Typical performance characteristics of the transmitter and receiver modules

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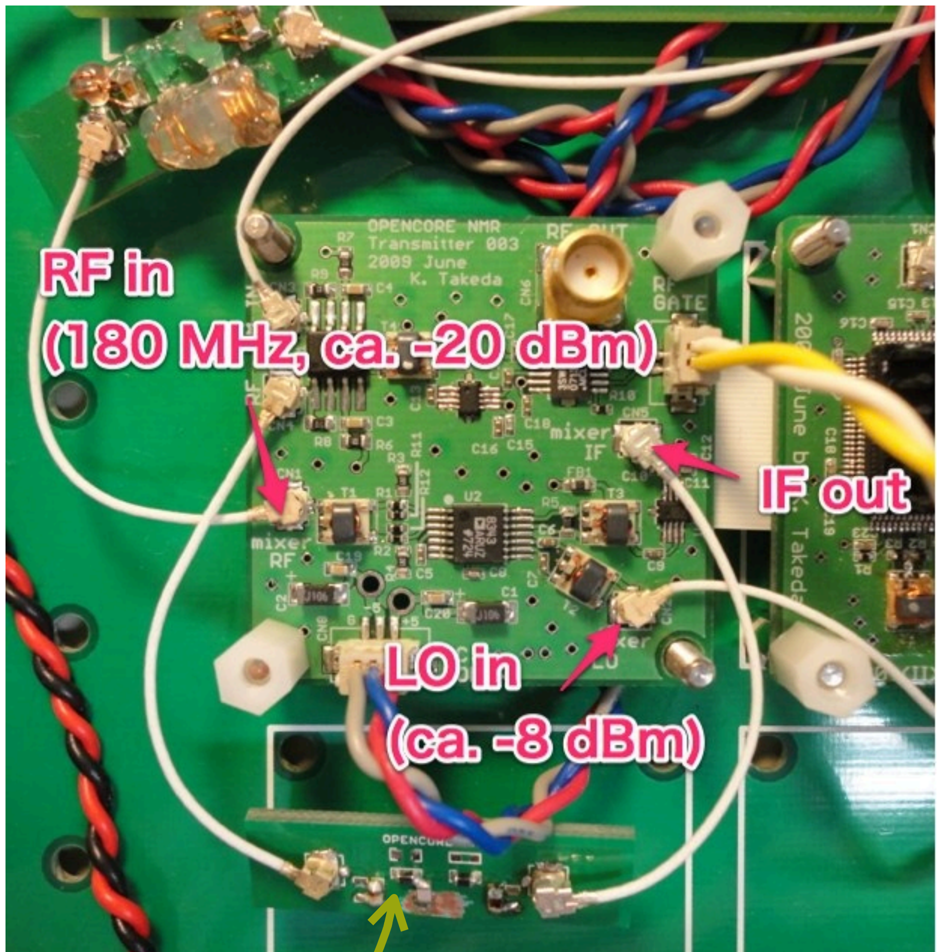
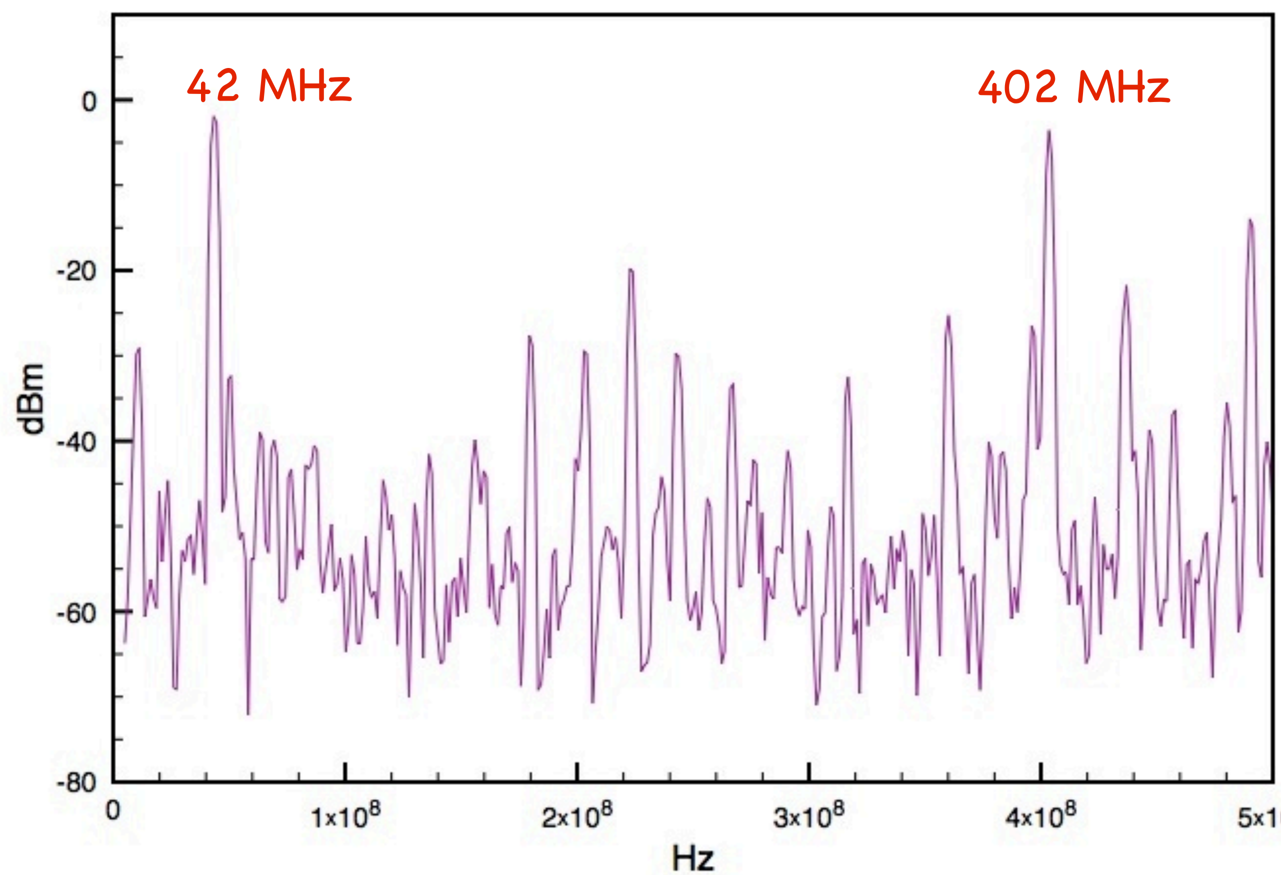
Transmitter test

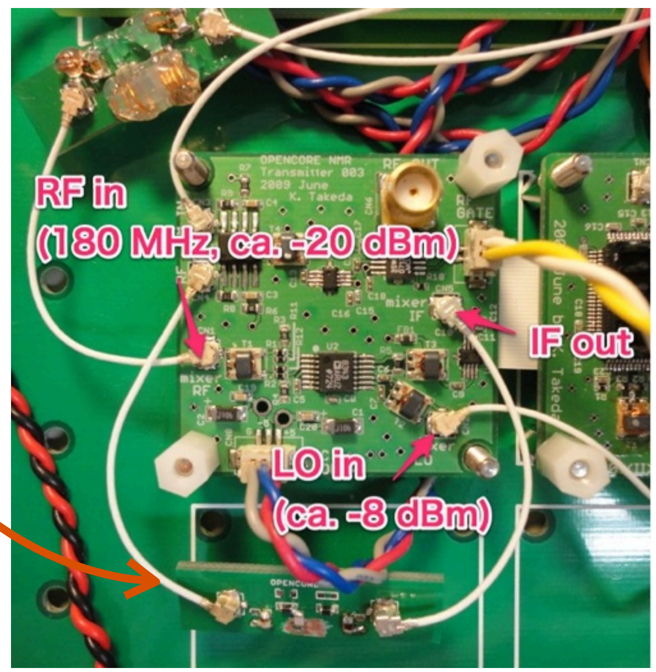
- First, let us see the function of the mixer part of the transmitter.
- We assume that a 180 MHz signal is connected to the RF port, and either F+180 MHz or F-180 MHz is applied to the LO port.
- Now, we look at the signal from the IF output port using a spectrum analyzer.



