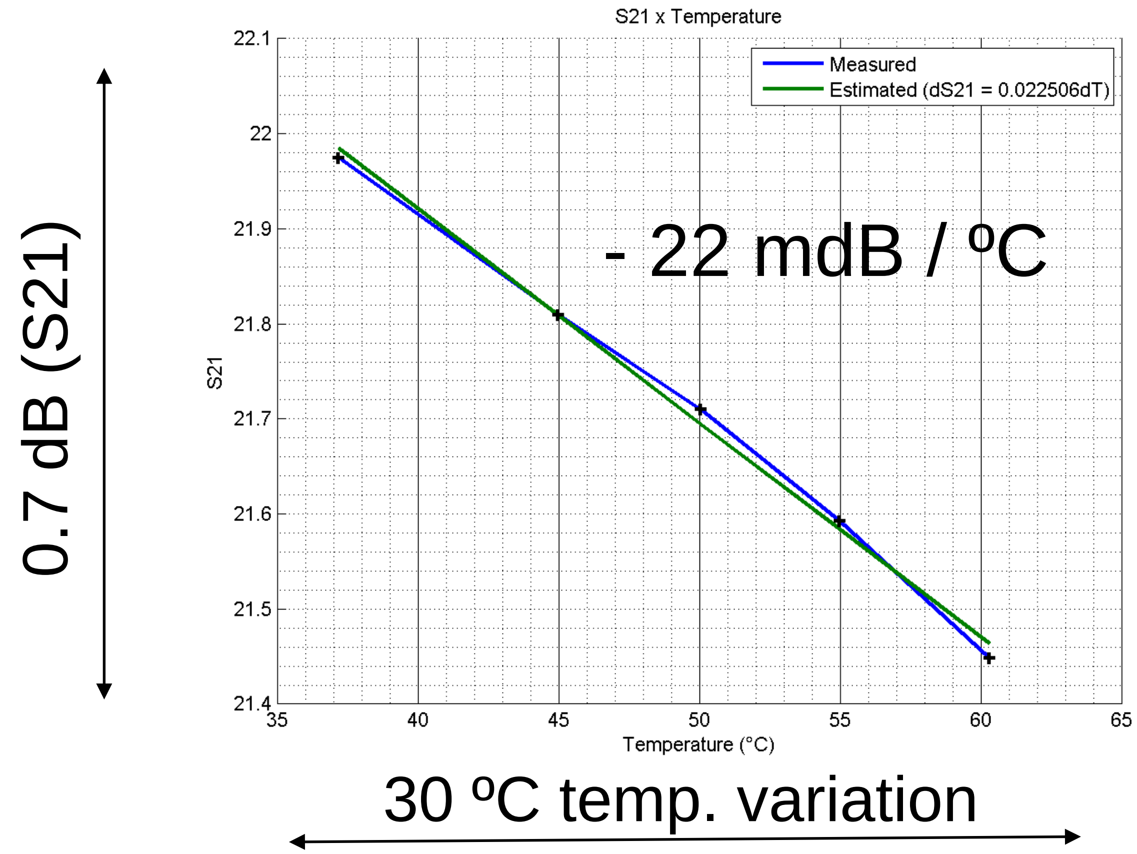
Strategies for achieving high stability

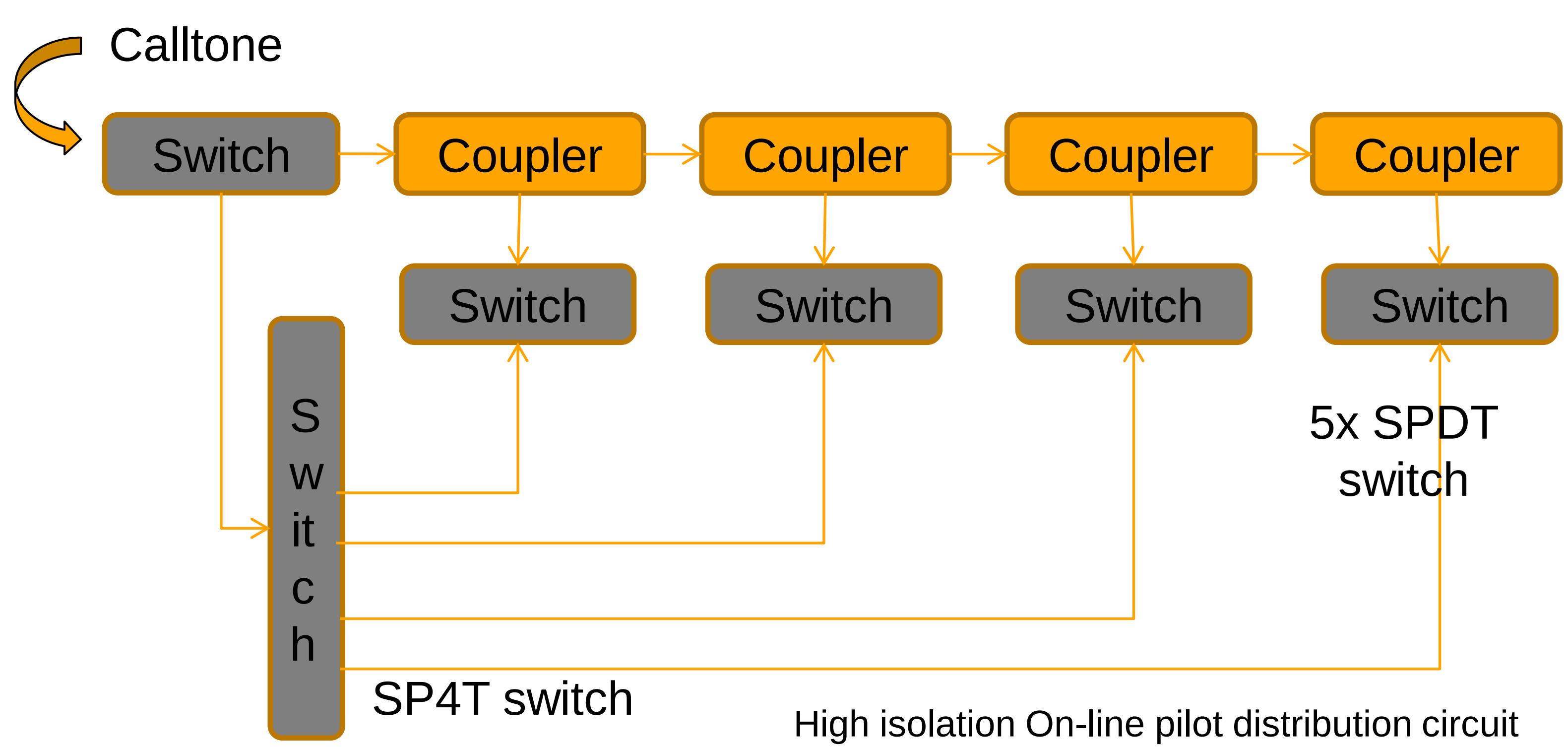
Four schemes have been implemented on the RF Front-End board aiming to achieve the long-term stability requirements, two out of the four strategies were extensively tested up to now.

The crossbar switching technology was first used by the I-Tech digital BPM electronics [4] and its effectiveness in improving the long-term stability is well known