Measurement report on

Processing Gain SML2400IP

Version 1.0
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Processing gain measurement SML2400IP

1. Scope

For the purpose of FCC type approval (FCC part 15, section 15.247(e)) the processing gain has been measured.

Processing gain is defined as the difference in signal to noise ratio between the input and output of the demodulator. This difference can be measured by measuring the difference in signal to noise ratio with the despreading switched on and off.

The theoretical processing gain of the SML2400IP is 11.7dB (10*Log(Codelength=15)).

2. Summary results

The processing gain was found to be between 10.2dB and 12.7dB.

3. Description of test

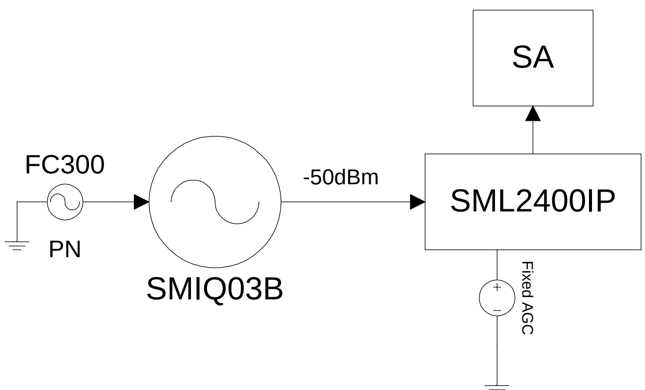
In FCC part 15, section 15.247(e) two measurement methods are described to measure the processing gain of the unit under test. For the measurement of the processing gain of the SML2400IP method (1) is used.

"15.247(e) The processing gain of a direct sequence system shall be at least 10 dB. The processing gain represents the improvement to the received signal-to-noise ratio, after filtering to the information bandwidth, from the spreading/despreading function. The processing gain may be determined using one of the following methods:
(1) As measured at the demodulated output of the receiver: the ratio in dB of the signal-to-noise ratio with the system spreading code turned off to the signal-to-noise ratio with the system spreading code turned on."

3.1. Equipment list

- Rohde Schwarz SMIQ03B signal generator with I/Q modulation inputs
- Yokogawa FC300 arbitrary signal generator (used to modulate the SMIQ03B)
- Rohde Schwarz FPS30 Spectrum Analyzer
- Adcon SML2400IP unit

3.2. Test setup



The SMIQ03B was modulated by the FC300 that generated the PN sequence. This combination served as a reference transmitter.
The SML2400IP under test was set at a fixed AGC level. The output of the despreader was monitored with the spectrum analyzer. The measurements of this document were taken after the despreader, but before the digital filtering occurs. There's no signal physically available to monitor after the digital filtering, so the unfiltered signal was measured in a bandwidth equal to the digital filtering bandwidth to include the effects of digital filtering (see later chapter "Justification of 250kHz measurement bandwidth"). The SML2400IP was setup in such a way that the despreading could be switched on and off.

All measurements were carried out well above the noise floor of the used equipment.

The following picture shows the output spectrum of the reference transmitter measured at the SML2400IP RF input:

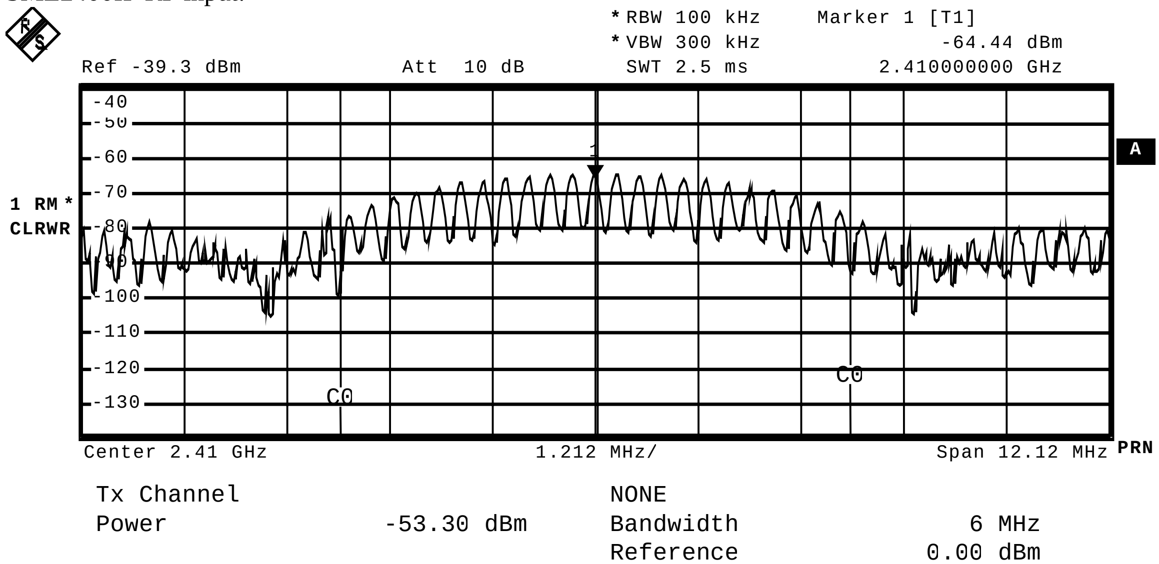


Figure 1. Output spectrum of the reference transmitter

3.3. Justification of 250kHz measurement bandwidth

As mentioned before, the measurements were carried out in a 250kHz bandwidth to include the effects of the digital filter. The following section describes why this is necessary.

A received signal is multiplied by a reference (PN code) with the same code and (assuming that the transmitter’s code and the receiver’s code are synchronous) the carrier inversions transmitted are removed and the original carrier is restored. This narrow band restored carrier can then flow through the band pass filter designed to pass only the baseband-modulated carrier.
Undesired signals are also treated in the same process of multiplication by the receiver’s reference, that maps the received direct sequence signal into the original carrier bandwidth. Any incoming signal not synchronous with the receiver’s coded reference (a wideband signal) is spread to a bandwidth equal to its own bandwidth plus the bandwidth of the reference.
Because an unsynchronized input signal is mapped into a bandwidth at least as wide as the receiver’s reference, the bandpass filter can reject most of the power of an undesired signal. For this to be true, the passband of the bandpass filter has to be the same as the bandwidth of the baseband signal.
This is the mechanism by which processing gain is realized in a direct sequence is realized; without filtering, no processing gain is realized.

Since the only signal available for monitoring purposes is the analog signal immediately after the receiver’s multiplier, processing gain can not be determined at this point without the employment of the necessary filtering. Since this filtering is performed in the digital domain and the demodulator output is not available for monitoring purposes, the output of the receiver’s multiplier has been measured with a 250kHz bandwidth, comparable to the digital filtering that is performed once the signal is in the digital domain.

Referring to chapter 3, FCC part 15, section 247, also describes that filtering to the information (data) bandwidth is necessary:
“The processing gain represents the improvement to the received signal-to-noise ratio, after filtering to the information bandwidth, from the spreading/despreading function.”

The following picture shows the block diagram of the SML2400IP. The spectrum analyzer was connected after the despreader and after the bandpass filter. Because the bandwidth of this filter (±2MHz) is much more wideband than the data bandwidth (±250kHz), additional filtering is necessary. This has been accomplished by choosing a 250kHz measurement bandwidth for the spectrum analyzer.