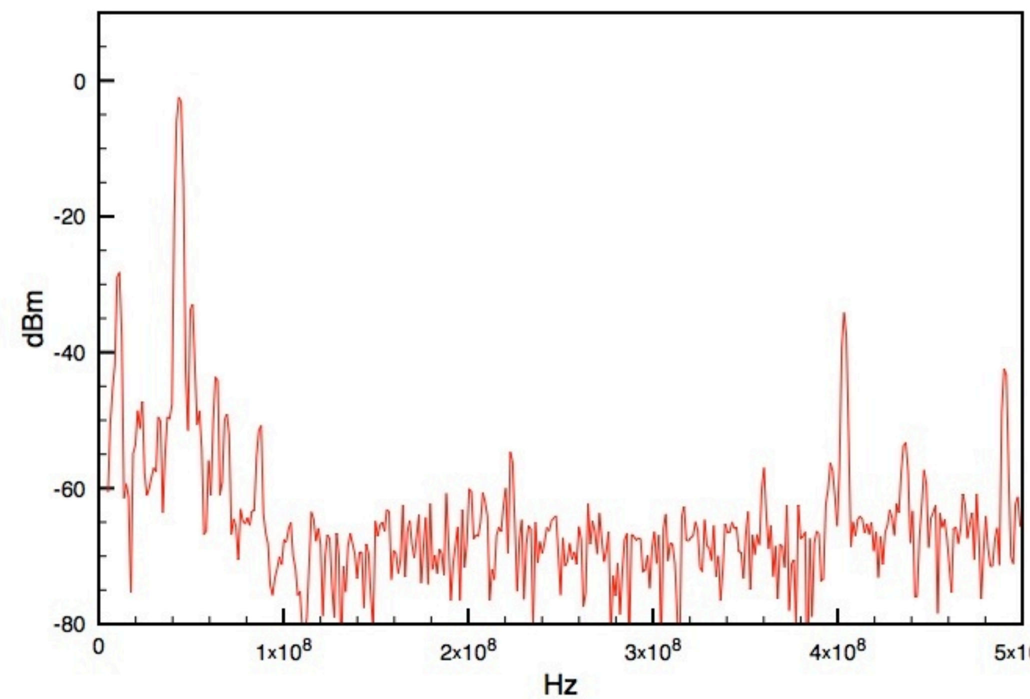


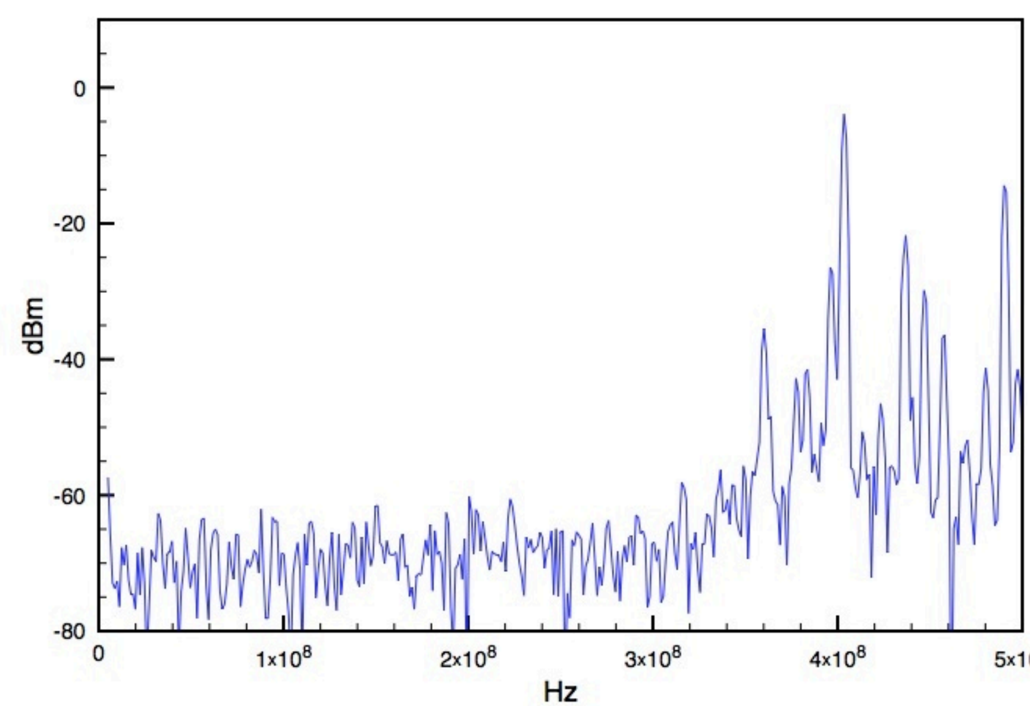
- The right figure shows the spectrum with a LO input frequency of 222 MHz. That is, the frequency of interest is either 42 MHz or 402 MHz.
- Using a filter, we want to eliminate the unwanted spurious components.

- The right top figure shows a spectrum measured at the output of a 50 MHz low-pass filter. Even though the spurious signals remain, the largest one is smaller than the main signal by nearly 3 orders of magnitude.