everywhere. For the SIRIUS RFFE the attenuation of the carrier is less than 3 dB if the switching frequency is below approximately 100 kHz.

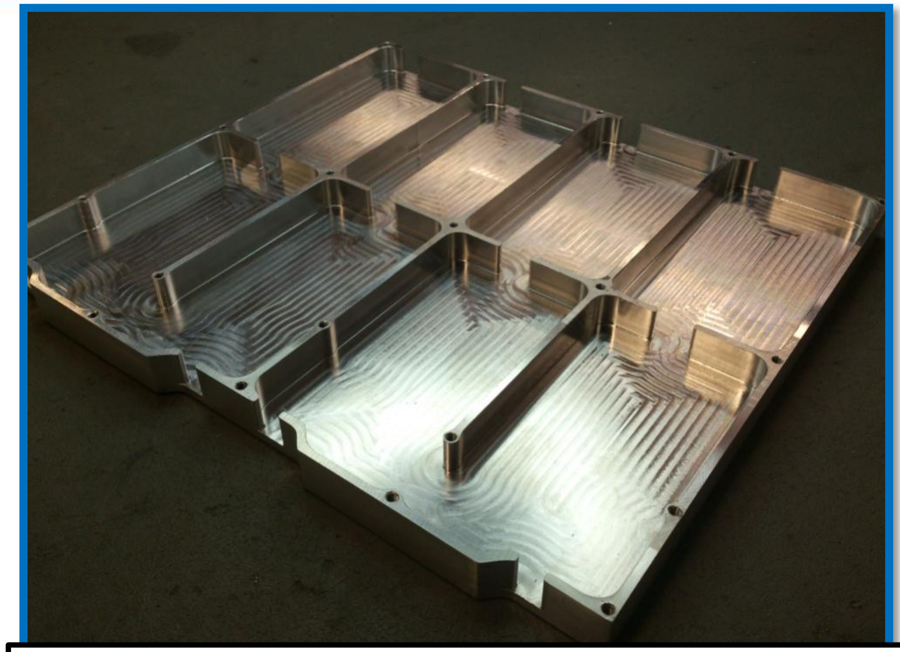
An onboard temperature control is also present in the RFFE board and can achieve ± 0.05 ºC peak-to-peak stability. The disadvantage of this solution is the reduction of the theoretical MTBF, as the average temperature is 40 ºC with the control turned on, 10 ºC higher than normal temperature.