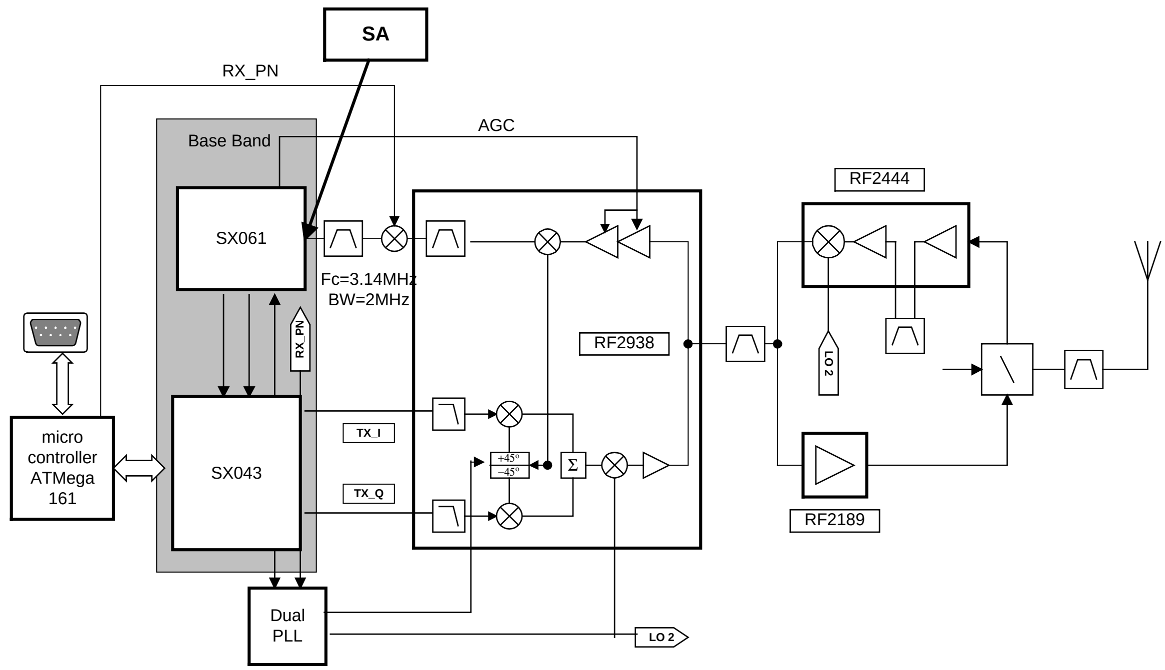


Figure 2. Block diagram of SML2400IP showing the SA measurement connection

The following picture shows the block diagram of the SX061. One of the tasks of this IC is the aforementioned digital filtering of the RX signal to the information bandwidth. This task is handled by the integrate and dump filters inside the SX061, that are set to the information bandwidth.