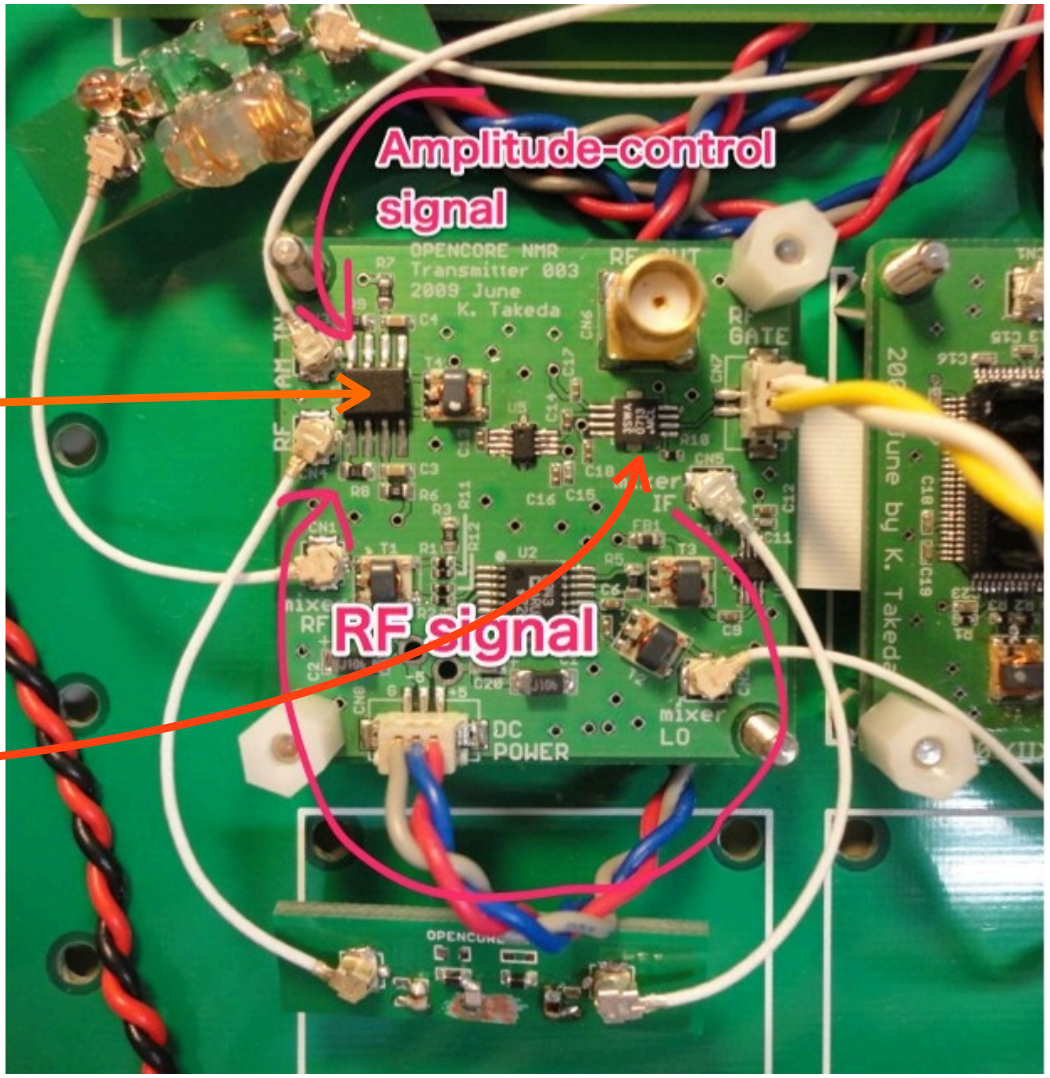


- In the right bottom figure plotted is a spectrum using a 400 MHz high-pass filter. For most cases, this works for NMR experiments at ca. 400 MHz. If you are not satisfied with it, you may want to employ a better filter.



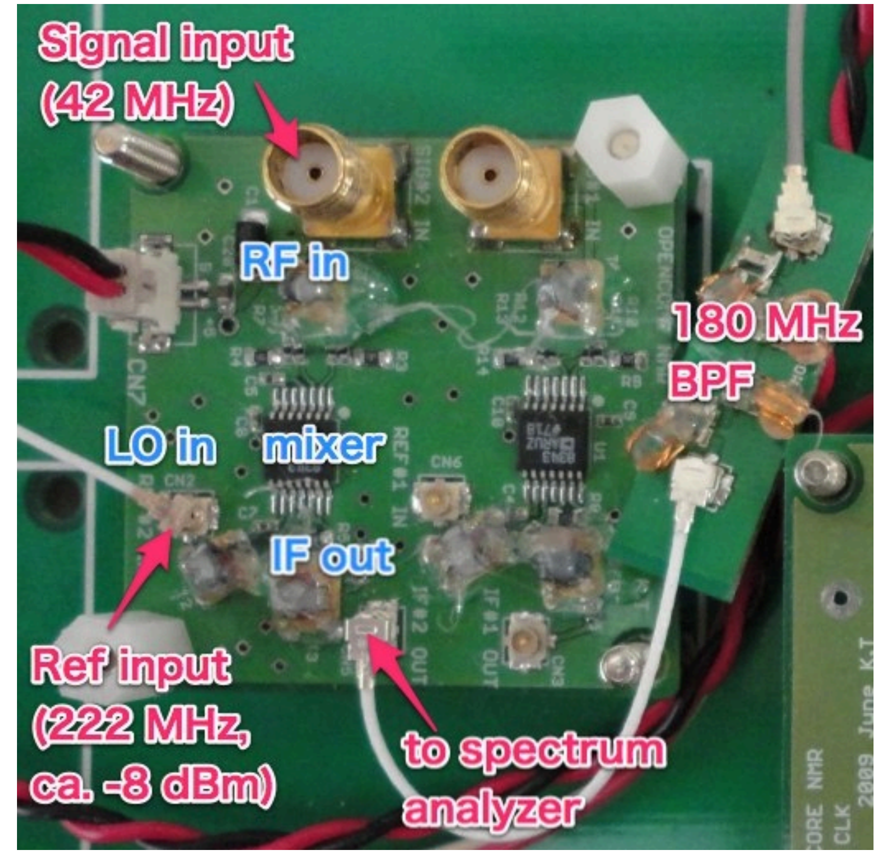


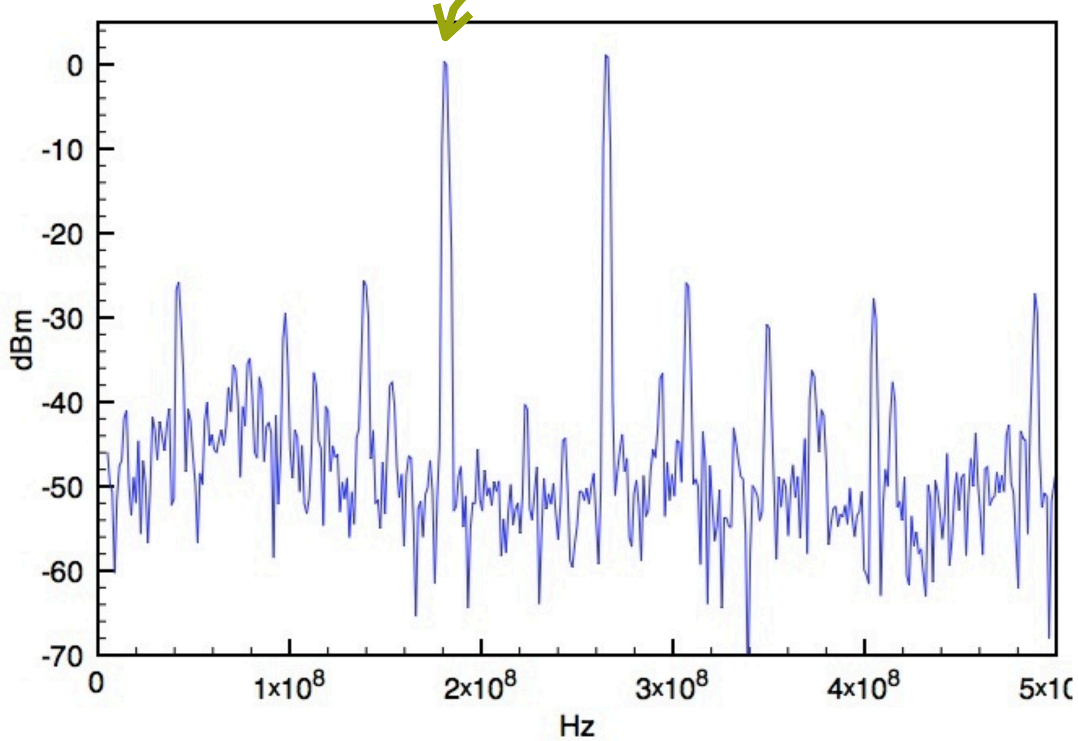
- The level of the RF signal is determined by the amplitude control signal.
- The maximum voltage should be around 0.64 V (measured with 50 Ohm impedance).
- A multiplier, AD834 (Analog Devices), is used.
- So far, the rf signal is a continuous wave.
- At the next stage, an rf switch is used to pulse-modulate the signal.
- The maximum output level of the rf pulse is ca. 0 dBm (it depends slightly on the frequency).
- Note that the phase of the rf pulse is controllable, and is determined by the phase of the 180 MHz signal.