Online and offline calibration tones are the last two strategies implemented for reaching high stability rely on calibration tones, both were not tested yet.

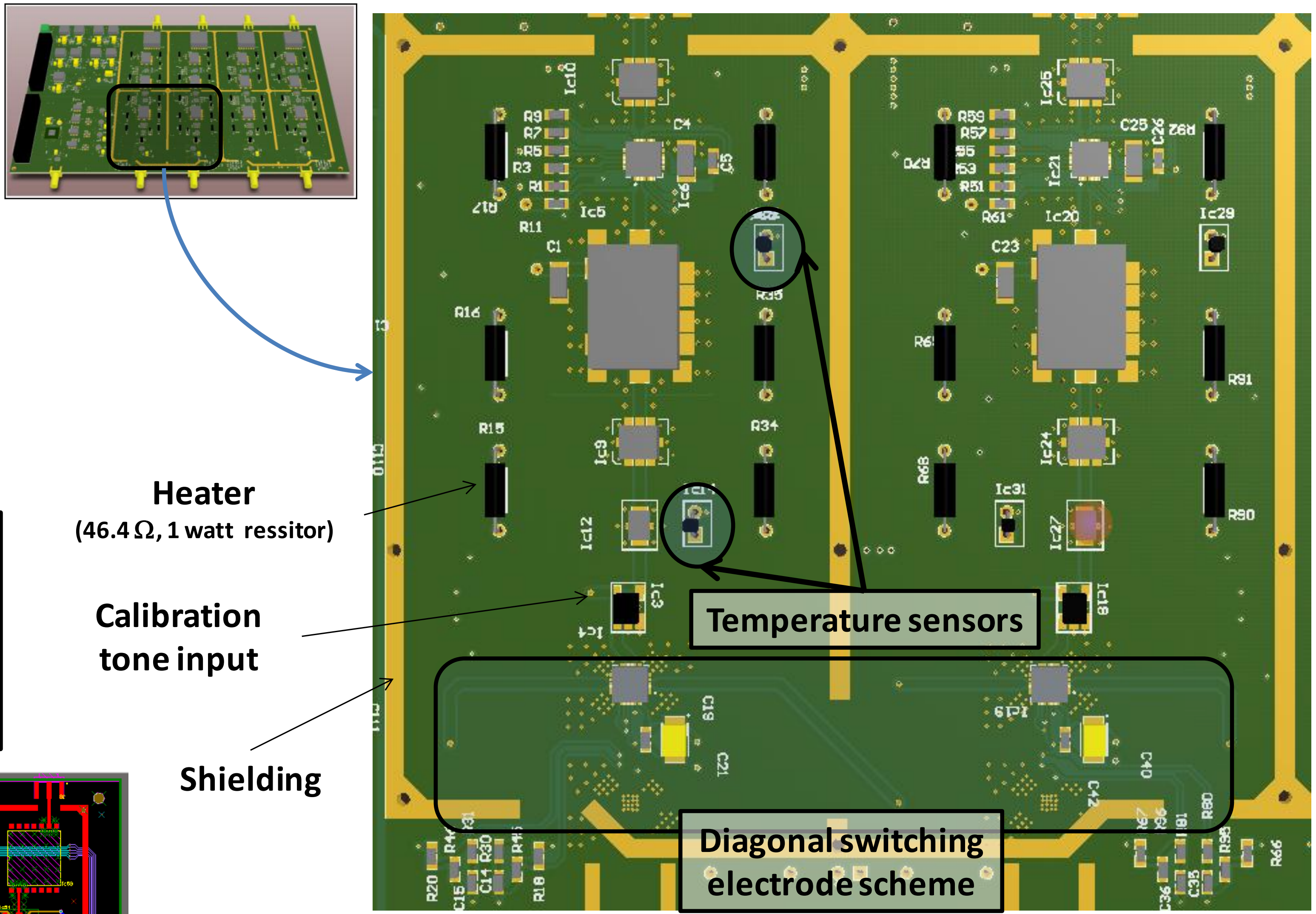


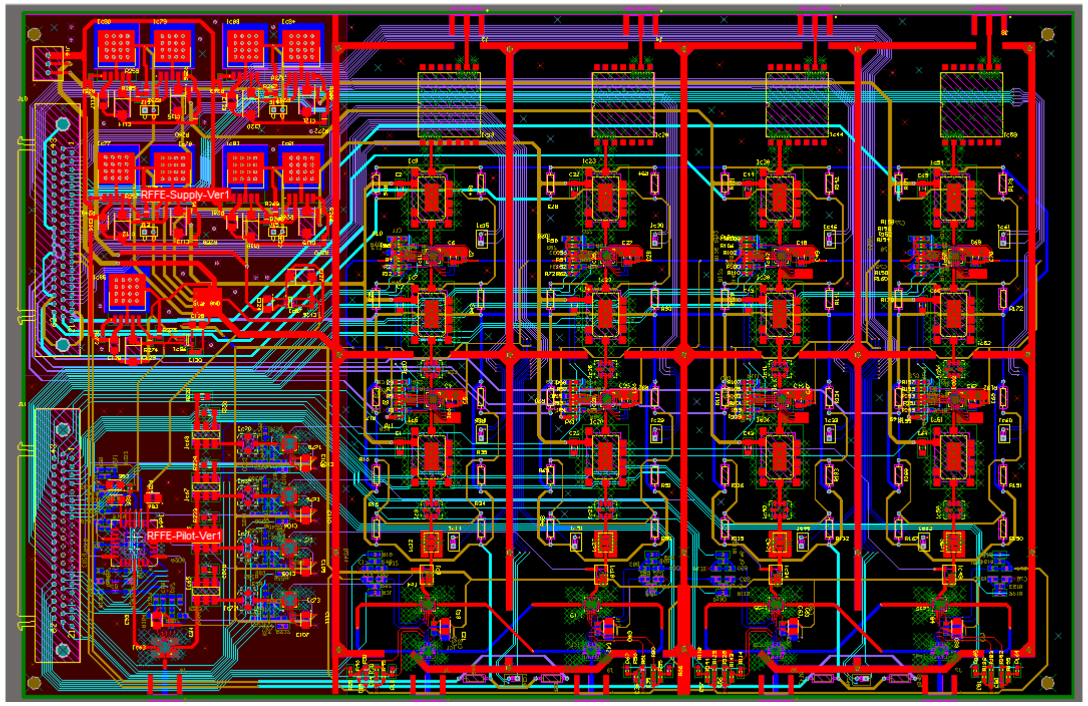


RF Front-End overview