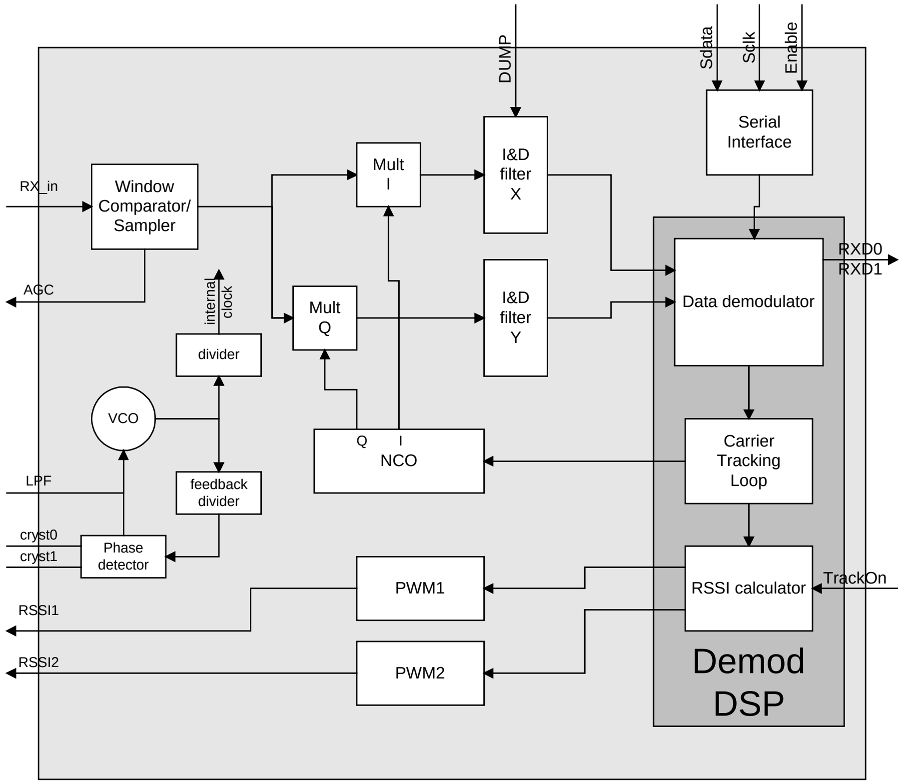


Figure 3. Block diagram of SX061

The following picture shows the insertion loss version frequency characteristics of the integrate and dump filters of the SX061:

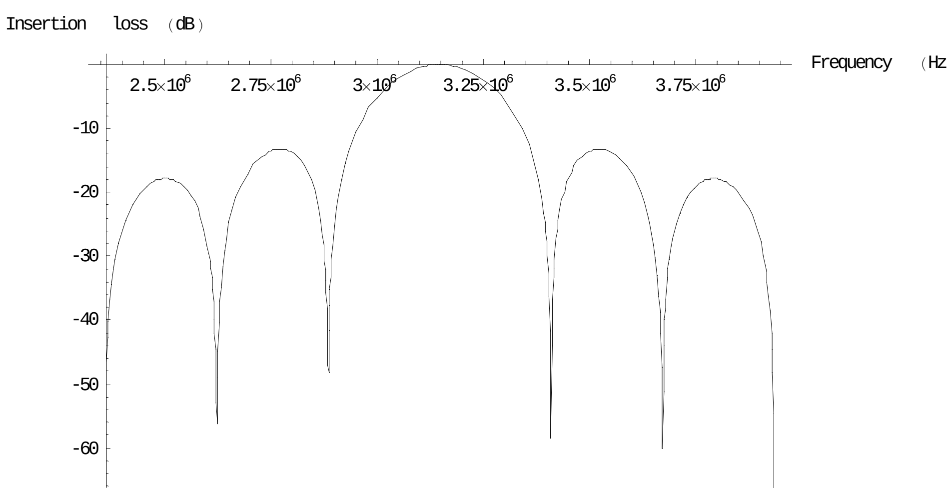


Figure 4. Insertion loss of digital filter

The –3dB bandwidth of this digital filter is about 230kHz.