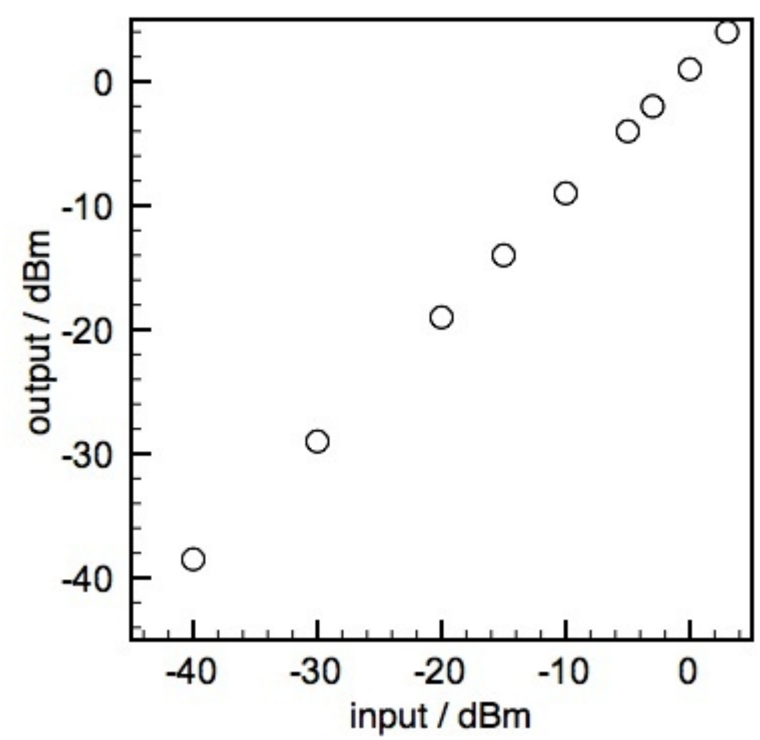


Receiver test

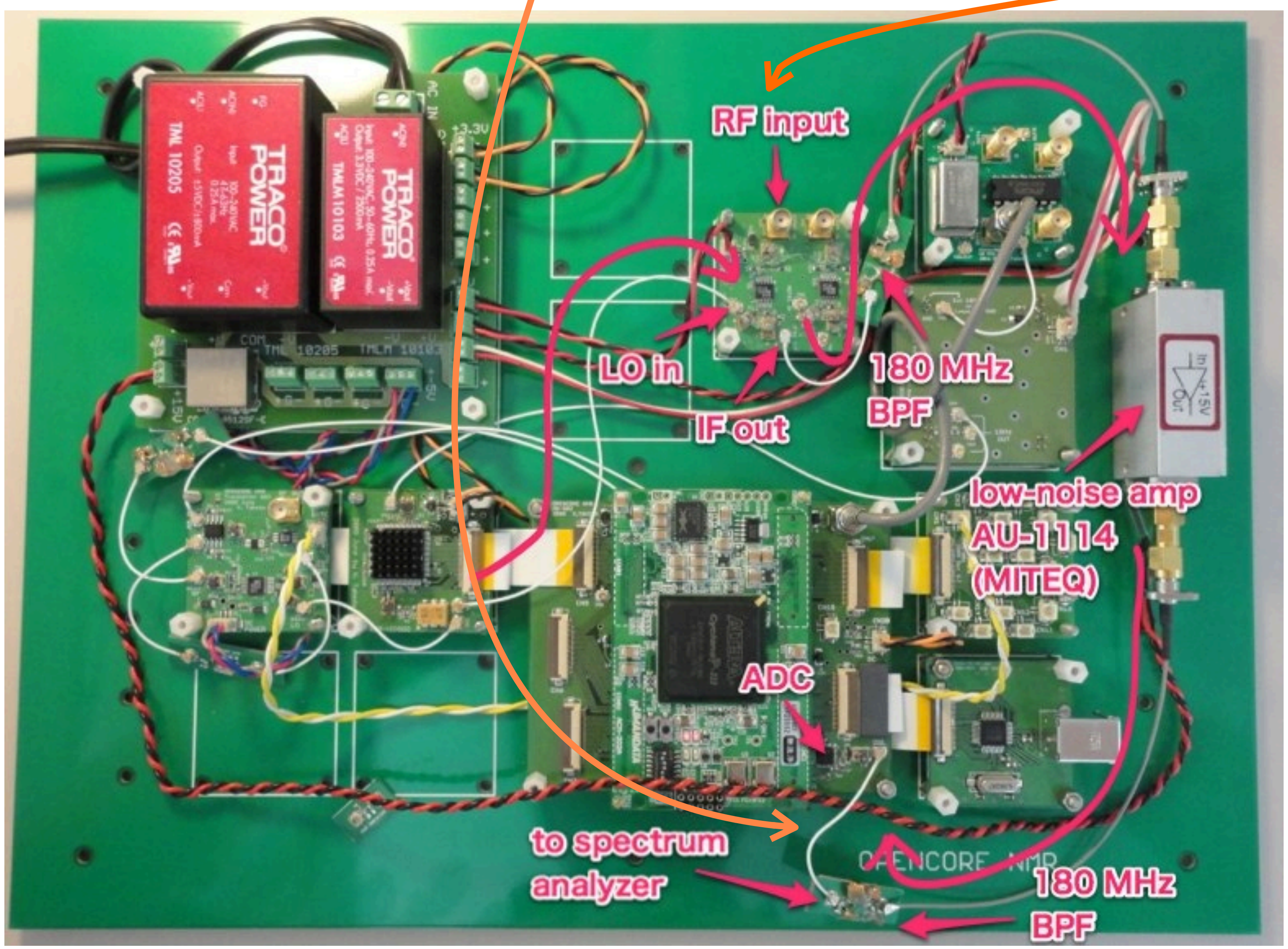
- For a test of the receiver board, a signal at 42 MHz was sent to the RF port. The reference signal at 222 MHz came from the DDS(II) board.
- The output signals at the IF port were examined for various input signal amplitudes.
- The bottom left figure shows a spectrum with input power of 0 dBm. The Fourier component at 180 MHz is of interest. The bottom right figure shows how the 180 MHz peak intensity depends on the input power. Linearity is fine in the range studied.