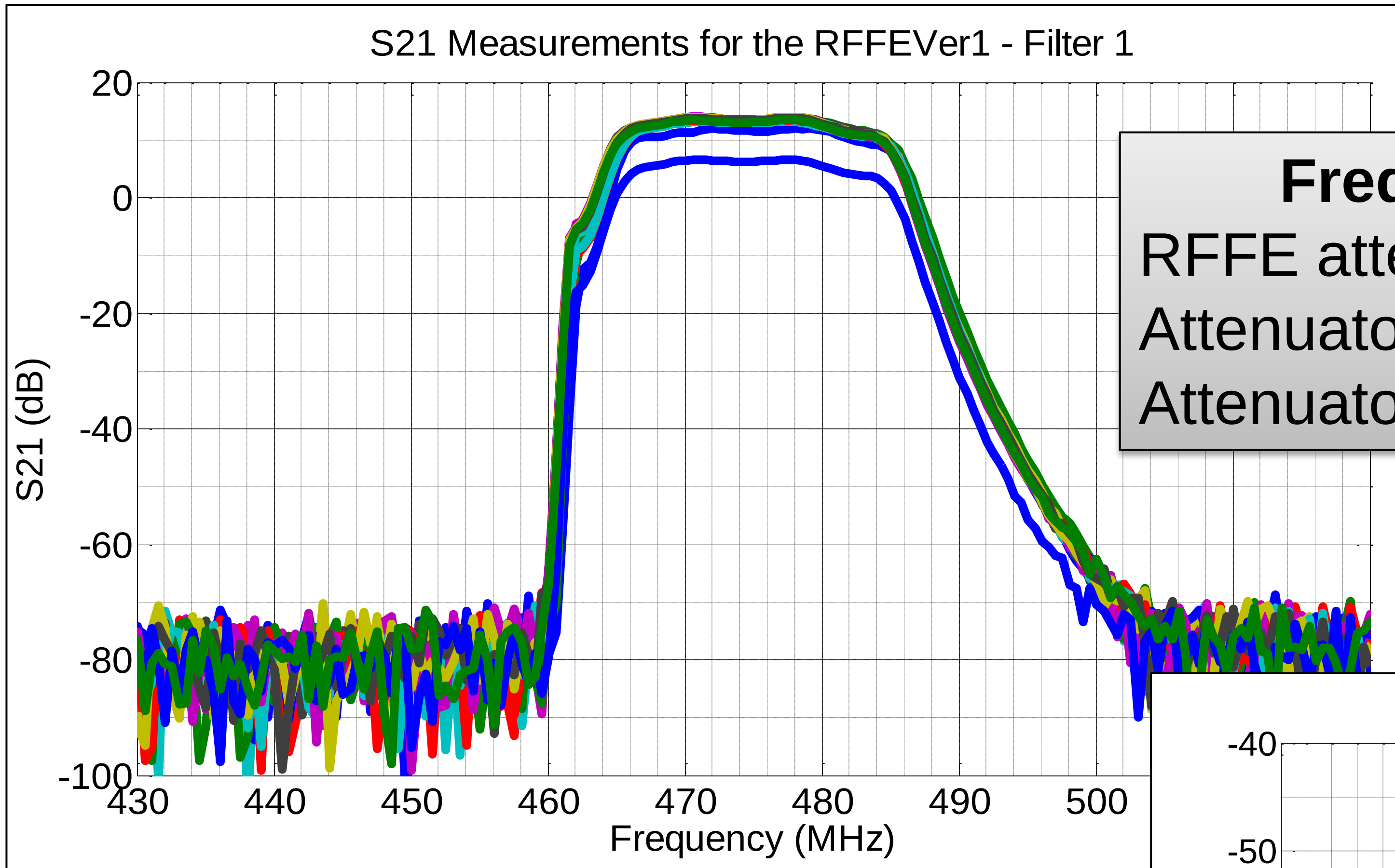
The RFFE board has been divided into 8 mechanical regions. Each environment has one temperature sensor as input variable for the control loop and four resistors distributed through the RF channel as heating elements