4. Measurement results

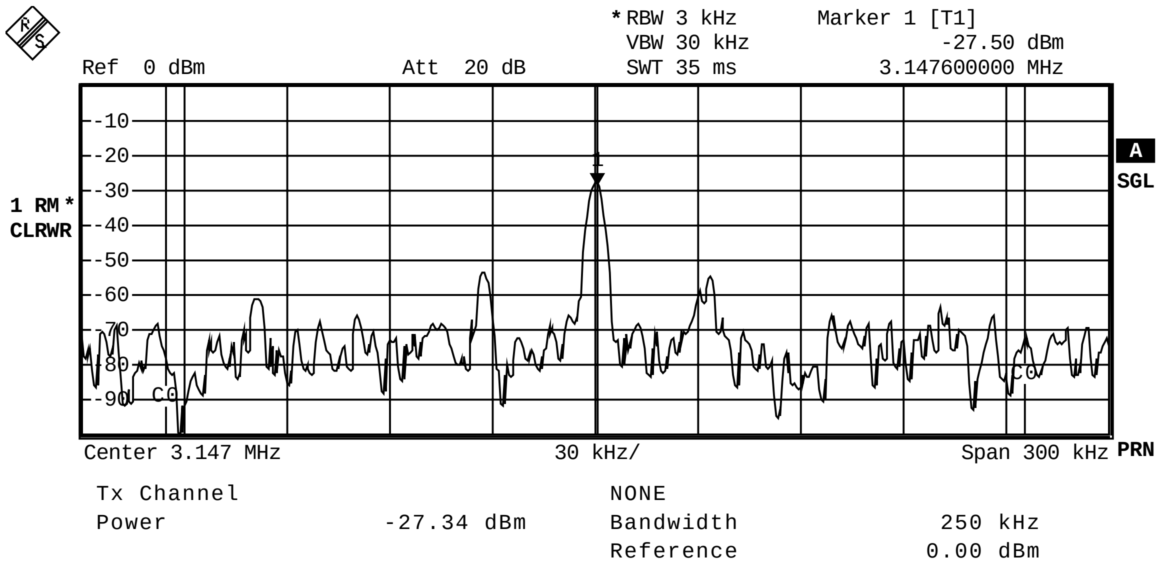


Figure 5. RF on, despreading on

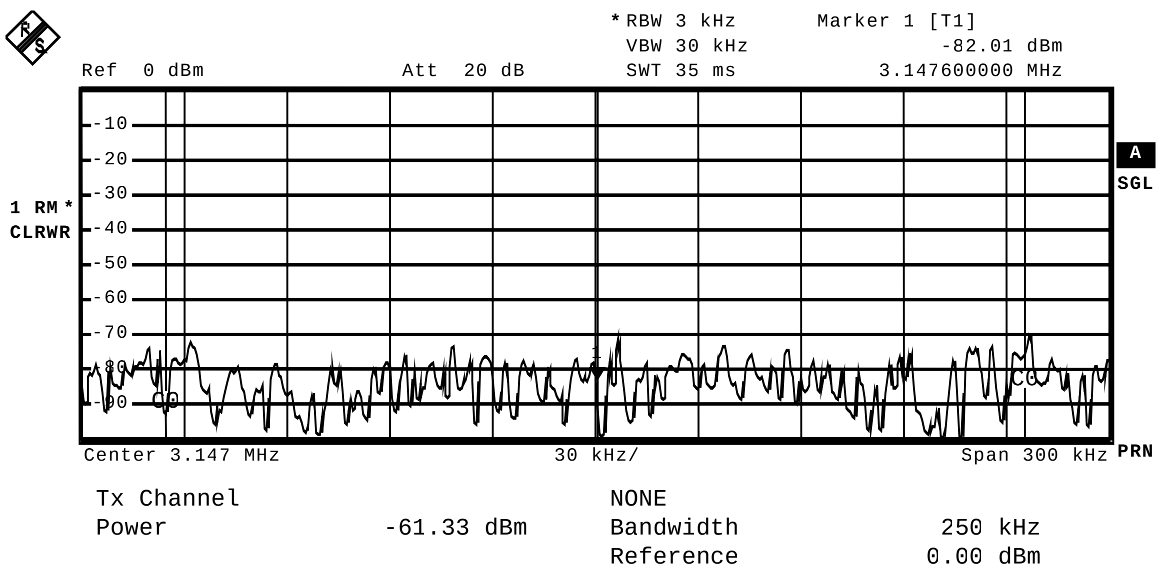


Figure 6 RF off, despreading on

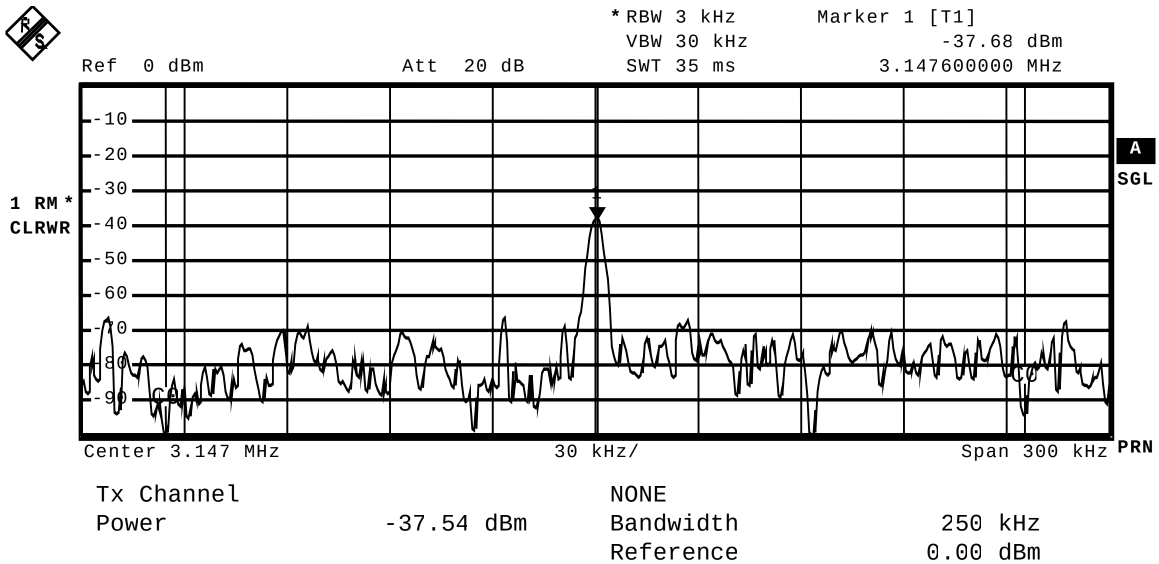


Figure 7. RF on, despreading off

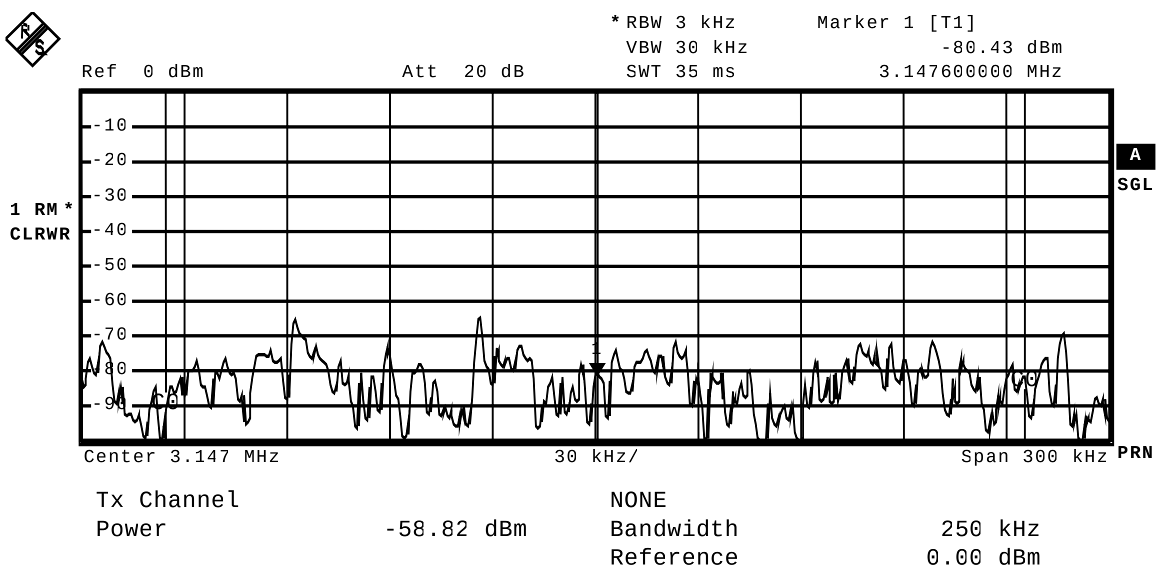


Figure 8. RF off, despreading off

From the first two measurements (figures 2 and 3) it follows, that the signal to noise ratio with despreading on was 34.0dB, looking at the difference between channel power[1] with “RF on” and “RF off”. The following two measurements (figures 4 and 5) show a signal to noise ratio of 21.3dB with despreading switched off.

5. Conclusions

The measurements of the previous chapter show, that despreading improves the signal to noise ratio by 12.7dB. Even if the noise floor is assumed constant between despreading switched on and off the signal to noise improvement is 10.2dB.

[1] Channel power is the available power in the channel bandwidth, that is set to 250kHz (the information bandwidth)