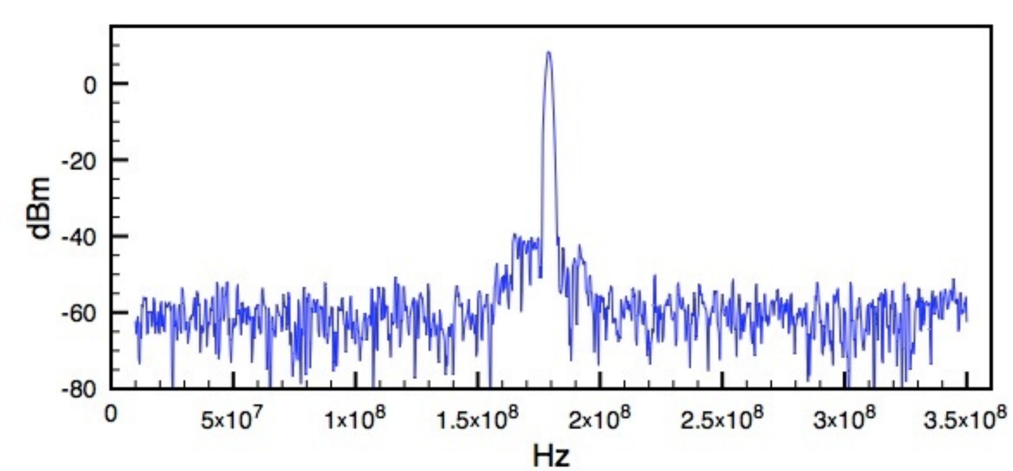


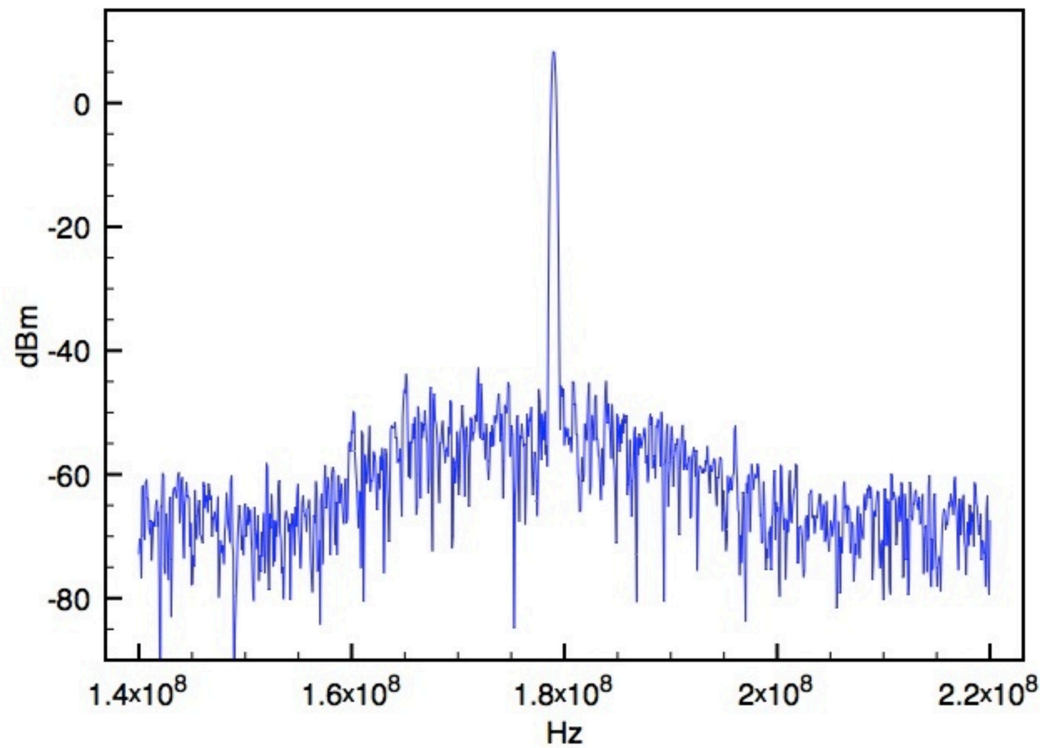


- The ADC input level was studied for various amplitudes of the input RF signal.



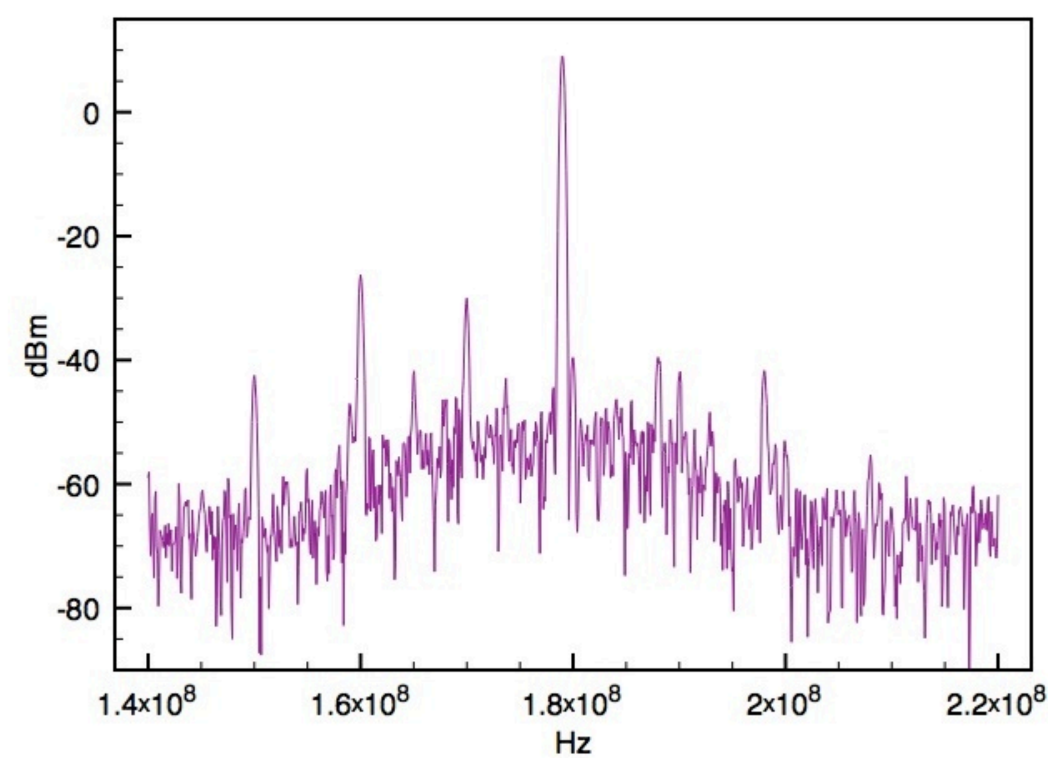
- The IF output signal passes through a 180 MHz band-pass filter, an amplifier, and another 180 MHz band-pass filter, before being sampled by ADC.
- In this example, AU-1114 (MITEQ) is used for the amplifier. The nominal gain is 36.3 dB, the output power at -1 dB gain compression is ca. 10 dBm.
- Currently, I am "trying" to find a less-expensive alternative amplifier...
- The spectrum of the signal at the ADC input look like the below figure.