10 layer PCB: several calibration schemes adopted

General tests

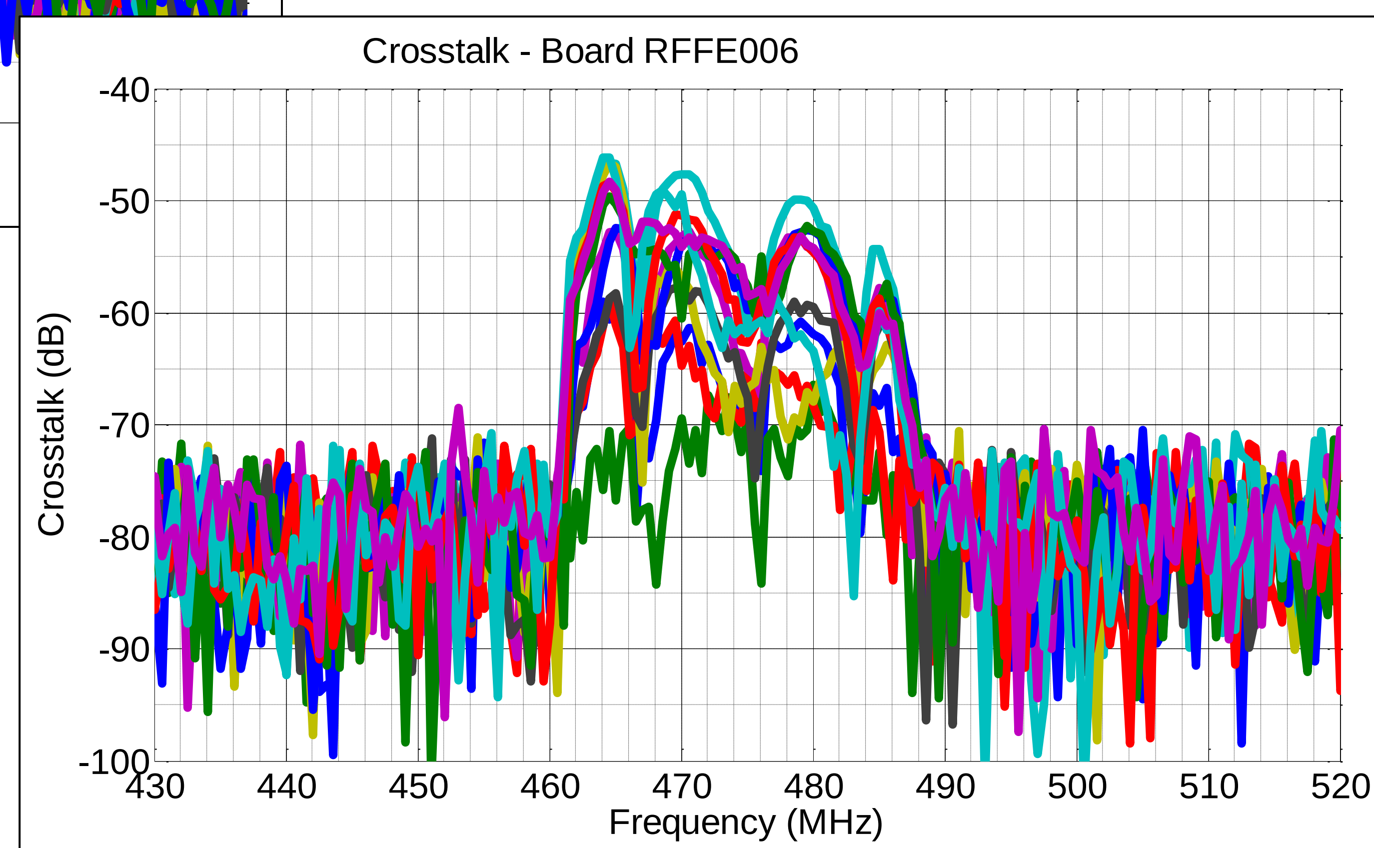


Frequency response

RFFE attenuator configuration:

Attenuator 1 = 10 dB

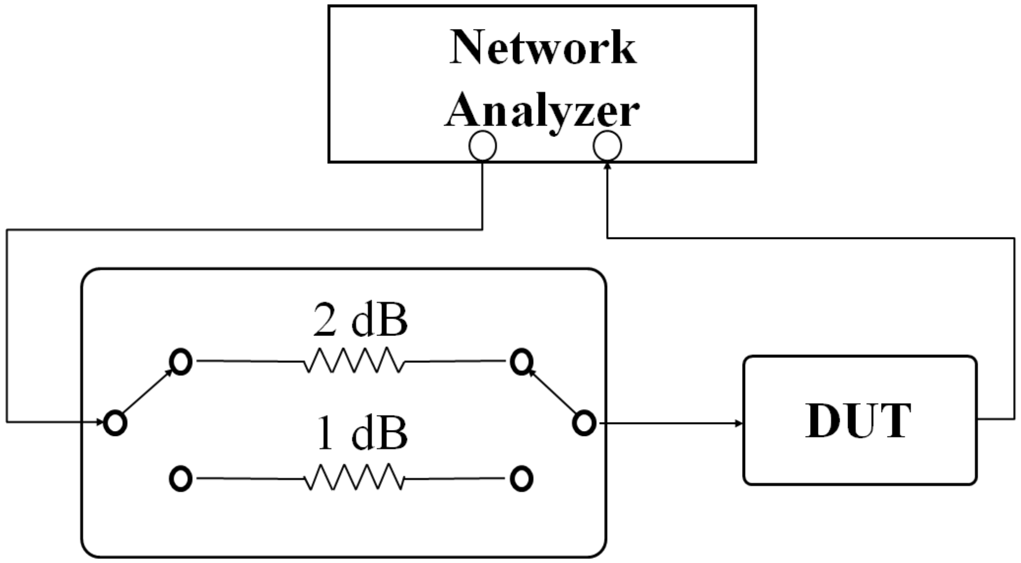
Attenuator 2 = 16 dB



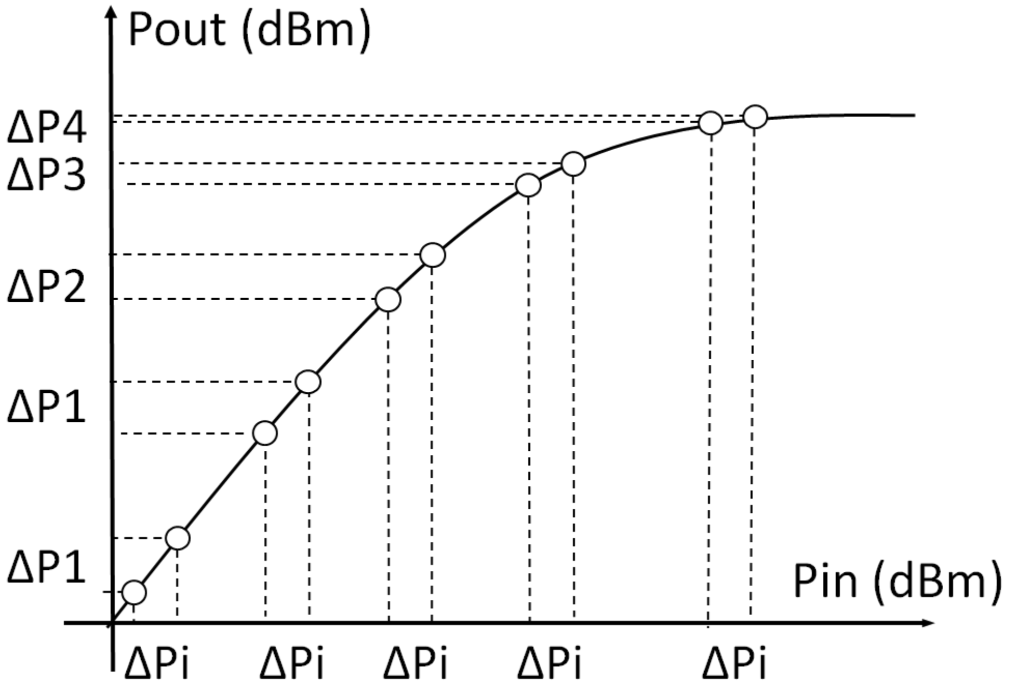
Crosstalk among the channels

LINEARITY BENCH TESTS

With highly linear switches it is possible to measure the nonlinearity of the DUT in the mdB range. The network analyzer must have about 0.001 dB resolution in the amplitude scale. It is not necessary to know the insertion loss of the switches