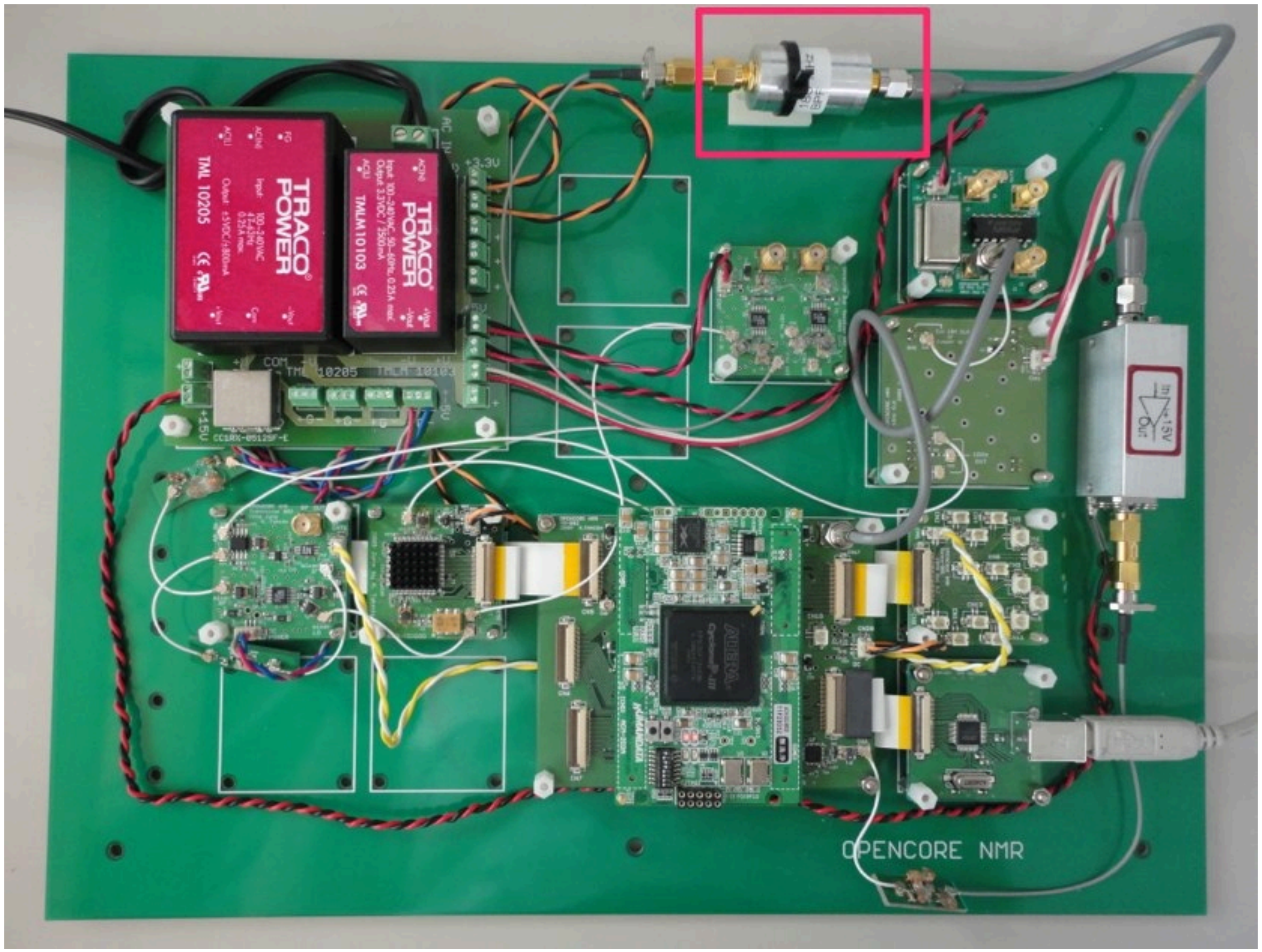


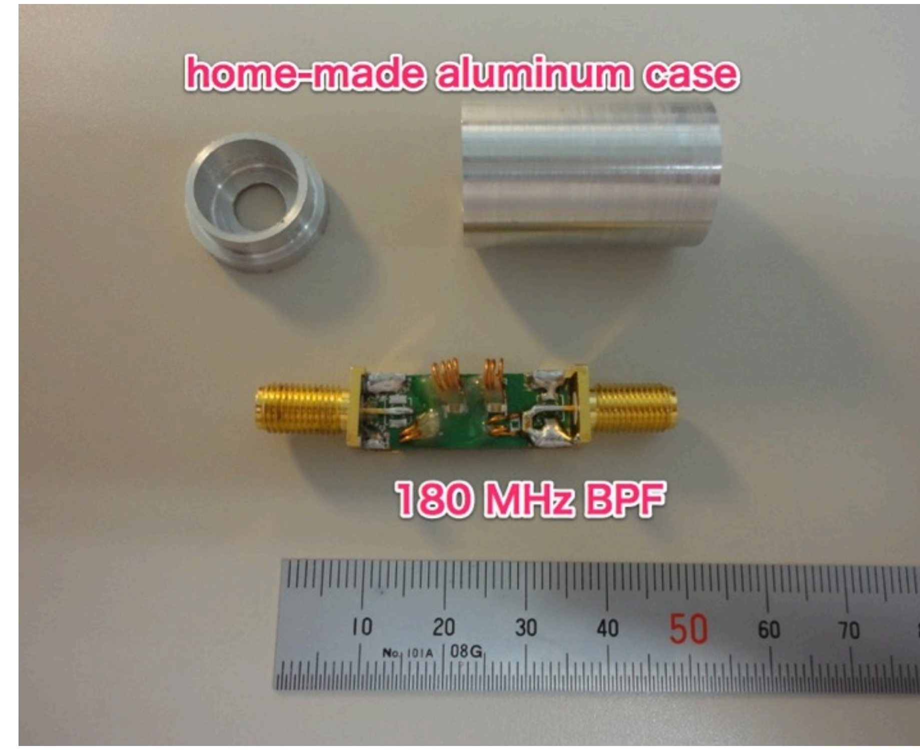
- The left figure shows a spectrum measured at the ADC input port (i.e., the output of the second 180 MHz BPF shown in the previous page) with the receiver input frequency and level of 42 MHz and -25 dBm.
- The baseline outside the pass-band is lower, thanks to the 180 MHz band pass filters.
- The width of the pass-band is supposed to be half the ADC sampling rate (i.e., 80/2=40 MHz), or smaller.

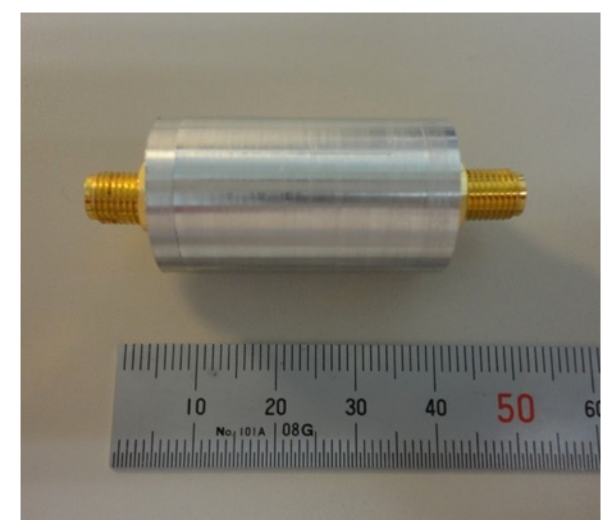
- The first 180 MHz band pass filter can pick up radiation from the 10 MHz clock module, causing a lot of distracting spurious components having nothing to do with the NMR signal, as shown in the right figure.
- If this is the case, put something (e.g., aluminum foil) to shield the filter.



- Indeed, when I made a shield case and put the 180 MHz band pass filter in it, the receiver system picked up much less noise.

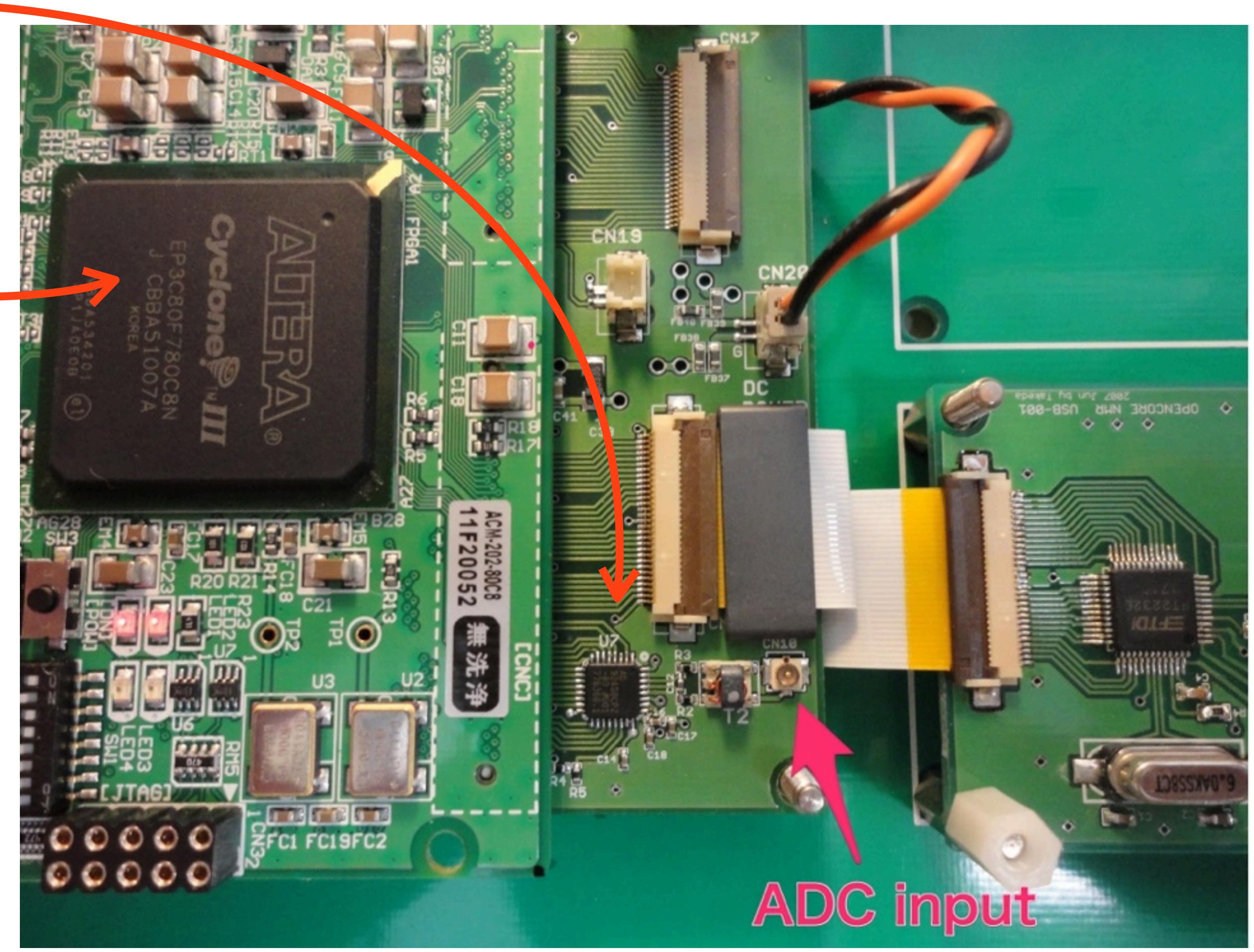


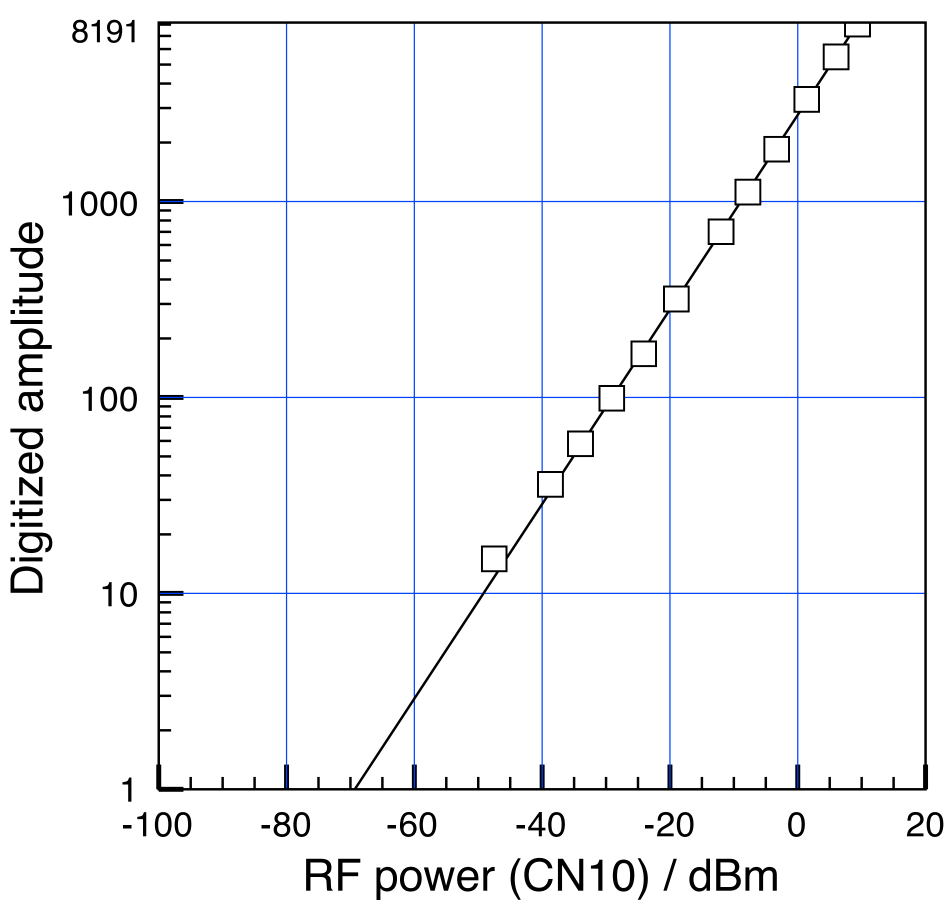




AD converter

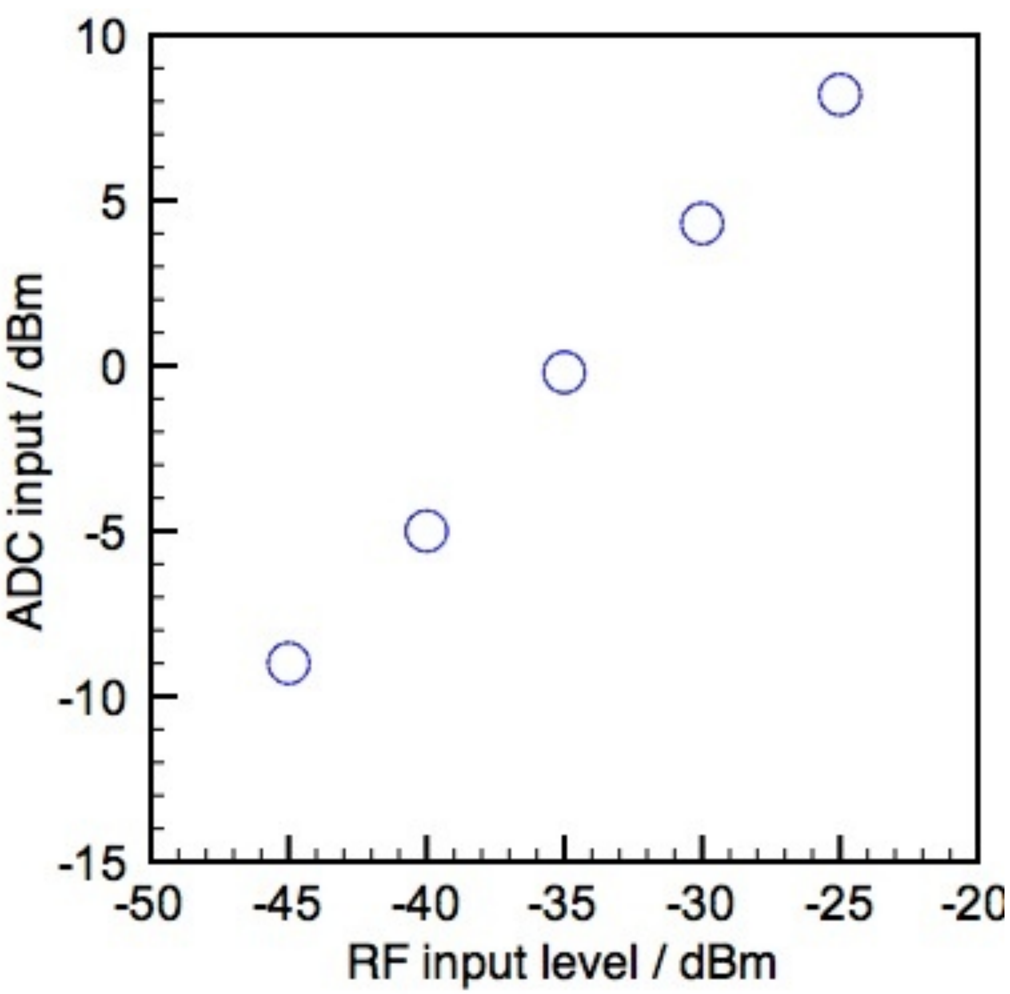
- AD9245BCPZ-80 (Analog Devices)
- The sampling rate is 80 MHz. The clock is provided by the FPGA.
- Under-sampling (or super-Nyquist sampling) is feasible. Here, 5th Nyquist zone ranging from 160 to 200 MHz is of interest.
- Thus, measurement of the input-power dependence was carried out at the center frequency of 180 MHz.