and attenuators with high precision; it only needs to be constant over input power. For the tests performed with the RF components as well as the RFFE board, the so called linearity box, the DUT and the network analyzer were installed in a temperature chamber with a ± 0.1 ºC stabilized temperature.



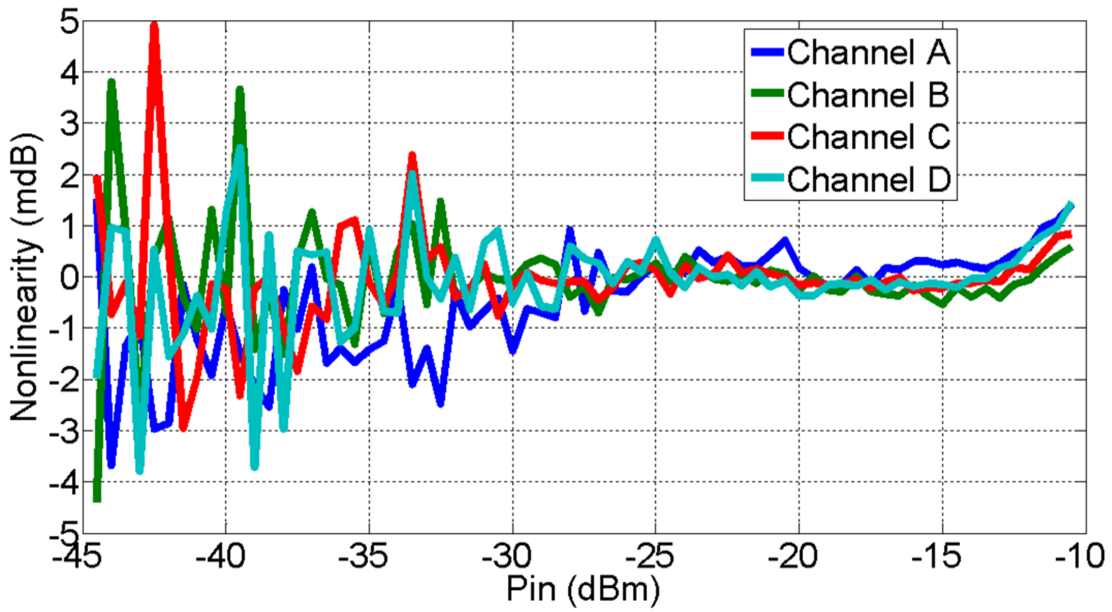
Block diagram of the setup used for measuring nonlinearity of RF electronics.



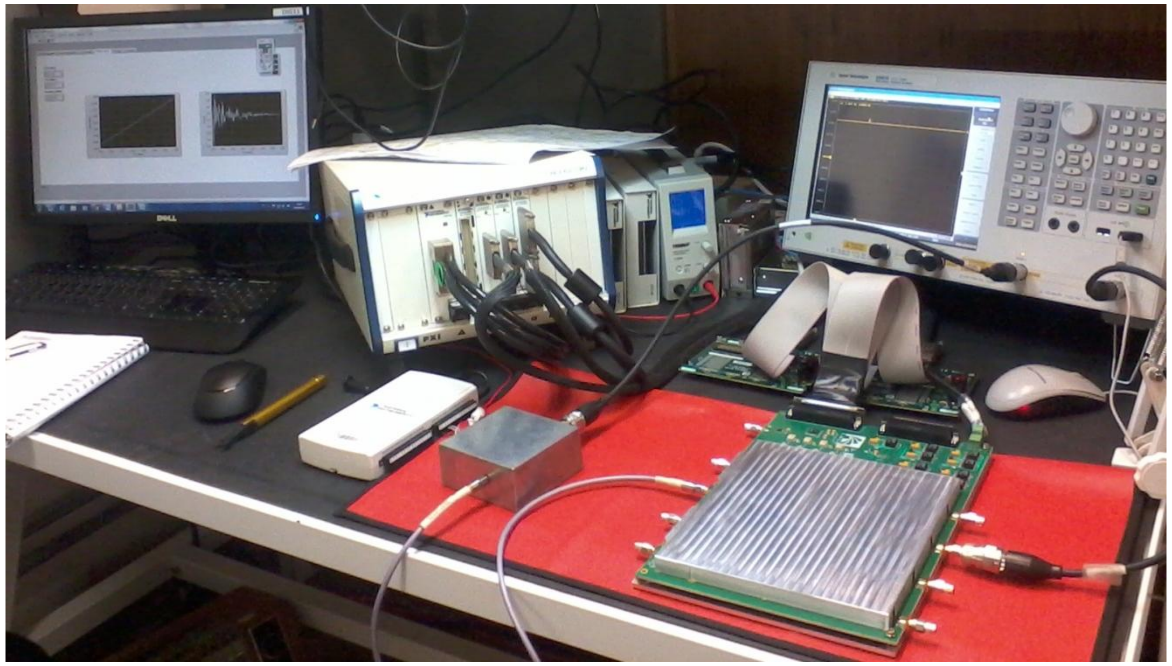
Main idea of the linearity test setup. It is possible to determine the linearity of the response of an RF device by measuring the difference in the output power for a known difference in the input power. If the difference between adjacent points on the output power remains constant, this determines the range of input power within which the system is linear.

LINEARITY BENCH TESTS

Automated test bench have been developed to measure the nonlinearity of the electronics. This procedure was repeated several times to allow for a statistical data analysis. As mentioned, all the instruments and electronics have been installed in a climatic chamber to avoid coupling thermal drifts to the nonlinearities under analysis. A typical result of linearity test is presented in Figure 6.



Nonlinearity measurements with the SIRIUS RFFE electronics.



Nonlinearity bench test. Better results obtained with the RFFE and the “linearity box” in a temperature chamber.

Conclusion and future work

The first prototype of RFFE has been tested and it has been verified that it could achieve the specifications for BPM system. For beam currents from 100 mA to 500 mA the input power will change from -31 to -17 dBm at RFFE input; in this range the RF channels are linear within ±1 mdB, even without the switching scheme.

Some improvements are being planned for future prototypes. Tests with the complete BPM system showed there is still room to enhance the performance: the noise floor can be reduced and the linear range can be extended, however the switching scheme, not completely explored up to date, can overcome the differences among the channels.

ACKNOWLEDGMENTS

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