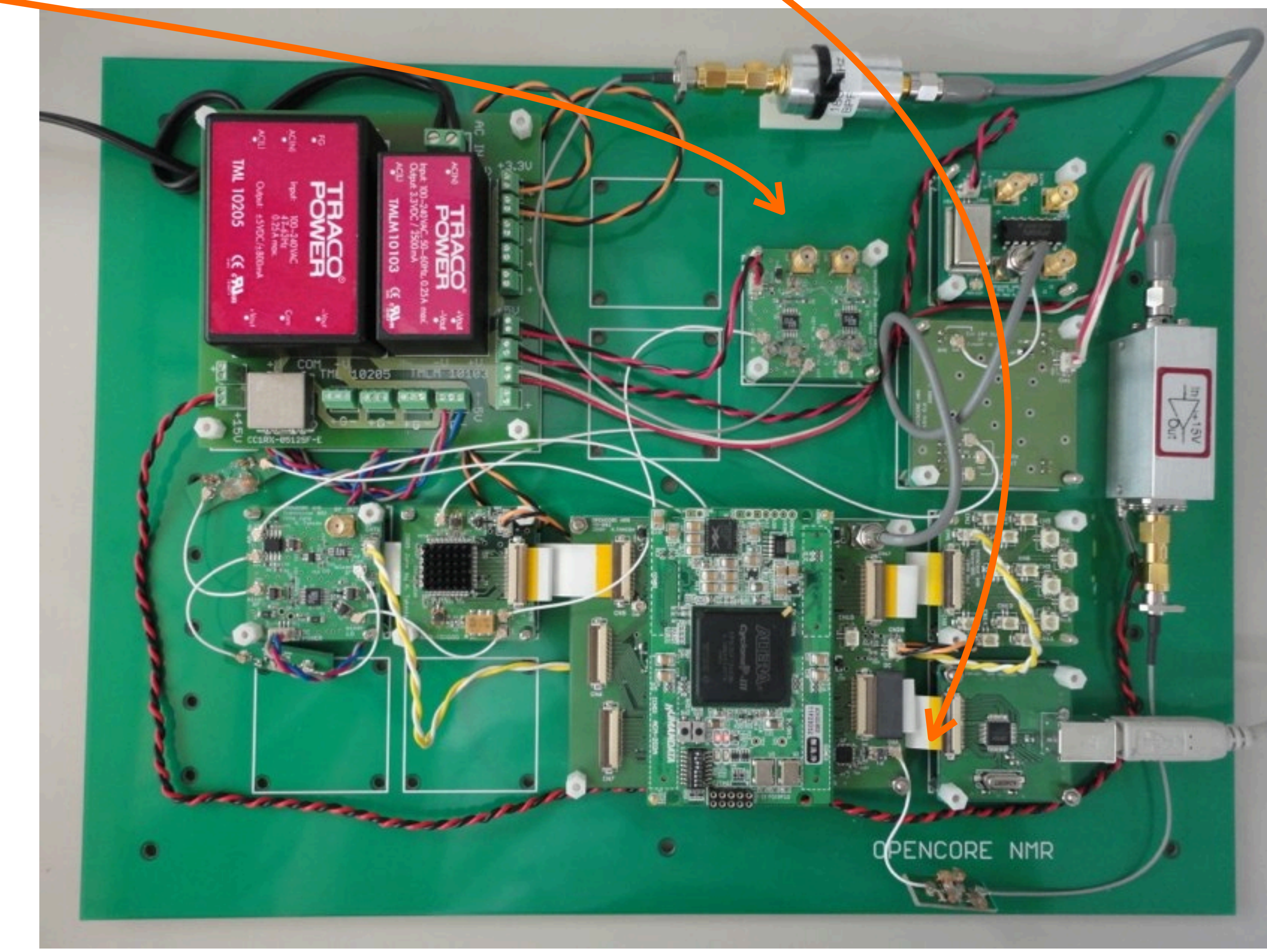




- The graph shows measured digitized signal amplitudes as a function of the input RF power. The frequency was 180 MHz.
- The ADC overflow occurred with an RF power of ca. 9.5 dBm.
- The underflow level was estimated from data extrapolation to be ca. -70 dBm.

- The graph shows a dependence of the ADC input level on the rf level at the input port of the receiver module.





- Up to the input level of -25 dBm, linearity is fine.

- Note that the ADC over-range level is ca. 9.5 dBm.